In the spirit of the Talanoa Dialogue, the America's Pledge initiative is pleased to share the following insights, informed by the latest groundswell of climate action happening across the United States from cities, states, businesses and other non-federal, "real economy" actors.

It is our hope that the recent experience of the America's Pledge initiative – and our research report, *Fulfilling America's Pledge*, published at the Global Climate Action Summit in San Francisco, California and appended here – can serve as a roadmap for bottom-up, whole-of-society climate action planning across a broad range of Parties to the Paris Agreement, especially as governments begin the process of revising their Nationally Determined Contributions over the coming years.

Where are we?

Despite the current lack of leadership at the federal level, a broad coalition of real economy actors – states, cities, businesses, investors, communities of faith, tribal communities, universities and more – has stepped up to commit continue accelerating climate action in the United States to meet the goals of the Paris Agreement. **This coalition of real economy actors is globally significant, representing over half of the U.S. population (173 million people) and nearly 60% of US GDP ($11.4 trillion). If it were a country, this coalition would be equivalent to the world's third largest economy and the world's fourth largest GHG emitter.**

The America's Pledge initiative (AP), in partnership with the We Are Still In coalition, is dedicated to understanding the impact of these actors on the U.S. emissions trajectory and to catalyze additional ambition to allow the country to continue building the groundwork to reduce greenhouse gas (GHG) emissions at a rapid rate. These entities are acting out of the urgent necessity for climate action, and are actively implementing ambitious policies, technologies, and partnerships to make even greater reductions a reality in the near-term.

This year, we released a major assessment, *Fulfilling America's Pledge*, of the impact of these real economy actions on the U.S. GHG trajectory and strategies to achieve high ambition. **We assess that even the current commitments by these actors will bring the U.S. ⅔ of the way toward its Paris goal, and that realistic levels of additional action for non-Party actors, using ten near-term, high impact climate action strategies and other ways to enhance ambition, can bring the United States within striking distance of its NDC—a 24% reduction in GHG emissions relative to 2005 levels by 2025.**

Where do we want to go?

America's Pledge reflects a powerful set of actions that within their immediate sphere of influence has the potential to deliver deep emissions reductions, in concert with each other. Through innovation and sharing of data and best practices, guided by the set of ten discrete opportunity areas within high impact sectors set forth by *Fulfilling America's Pledge*, the

potential impacts of real economy actors will place the U.S. within striking distance of our Paris goal, of 24% by 2025. As the world's largest real economy, the collaborative efforts of these set of actors is a powerful signal to the rest of the world that the U.S. is very much still in the Paris Agreement. **By leveraging the power of the real economy, it also sets lays the groundwork for the United States to deliver accelerated ambition for a long-term and rapid pathway to deep decarbonization.**

How do we get there?

Our coalition is large and growing, the near-term policy levers are significant, and the opportunities are great. Through extensive analysis and consultation across our communities, we have built out ten Climate Action Strategies that our real economy actors have capacity and authority to implement today, even without Federal government leadership. These strategies are:

1. **Double down on renewable energy targets;**
2. **Accelerate the retirement of coal power;**
3. **Encourage residential and commercial building energy retrofits;**
4. **Electrify building energy use;**
5. **Accelerate electric vehicle adoption;**
6. **Phase down super-polluting HFCs;**
7. **Stop methane leaks at the wellhead;**
8. **Reduce methane leaks in cities;**
9. **Develop regional strategies for carbon sequestration on natural and working lands; and**
10. **Form state coalitions for carbon pricing.**

Our assessment is that these ten climate action strategies, implemented vigorously in areas that are politically feasible in the next few years, would reduce emissions up to 21% below 2005 levels by 2025. We further estimate that implementing additional feasible near-term actions in other sectors and at deeper levels of engagement could deliver reductions of over 24% below 2005 levels by 2025--bringing the United States close to our 2025 NDC. Moreover, **the groundwork built by these real economy actions allows for an acceleration of our decarbonization rate to over 2% annually after 2025, underscoring the key role of the real economy actors in enabling more rapid emissions reductions to track toward our deep decarbonization goals.**

Real economy actors across the United States and globally have already embraced the future of a clean economy and have made both leading commitments to, and real progress toward, decarbonization already. And they are stepping up to do more. They pledged a new ambitious set of goals at the Global Climate Action Summit in San Francisco, CA in September 2018. For example, in California, the 5th largest economy in the world, passed a bill that requires 100 percent of all electricity to be generated from renewable and zero carbon sources by 2045—and

moreover set a highly ambitious goal of full carbon neutrality for 2045. To address vehicle emissions, now the largest source of emissions in the U.S., 26 businesses, states, cities and regions representing millions of dollars in purchasing power committed to transition fully-zero-emissions vehicles in the next decade. Thirty-eight signatories made up of 12 businesses, 22 cities and four states and regions, signed on to the Net Zero Carbon Buildings Commitment with a 2030 deadline for all new buildings they operate, own or build. More businesses pledged to achieve a 100% renewable goal, such as Sony, McKinsey Group, WeWork and the Royal Bank of Scotland, joining approximately 140 other companies with this commitment. A coalition of 17 philanthropies pledged to fund $459 million around the world to the protecting, restoring and expanding forest and land resource management. As a result of these and many other actions and commitments by leaders across the United States, the We Are Still In coalition now counts 3,540 signatories pledging to uphold the goals of the Paris Agreement. **These new actions by a growing coalition of American real economy actors demonstrate an accelerating trend of much deeper and more rapid progress.**

Integrating the leadership and implementation from real economy actors with national processes to raise ambition in 2020 is the core challenge of the next two years. And it presents a real opportunity for the global community to innovate. In order for countries around the world to collectively raise ambition, new approaches for assessing their real economies must be implemented, one that folds in the role of subnational and non-state actors. The multi-stakeholder governance structure highlighted in the Paris Agreement invites all parties at all levels to the table. America's Pledge has developed a three-part structure to integrate broad-based engagement with real economy actors, communicating options and progress to a broader population, and analysis to support more ambitious action at all levels. Melding bottom up actions from the real economy with national-level integration to assess emissions reduction potential and tightly woven subnational and national level target setting. Such approaches can catalyze the necessary coalitions of national and real economy actors — unified and motivated by coordination, data, and analysis — to impact national ambition globally. **New institutional approaches such as these that integrate national ambition with real economy action will enable the full potential for each country to help meet the collective goals of the Paris Agreement, and realize actions to keep the world on a pathway toward 1.5 degrees C.**

FULFILLING AMERICA'S PLEDGE

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

Bloomberg Philanthropies

For more information, see www.americaspledge.com

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Climate leadership by states, cities, businesses, and other real economy actors can drive down overall U.S. emissions at an accelerating rate between now and 2030.

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About America's Pledge

When President Donald Trump announced his intention to withdraw the United States from the Paris Agreement in June 2017, the response from across the country was swift and significant. An unprecedented coalition of U.S. states, cities, businesses, universities, and other organizations spoke out in continued support for America's climate pledge to the world.

Coalitions backing the Paris Agreement, including the notable "We Are Still In" network, have since doubled in size, with over 3,000 signatories. States, cities, and businesses all over the United States are continuing to lead by adopting greenhouse gas (GHG) emissions reduction targets and other policies to deliver emissions reductions.

In July 2017, former New York City Mayor and United Nations Secretary-General's Special Envoy for Climate Action Michael R. Bloomberg and California Governor Edmund G. Brown, Jr., launched an initiative, known as America's Pledge, to analyze, catalyze, and showcase climate action leadership by U.S. governors, mayors, business leaders, and others. Five months later, at the 23rd Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-23), Michael Bloomberg and Governor Brown published a comprehensive survey of U.S. climate action led by such real economy actors. This first report estimated that real economy actors representing more than half the U.S. economy—whose economic activity is equivalent to that of the third-largest country in the world—were actively engaged in fulfilling the Paris Agreement and had demonstrated their potential to drive decarbonization swiftly and effectively.

This report, *Fulfilling America's Pledge,* builds on our 2017 report and provides the most comprehensive assessment to date of how U.S. states, cities, businesses, and others (often referenced within this report as "real economy actors") are embracing new economic opportunities and technologies to implement climate targets and deliver emissions reductions within their own jurisdictions and operations under their own authority. This report includes an assessment of the impact of their existing commitments on the overall U.S. emissions trajectory, and provides a concise roadmap of 10 broad opportunities for action that together can lay the groundwork for even deeper emissions reductions from the real economy. This report also provides an internationally applicable toolkit to help policymakers and other stakeholders understand how real economy actors can drive more ambitious climate outcomes and serve as implementing partners in the context of other national governments' nationally determined contributions under the Paris Agreement.

Acknowledgments

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Executive Summary

KEY POINTS IN THIS REPORT

1. Implementing the vision of the Paris Agreement calls for broad, rapid, and significant engagement across all parts of society in order to reap the benefits of a low-carbon, climate-resilient future fueled by clean jobs and economic growth. In the United States, cities, states, and businesses, and other real economy actors have embraced this future—helping drive better outcomes for their own citizens and business operations. Although their efforts are driven in part by necessity, in light of the lack of national-level leadership on climate change, these real economy actors have embraced action for the benefit of their own constituents and stakeholders while helping bend the emissions curve downward.

2. Today, we are almost halfway to the original U.S. target under the Paris Agreement of 26-28 percent below 2005 levels by 2025. Across the country, real economy actors have established policies and commitments which, as they are implemented, will drive continued substantial progress towards the Paris pledge.

3. Current federal and real economy commitments, combined with market forces, will drive U.S. emissions to 17 percent below 2005 levels by 2025, roughly two-thirds of the way to the original U.S. target.

4. This report presents a roadmap for 10 *Climate Action Strategies* that are high-impact, near-term, and readily available for implementation by cities, states, businesses, and other actors. This analysis estimates that fully implementing these measures could drive emissions down further, to 21 percent below 2005 levels by 2025.

5. But "readily available" cannot be our limit. Broader engagement and mobilization of motivated cities, states, and businesses can both serve their immediate short-term priorities and enable continued American leadership on climate. It is vital for real economy actors to identify and drive climate reforms that benefit their constituents and stakeholders.

6. Broader engagement of this real economy coalition, within realistic legal and political limits, has the potential to reduce emissions by more than 24 percent below 2005 levels by 2025. This would be within striking distance of the Paris pledge, making the 26 percent threshold achievable shortly thereafter.

7. As we move onward from the Paris pledge, this momentum in turn sets the stage for more rapid decarbonization in the 2025-2030 period. This analysis demonstrates that essential deep decarbonization (80 percent or more by 2050) can be led by the bottom-up efforts of real economy actors—but only with deep collaboration and engagement.

In 2015, the world came together in Paris to forge the first truly global climate agreement: a robust, long-term framework designed to reduce GHG pollution in order to hold global temperature increases to well below 2 degrees Celsius and prevent "dangerous anthropogenic interference with the climate system."[1]

The Paris Agreement entered into force in record time, and with one notable exception, the United States, national leaders in all countries of the world have continued to support the Paris Agreement's goals and approach. The reasons are clear: the risks of climate change to human health and ecosystems are too great, and the benefits of embracing clean energy innovations for well-being, jobs, and economic growth are many. Such action demands full partnership and deep collaboration between national governments and the full range of stakeholders and entities that they represent on the international stage: states, cities, businesses, universities, and communities. It is these *real economy actors* whose decisions shape greenhouse gas (GHG) emissions, drive innovation, and determine the speed of the global energy transition. And nowhere is this kind of decentralized climate leadership currently more important than in the United States.

This report refers to the many U.S. entities taking action on climate change outside the federal government as **real economy actors.**

This term covers a diverse set of such actors, including cities, states, businesses, investors, counties, regional associations, faith institutions, and universities. The term 'real economy actor' is derived from economic governance literature.[3]

Though the meaning can shift in different contexts, it is utilized in this report to differentiate their actions from the current actions of the federal government. In other reports and in the context of the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC), such groups are sometimes called "non-state actors," "sub-national actors," or "non-Party stakeholders."

Photo by Dennis Schroeder / NREL

Three scenarios in this report build out this ladder of ambition:

- First, the *Current Measures* scenario estimates the extent to which existing state, city, and business commitments and policies are likely to reduce emissions;

- Second, an extensive consultation and analysis process identified a discrete set of 10 high-impact, near-term, and readily available opportunities, and estimated their potential to reduce emissions via the *Climate Action Strategies* scenario; and

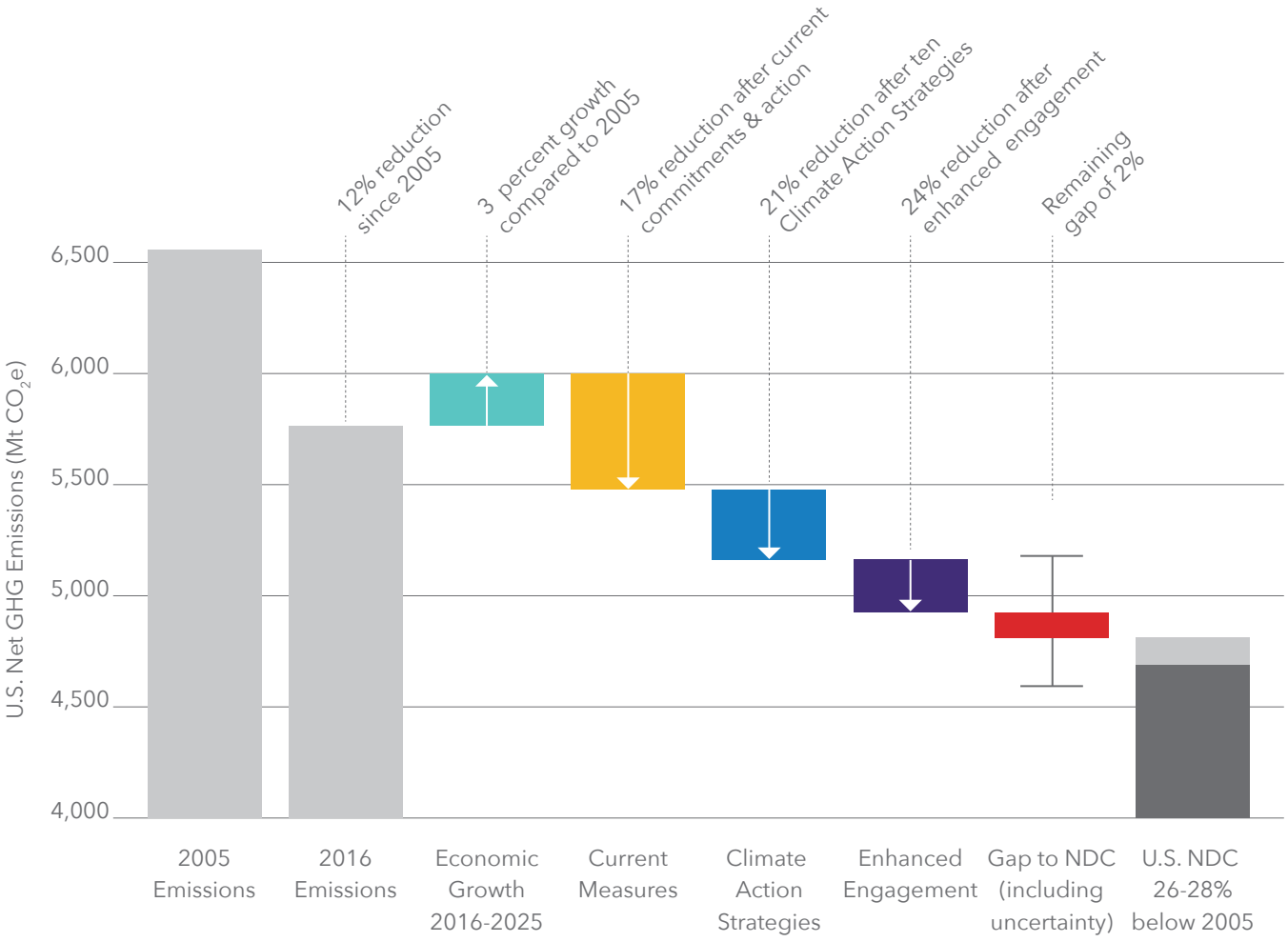
- Third, the *Enhanced Engagement* scenario models what might be possible if an even broader set of ambitious undertakings by states, cities, and businesses were implemented across the economy.

Importantly, even the most ambitious scenario modeled here focuses on what can plausibly be achieved through state, city, and business actions, prior to federal reengagement, taking into consideration limitations, including legal barriers to scaling specific policies and the political unwillingness of local government in certain regions of the United States to take up climate policies.

Photo by Werner Slocum / NREL

The basis for this analysis is an innovative modeling approach developed specifically for the America's Pledge initiative. It integrates a well-established top-down, economy-wide integrated assessment model (the Global Change Assessment Model for the United States of America, or GCAM-USA) with a new, bottom-up aggregation tool developed specifically for this effort to fully and accurately account for the GHG abatement impact of state, city, and business climate action (the Aggregation Tool for modeling Historic and Enhanced Non-Federal Actions, or ATHENA). GCAM-USA is the same economy-wide modeling tool employed by the U.S. federal government in projecting emissions for its Mid-Century Strategy (MCS) report to the UNFCCC.

Figure ES-1: State, City, and Business Actions can Significantly Cut U.S. Emissions in 2025 and Accelerate Momentum for Long-term Decarbonization



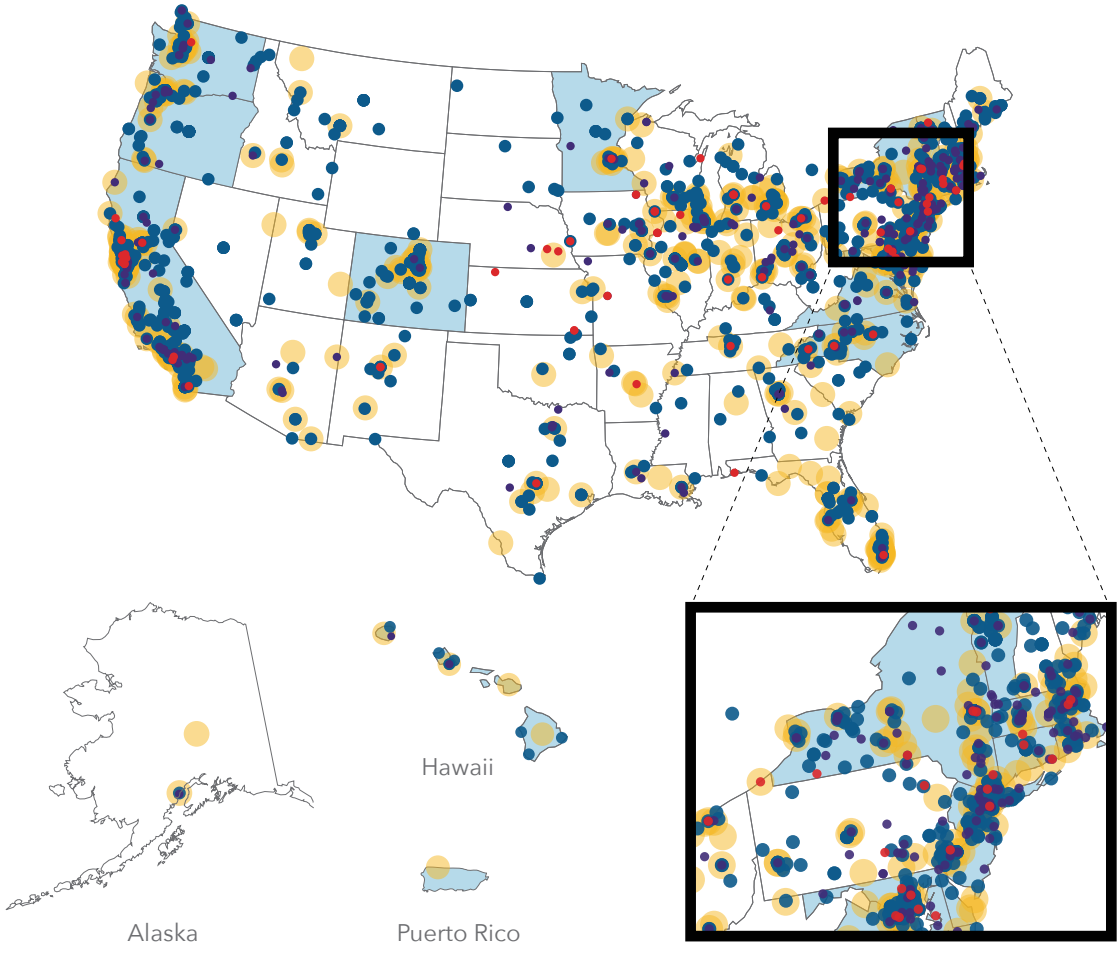
Climate Action Strategies:

- #1: Double down on renewable energy targets
- #2: Accelerate the retirement of coal power
- #3: Encourage residential and commercial building efficiency retrofits
- #4: Electrify building energy use
- #5: Accelerate electric vehicle (EV) adoption
- #6: Phase down super-polluting hydrofluorocarbons (HFCs)
- #7: Stop methane leaks at the wellhead
- #8: Reduce methane leaks in cities
- #9: Develop regional strategies for carbon sequestration on natural and working lands
- #10: Form state coalitions for carbon pricing

Source: Historical emissions data is from the U.S. EPA "Inventory of GHG Emissions and Sinks: 1990-2016"; projected emissions based on modeling from the America's Pledge research team

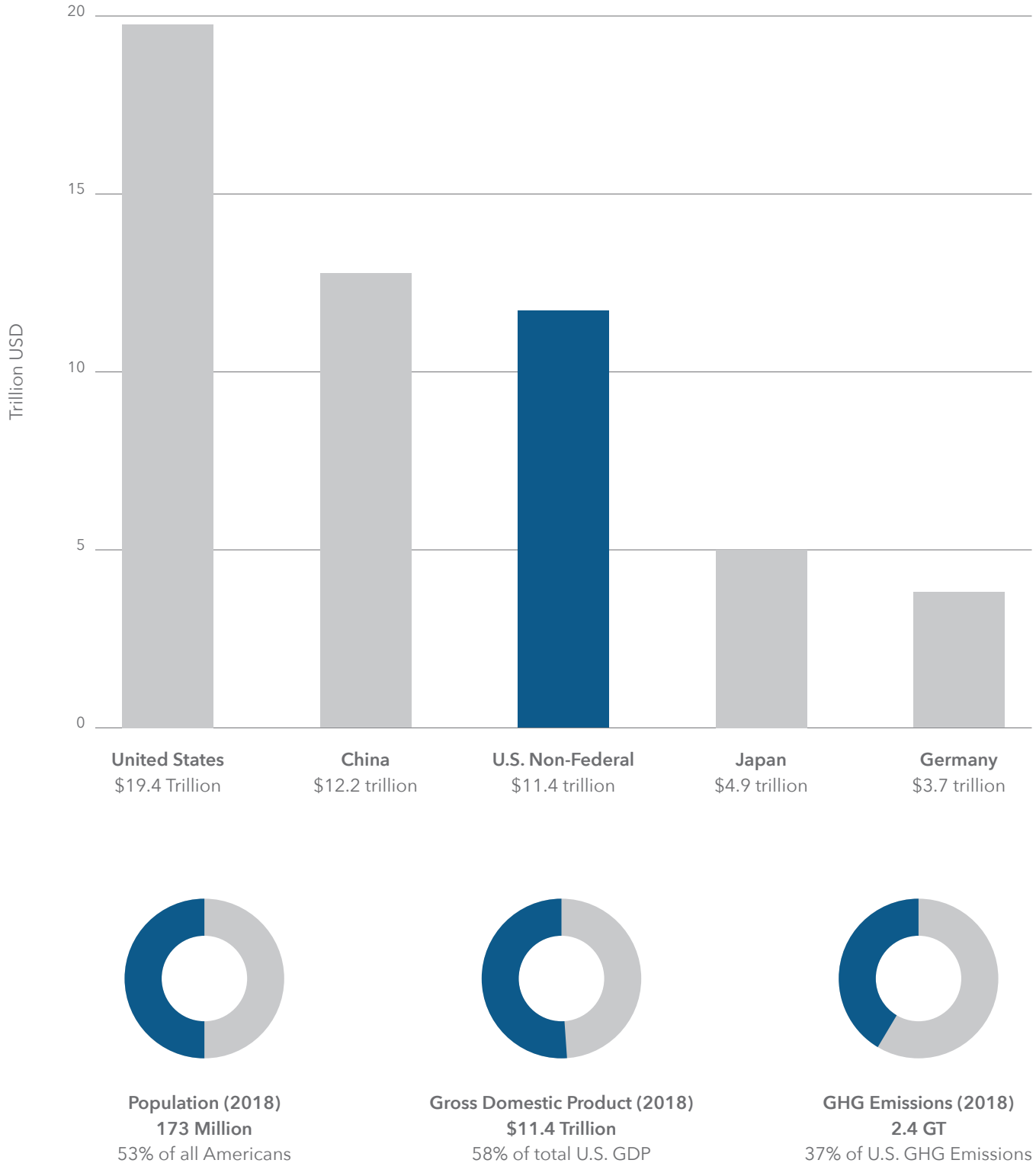
Current Efforts by States, Cities, and Businesses Are Yielding Significant Results

In the year since the Trump Administration announced its intent to withdraw from the Paris Agreement, over 3,000 real economy actors have pledged their support for the Paris Agreement and commitment to continued action on climate change by joining the "We Are Still In" declaration and participating in other networks such as the U.S. Climate Alliance and the Climate Mayors. The economic activity of this "coalition of the willing" is significant, equivalent to that of the third-largest country in the world (Figure ES-2). Specifically, the U.S. states, cities, businesses, and other leaders of the real economy that remain committed to the Paris Agreement represent over half of the U.S. population (173 million people), over half of the American economy ($11.4 trillion), and over 35 percent of nationwide GHG emissions.



States (17)
Cities, Counties and Tribes (540)
Businesses and Investors (1,914)
Faith-Based and Cultural Organizations (253)
Higher Education (343)

Figure ES-2: U.S. States, Cities, and Businesses Supporting the Paris Agreement Make Up a Large and Growing Footprint



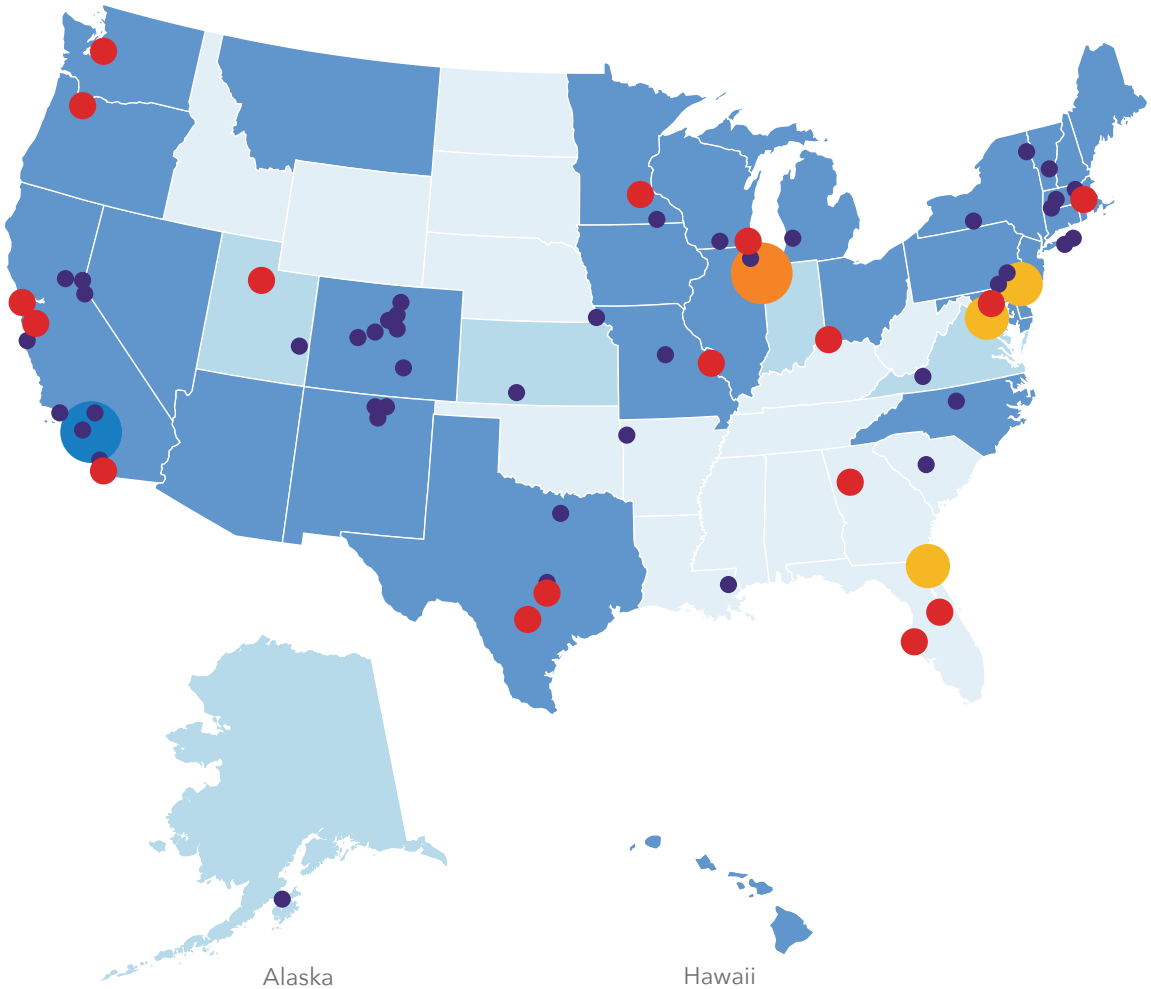
Note: Coalitions represented in the map include: We Are Still In, U.S. Climate Alliance, and Climate Mayors. Information presented on the map was based on available data as of August 2018. The coalitions represented are dynamic and the data will change over time.

U.S. real economy actors are already cutting emissions and scaling clean energy, not just to address climate change but to help create economic opportunities and jobs, and to deliver immediate benefits to public health. This report provides an updated survey of sector-specific actions across all 50 states, the largest 285 cities (with populations above 100,000), and a wide number of businesses in order to assess the impact of climate actions. Among the key findings:

- States, cities, and counties with GHG emissions reduction targets already on the books could cut annual emissions by 500 million metric tons of carbon dioxide equivalent (Mt CO_2e) from business-as-usual levels by 2025 if they are fully implemented;
- State, city, and business clean energy procurement policies (e.g. renewable portfolio standards) should increase demand for non-hydroelectric renewable generation to 500 terawatt-hours (TWh) by 2025 - enough to power 56 million homes for a year (Figure ES-3);
- Energy efficiency policies enacted by states, cities, and utilities could result in annual energy savings of over 200 TWh per year by 2025;
- Implementation of zero-emissions vehicles (ZEVs) mandates would lead to having 4 million new ZEVs on the road by 2025;
- State and city commitments to sustainable transportation networks could cut annual vehicle miles traveled by 36 billion miles, compared with business-as-usual projections by 2025;
- State, city, and business initiatives to cut hydrofluorocarbon (HFC) emissions could reduce these emissions by 6 percent from 2015 levels by 2025; and
- Policies and corporate actions designed to address fugitive methane leaks from oil and gas operations could cut national emissions by 17 percent by 2025, relative to 2005 levels.

Photo by Robert Beadle

Figure ES-3: States and Cities From Across the U.S. Have Adopted Clean Energy Targets and Goals



Source: American Council for an Energy-Efficient Economy; Lawrence Berkeley National Laboratory; World Resources Institute

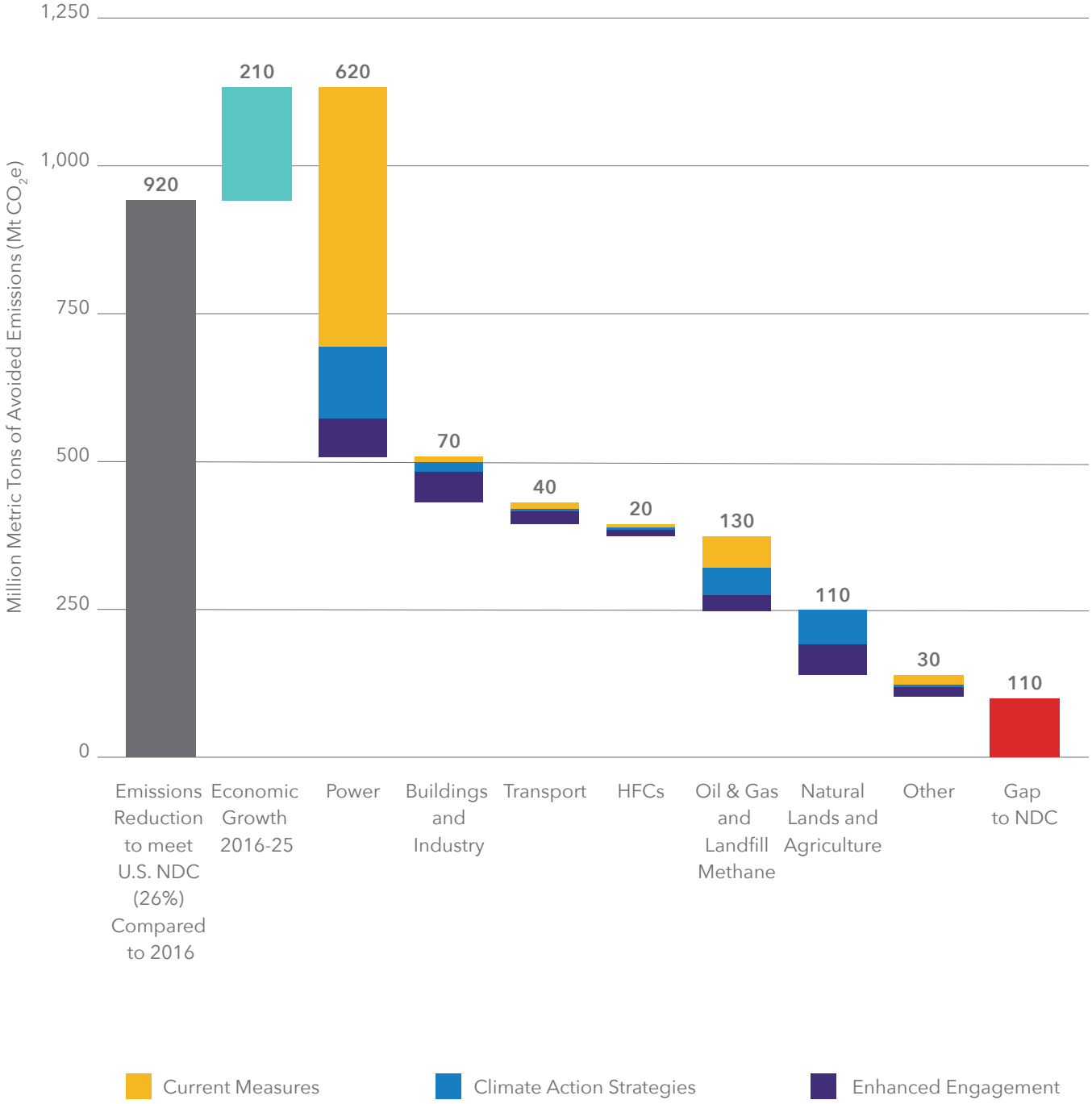
This kind of decentralized, bottom-up climate action is already delivering results. In 2017, U.S. energy-related carbon dioxide emissions fell to their lowest levels in 25 years. Despite the Trump Administration's stated pro-coal policies, announced coal plant retirements are occurring at a faster rate than ever before. Since June 1, 2017, the United States has added enough renewable energy to power more than 3 million homes for a year. States accounting for 35 percent of the U.S. economy are expected to have a price on GHG pollution by the end of this year. And more than 70 U.S. companies have announced emissions reduction targets in line with the Paris Agreement.

A Bottom-Up Opportunity Agenda for the Real Economy

Looking forward, we project that current policies and existing pledges from real economy actors, along with market forces and technology change (our *Current Measures* scenario), will deliver economy-wide emissions reductions of 17 percent below 2005 levels by 2025, even accounting for economic and population growth—taking the nation two-thirds of the way to its Paris pledge. This report goes on to build out a detailed picture of potential future actions that could go well beyond decarbonization commitments currently on the books. Such actions include a broad suite of emissions reduction opportunities spanning most major economic sectors and greenhouse gases—including electricity, transportation, buildings, oil and gas methane, natural and working lands, and hydrofluorocarbons (see Figure ES-4). We present potential sectoral impacts as a range of real-world outcomes with the 10 *Climate Action Strategies* at the accessible end and the full *Enhanced Engagement* potential at the more ambitious end. The 10 strategies were selected because they each represent significant opportunities to achieve impact by 2025 through collaborative action that can most easily begin by 2020 (see details of the 10 *Climate Action Strategies* on page 25). Moving from the low to the high end potential requires both recruiting new cities, states, and businesses to undertake commitments defined in the *Climate Action Strategies*, and expanding the range of actions by already committed real economy actors using the levers of change described in this report.

Broader engagement of this real economy coalition, within realistic legal and political limits, has the potential to reduce U.S. emissions by more than 490 additional Mt CO_2e to 24 percent below 2005 levels by 2025 (with a range of uncertainty of 20 to 30 percent). This would be within striking distance of the Paris pledge, making the 26 percent threshold achievable shortly thereafter. Moreover, such action would drive an even faster rate of economy-wide decarbonization between 2025 and 2030.

Figure ES-4: Achieving Full Potential Entails Actions Across All Major Economic Sectors and GHG Gases (Mt CO_2e in 2025)



Source: America's Pledge modeling results

Table ES-1: Key Climate Action Levers and Associated Potential

Sector	2005 Emissions ($MtCO_2e$)[1]	Change in Sector Emissions in 2016 relative 2005 ($MtCO_2e$)[2]	Percent Change in Sectoral Emissions 2016 Compared to 2005[3]	Scenario	Change in Sector Emissions in 2025 by Scenario($Mt CO_2e$)[4]	Total Feasible In-Sector Emissions Reductions 2005-25 as % of 2005[5]
Power	2,439	-593	-24%	Current	-440	-50%
				Strategies	-120	
				Enhanced	-60	
				Total	-620	
Buildings	1,696	-160	-9%	Current	-10	-14%
				Strategies	-10	
				Enhanced	-50	
				Total	-70	
Transportation	1,904	-99	-5%	Current	-10	-7%
				Strategies	-10	
				Enhanced	-20	
				Total	-40	
HFCs	103	+56	+54%	Current	-5	+35%
				Strategies	-5	
				Enhanced	-10	
				Total	-20	

For additional details on all sector assumptions and associated values for modeled emissions reductions in 2025, please see the Technical Appendix.

Oil & Gas and Landfill Methane[7]	469	-20	-4%	Current	-50	-32%
				Strategies	-50	
				Enhanced	-30	
				Total	-130	
Natural & Working Lands and Agricultural Emissions[8]	-211	+57	+26%	Current	0	-25%
				Strategies	-60	
				Enhanced	-50	
				Total	-110	
Total Net GHG Emissions[9]	6,589	-795	-12%	Current	-530	-24%
				Strategies	-250	
				Enhanced	-240	
				Economic Growth[9]	+210	
				Total	-810	

Notes:

1. Sector emissions based on 2016 U.S. EPA GHG inventory estimates. Some small sectors are omitted and therefore sum does not add to total net GHG emissions. As some sectors are estimated and calculated, values may differ slightly from EPA GHG inventory.
2. Change in sector emissions between 2005 and 2016 calculated based on 2016 U.S. EPA GHG inventory estimates.
3. Percent sectoral emissions reductions between 2005 and 2016 as % of 2005 sectoral emissions (based on 2016 U.S. EPA GHG inventory)
4. Total sector emissions reductions across three scenarios modeled by America's Pledge relative to a 2025 reference scenario.
5. Total feasible in-sector emissions reductions quantified as the total emissions reductions between 2005 and 2016 (based on U.S. EPA GHG inventory) and modeled emissions reduction between 2017 and 2025 (based on America's Pledge analysis), compared to the 2005 baseline.
6. Direct emissions from residential, commercial and industrial sectors. Does not include indirect emissions associated with electricity consumption which is included in power sector. Does not include industrial-related methane and HFCs included in other sectors.
7. GCAM assumes significant growth in methane emissions between 2005 and 2025. While total emissions grow, actions taken by real economy actors has the potential to cut emissions by over 30% against below 2005 levels. Agricultural methane included in Natural and Working Lands
8. Net change in emissions inclusive of land-sector sink and agricultural emissions. Both land-sector sink diminished in magnitude and agricultural emissions increased between 2005 and 2016, resulting in net increase in emissions of 26%.
9. Total GHG emission increases by 210 Mt CO2e in the GCAM reference scenario from 2016 to 2025. Emission reductions are measured relative to this scenario.

The Ten Climate Action Strategies

#1: DOUBLE DOWN ON RENEWABLE ENERGY TARGETS

Ratcheting up renewable energy targets at a time of plummeting solar and wind costs and rapid evolution of business model solutions could achieve a major portion of the overall potential within the electricity sector. State, city, and business renewable energy commitments embodied in this strategy could readily lead to the deployment of an additional 130 TWh of total renewable energy beyond current policies and commitments by 2025—taking the U.S. to 990 TWh of renewable energy annually, up from 600 TWh in 2016.

#2: ACCELERATE THE RETIREMENT OF COAL POWER

States, cities, and businesses can accelerate the transition from fossil fuels to clean energy and shape the evolution of the electricity grid by insisting on the retirement of coal plants that are no longer competitive, fail to meet public health standards, or violate community clean energy goals. Working together, states, cities, businesses, advocates, and other stakeholders can speed this transition and ensure that 94 gigawatts (almost 30 percent) of the 2005 U.S. coal fleet has retired by 2025.

#3: ENCOURAGE RESIDENTIAL AND COMMERCIAL BUILDING EFFICIENCY RETROFITS

Cities can collaborate with the real estate industry, utilities, and state regulators to develop and implement ambitious building energy efficiency programs and policies. Cities can accelerate building retrofits by implementing a tested suite of approaches, including energy disclosure ordinances, requirements for building upgrades at key trigger points, and scaling retrofit incentive programs. Doubling the number of cities with energy efficiency targets and associated implementation mechanisms would result in an additional savings of 13 TWh per year by 2025 compared with what is modeled under our *Current Measures* scenario, enough electricity to power 1.5 million homes for a year.

Photo by Dennis Schroeder / NREL

#4: ELECTRIFY BUILDING ENERGY USE

States, cities, and utilities can collaborate to electrify building energy use. This would begin the transition away from the 500 million tons of carbon dioxide pollution that comes from burning fossil fuels inside U.S. homes and businesses each year. Targeting collaborative action by states, cities, utilities, and industry organizations in the Northeast and Midwest regions, where electrification retrofits are most cost-effective today, could deliver a 2025 impact of over 800 tera Btu of total savings (enough energy to power 25 million homes for a year) and a significant start in the transition away from fossil fuels.

#5: ACCELERATE ELECTRIC VEHICLE (EV) ADOPTION

States, cities, corporate fleet owners, utilities, vehicle manufacturers, transportation network companies, and other private-sector innovators have the power to substantially increase the rate of EV deployment, particularly when they work together. Collaborative action can lift uptake of EVs in the United States such that an estimated 8.4 million EVs will be on the road by 2025, more than doubling the 4 million EVs anticipated to be sold under current policies and conditions.

#6: PHASE DOWN SUPER-POLLUTING HYDROFLUOROCARBONS (HFCS)

Expanding the California Significant New Alternatives Policy (SNAP) program to include HFC aerosols, replicating this program in a broader subset of states that includes all 16 current members (and Puerto Rico) of the U.S. Climate Alliance, and broadening EPA's GreenChill program could reduce HFC emissions by an additional 5 percent beyond current policies by 2025.

#7: STOP METHANE LEAKS AT THE WELLHEAD

States, supported by industry and environmental groups, can put in place important regulations and/or permitting programs to manage methane emissions from oil and gas facilities. Setting standards and implementing innovative detection technologies in seven states considering new or updated actions to address methane emissions could reduce national emissions from this source as much as 23 percent below 2005 levels by 2025.

#8: REDUCE METHANE LEAKS IN CITIES

Cities, utilities, and commercial service providers can work with urban gas distribution utilities in key states to develop and implement plans to use advanced leak detection and data analytics to identify and abate the largest leaks from municipal natural gas distribution systems. Using innovative, data-driven approaches to identify and prioritize the repair of the top 20 percent of leaks in the eight states with the highest leakage, we estimate that coordinated action by states, cities, and businesses in a subset of U.S. states with leak-prone urban infrastructure could cut nationwide distribution system emissions by 30 percent by 2025.

#9: DEVELOP REGIONAL STRATEGIES FOR CARBON SEQUESTRATION ON NATURAL AND WORKING LANDS

States and businesses, nurtured with support from coalitions of philanthropies and NGOs, can spark regional initiatives for enhanced carbon sequestration on natural and working lands. Through collaborative action in U.S. Climate Alliance states and other states, real economy actors can reduce emissions by 60 Mt CO_2e by 2025.

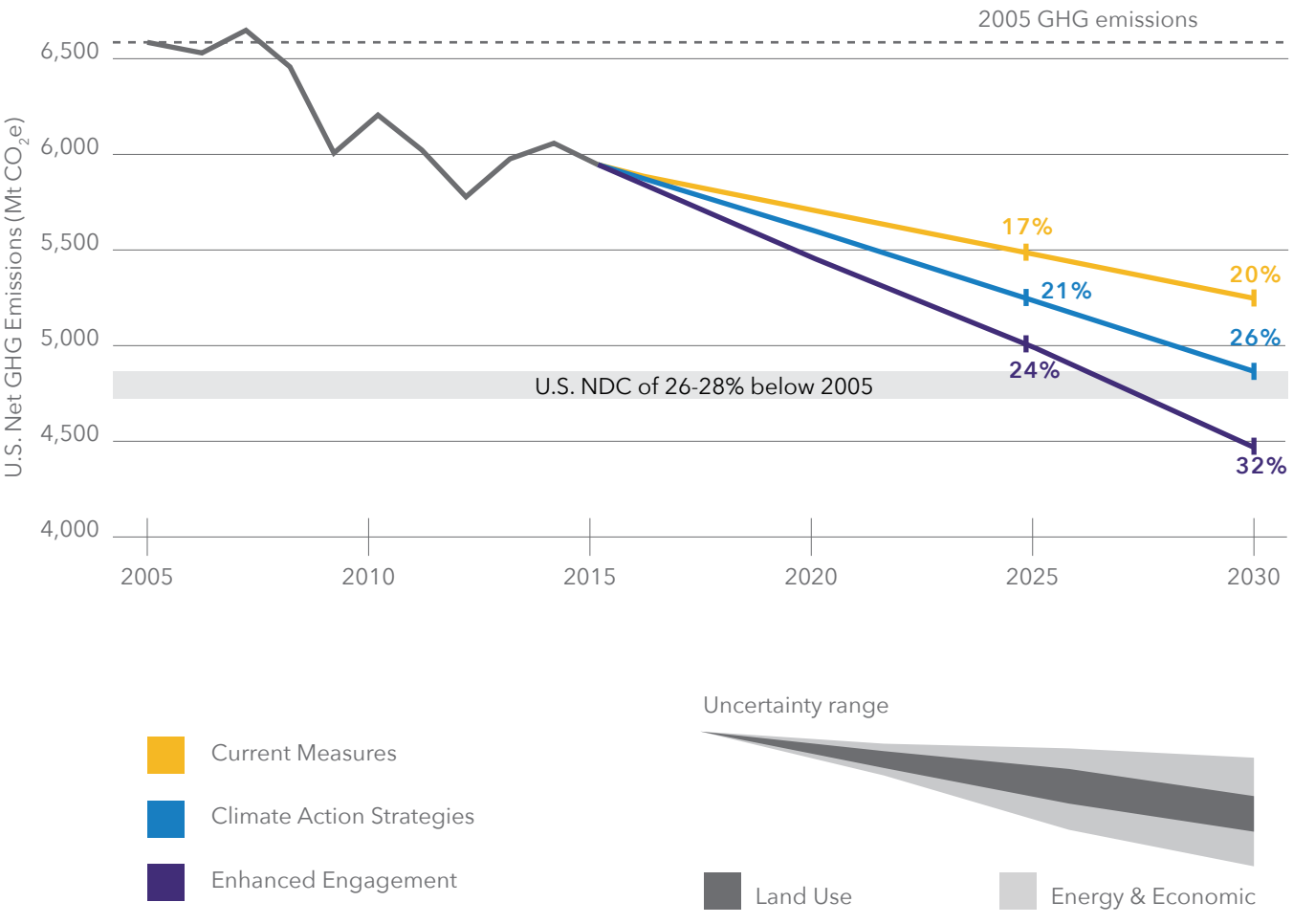
#10: FORM STATE COALITIONS FOR CARBON PRICING

Real economy actors can establish economy-wide limits on carbon pollution in geographically diverse states, using emissions targets consistent with the near- and long-term reductions necessary to achieve the goals of the Paris Agreement. Today eight states have mandatory economy-wide GHG targets, and another eight states and the District of Columbia have aspirational GHG targets (e.g., set by executive order). If these states put into place a limit on carbon pollution consistent with U.S. targets under the Paris Agreement and implement appropriate sector-specific programs and policies, the United States could reduce energy-related CO_2 emissions economy-wide by more than 350 Mt CO_2e by 2025. Note that many of the sector-specific emission reductions identified in the first nine strategies are vital components in the ability of these states to meet their economy-wide targets.

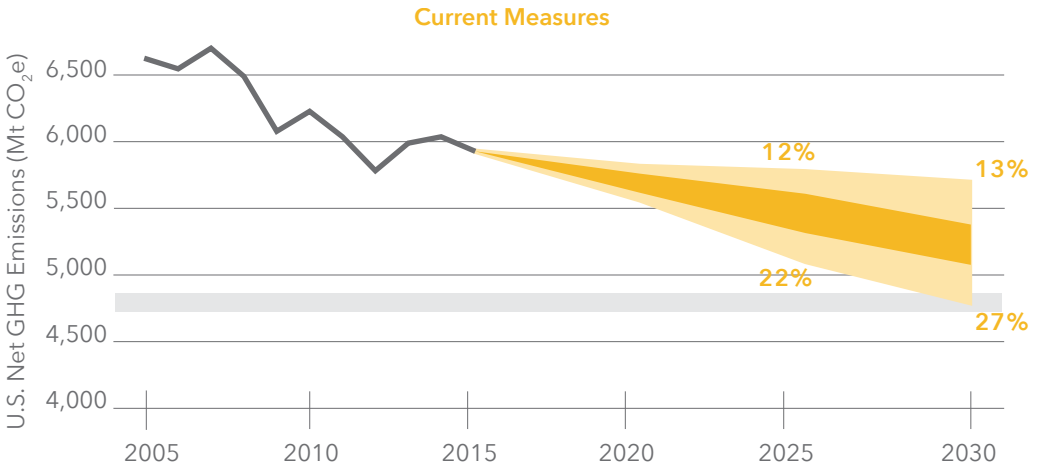
Pathways to America's Low-Carbon Future

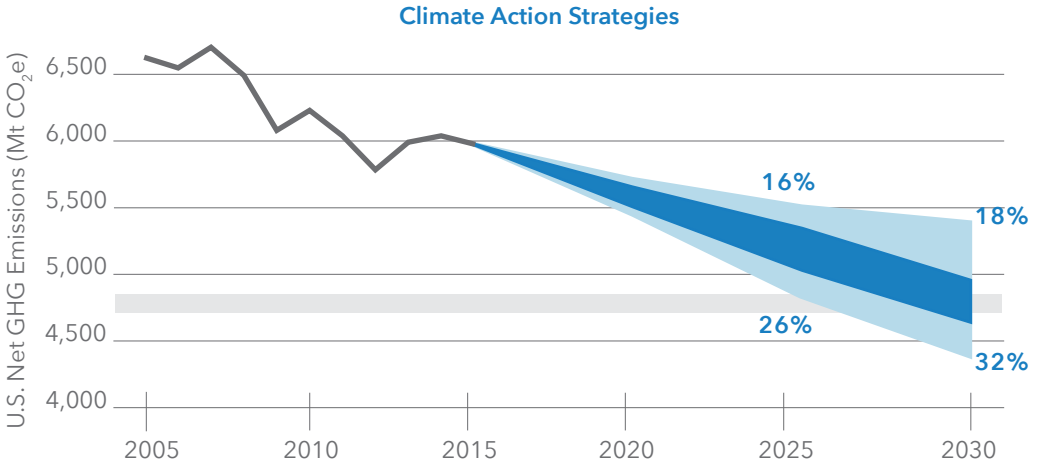
Figure ES-5 shows the modeled evolution of U.S. emissions between 2005 and 2030, illustrating both the potential of real economy impact by 2025, and the even more significant emissions reductions such action will trigger in the critical period between 2025 and 2030. This graph presents a central estimate as well as a range of potential outcomes flowing from uncertainty in key variables, specifically economic growth, energy prices , and land use changes.

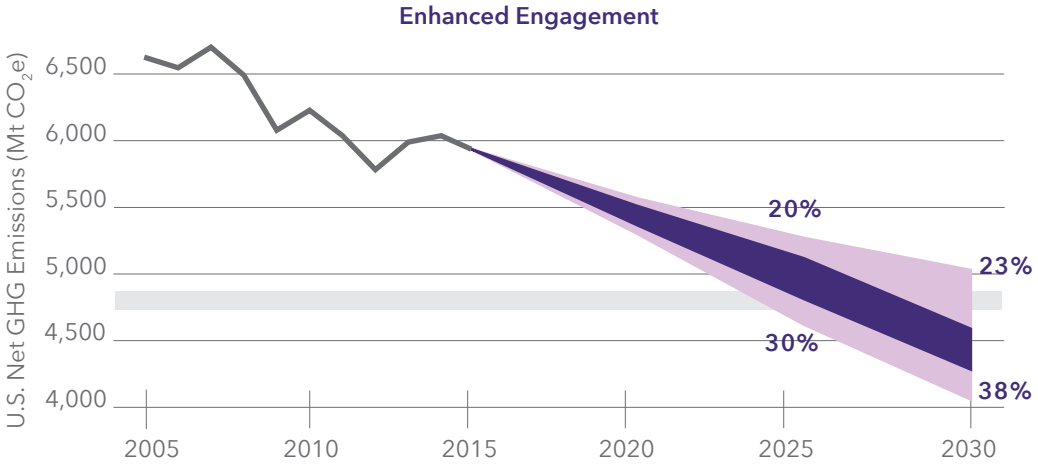
Figure ES-5: Progress Toward Near-and Long-term Climate Goals Varies Across the Three Scenarios (Mt CO_2e)



Source: America's Pledge modeling results


Current Measures
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
12%
13%
22%
27%


Climate Action Strategies
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
16%
18%
26%
32%


Enhanced Engagement
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
20%
23%
30%
38%

Broader engagement of this real economy coalition, within realistic legal and political limits, has the potential to reduce emissions by more than 24 percent below 2005 levels by 2025. This would be within striking distance of the Paris pledge, making the 26 percent threshold achievable shortly thereafter.

This result is compatible with the emissions projections presented by the Obama Administration to the global community in its 2016 Biennial Report to the UNFCCC. Those projections demonstrate that the U.S. target for 2025 is a stretch goal, but is achievable with concerted effort. However, whereas the Obama Administration's 2025 projections assumed continued, and indeed enhanced, federal engagement in the period from 2017 through 2025, our analysis demonstrates that during the current hiatus in federal leadership, real economy actors are substantially maintaining, and can fully maintain, the momentum of the nation's decarbonization trajectory for 2025 and beyond.

The annual rate of decarbonization in the *Enhanced Engagement* scenario is 1.6 percent between 2016 and 2025, accelerating to 2.1 percent for 2025–30. This is substantially higher than the actual 1.1 percent rate for the period 2005–16. The post-2025 trajectory approaches the rate of decarbonization needed to hit 80 percent below 2005 levels by 2050 (2.3 percent).[2] The acceleration we model after 2025 is attributed to the fact that several sectors of the economy—transportation and buildings, for example—have long lead times for capital turnover. Policies put in place between now and 2025 will deliver the bulk of their emissions reduction benefits only after 2025, and will continue to have an effect after 2030 as buildings, fleets, industrial processes, and other infrastructure are modernized.

Fulfilling America's Pledge

This analysis demonstrates for the first time that despite federal policy inaction, the United States can get on track to approach its Paris Agreement pledge for 2025 through the concerted effort of real economy actors. Moreover, implementing such actions today can support accelerated reductions beyond 2025, driving even steeper overall U.S. emissions reductions between 2025 and 2030. Federal reengagement undertaken as rapidly as possible will be essential in sustaining and accelerating the needed breadth and depth of emissions reductions across all sectors of the U.S. economy, both to close any remaining gap in 2025 and for long-term decarbonization.

The insights contained in this report about bottom-up climate action potential in the United States may also hold important lessons for the broader international community as policymakers and leaders across society consider how to accelerate and deepen implementation of the Paris Agreement. While national governments and policies were in the spotlight during the run-up to the Paris Agreement in 2015, the focus of international negotiations has now shifted to a more detailed examination of what it will take to formulate and implement increasingly ambitious national climate goals. The case of the United States demonstrates that real economy actors can lead ambitious and sustained commitments to climate action from all levels of government and across the economy.

The results of this analysis are therefore a call to action for the global community as a whole. Achieving the goals of the Paris Agreement has always been recognized as demanding the full participation of and deep collaboration between national governments and their broader societies. This moment presents the opportunity to make that collaboration a reality.

Chapter 1

Introduction

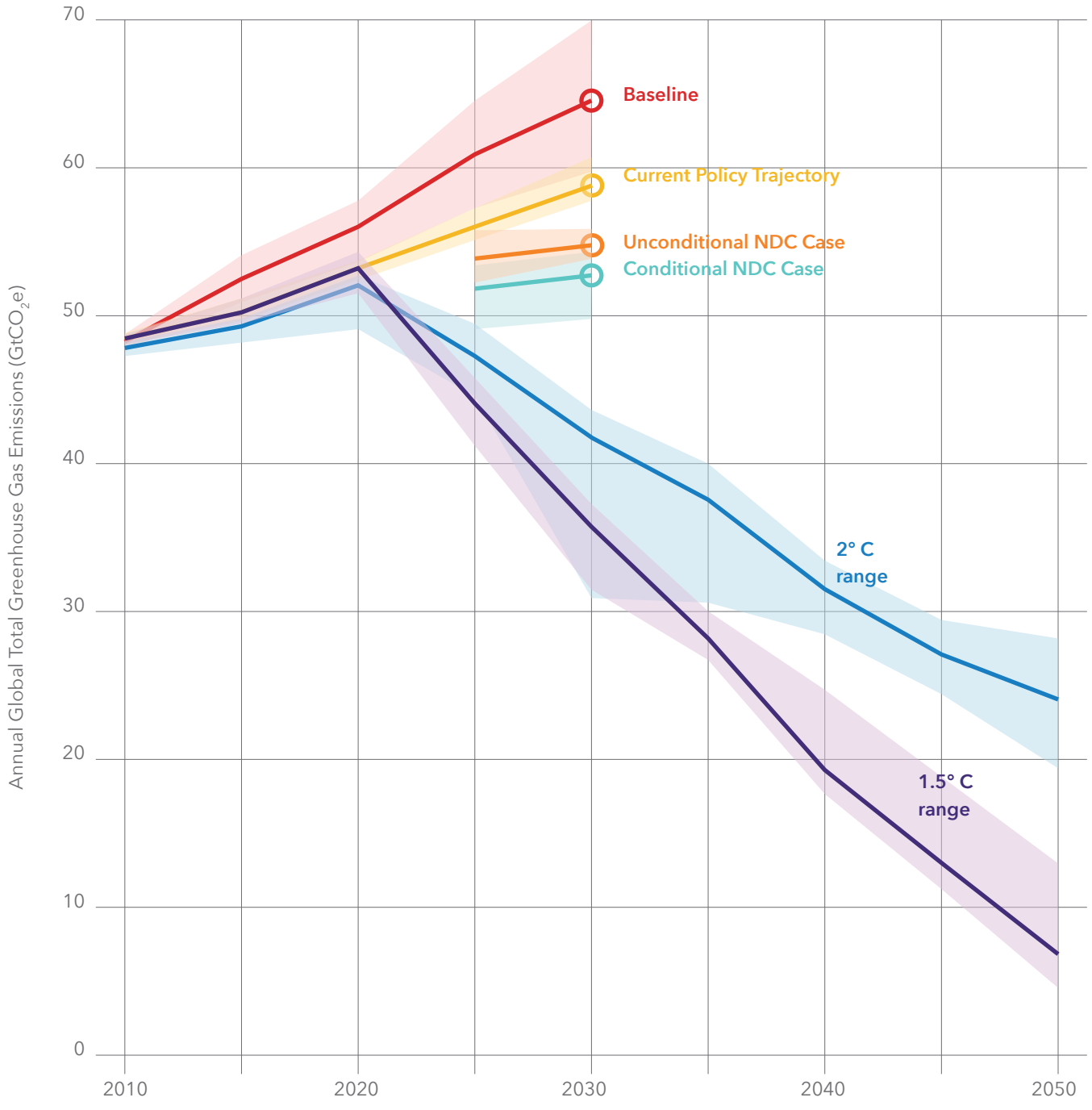
The Paris Agreement was the culmination of nearly 30 years of efforts to devise a durable strategy for ratcheting down global GHG emissions at a pace that would avoid the most dangerous effects of climate change.

This landmark accord envisages shared responsibilities among all nations and promotes continually increased ambition over time. The Paris Agreement entered into force in record time, with more than 170 national governments formally submitting their pledges—nationally determined contributions (NDCs)—less than three years after the Paris Agreement was finalized. With just one notable exception, all national Parties to the Paris Agreement, together with the many thousands of disparate actors such as states, cities, and businesses in every country around the world, remain committed to moving forward toward the goals of the Paris Agreement.[4]

Yet despite this unprecedented progress, meeting the ambitious goals of the Paris Agreement will require faster and bolder action. Although national commitments under the

Paris Agreement are an important first step, as outlined in the United Nations Environment Programme (UNEP) Emissions Gap Report (see Figure 1-1), there remains a gap between this initial batch of NDCs for 2025–30 and the rate of decarbonization needed to limit temperature rise to below 2 degrees Celsius and approach 1.5 degrees.[5] Therefore, in the coming years the world must accelerate emissions reductions, utilizing the full range of potential levers available. Such transformation demands a full partnership and deep collaboration among national governments and their broader societies: states, cities, businesses, universities, and communities whose decisions affect greenhouse gas emissions, drive innovation, and shape the speed and direction of the global energy transition. Nowhere is this kind of decentralized climate leadership more important than in the United States, where the recent change in presidential administrations has resulted in an abandonment of federal climate leadership.

Figure 1-1: Even with Current Paris Agreement Commitments, a Substantial Ambition Gap Remains



Blue area shows pathways limiting global temperature increase to below 2° by 2100 with >66% chance.

Purple area shows pathways limiting global temperature increase to below 1.5° by 2100 with 50 to 66% chance.

Source: UN Environmental Program, "The Emissions Gap Report 2017," 2017.

Real Economy Actors: Working Together to Close the Ambition Gap

Across the globe, cities, states, businesses, and other real economy actors are taking on increasing responsibility for implementing climate targets. In the multilevel U.S. federal political system, each of these actors has a powerful set of tools within its sphere of influence that it can use to reduce greenhouse gas emissions (Figure 1-2).

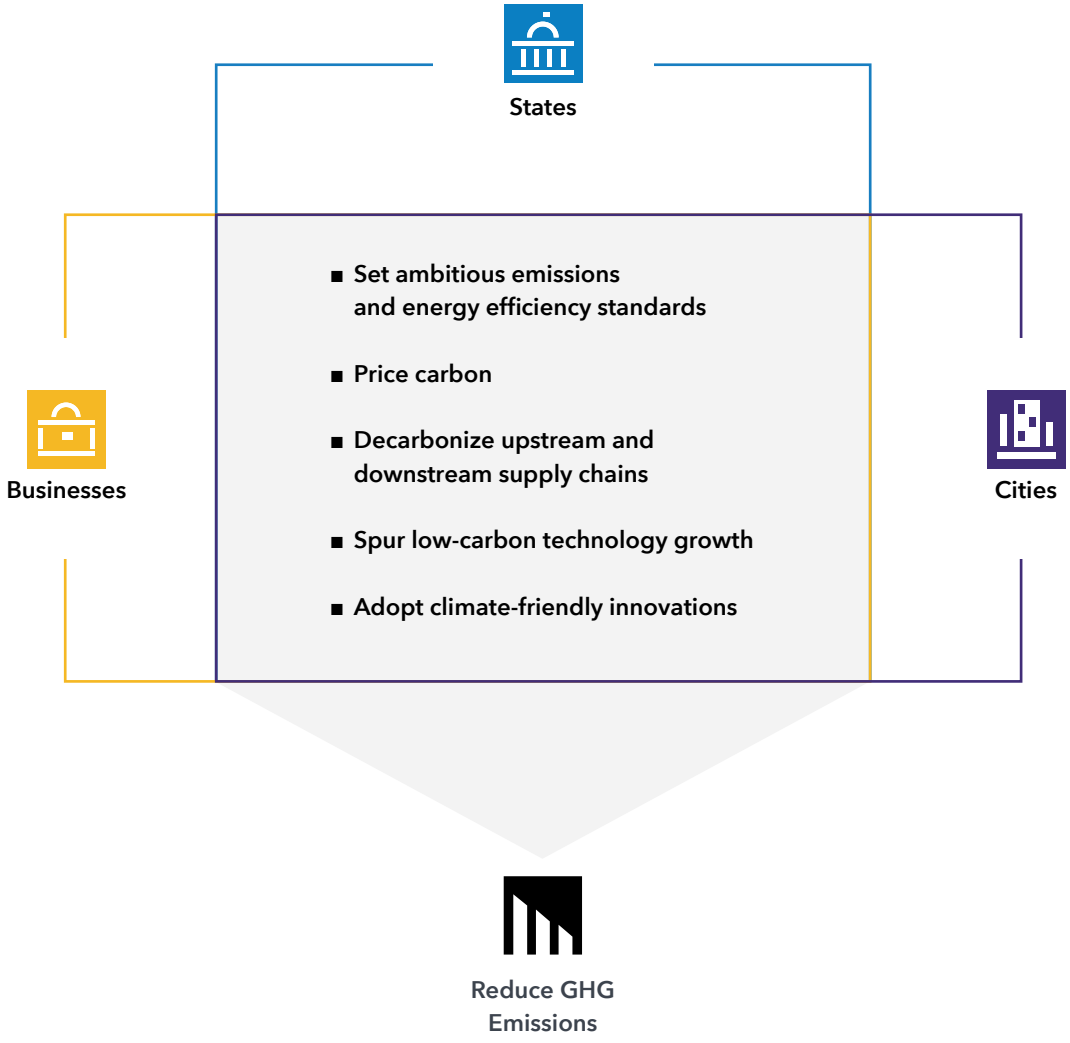
States control many of the most powerful energy and climate policy levers, such as renewable portfolio standards and air pollution regulations. States will often experiment and emulate peers: early mover states typically demonstrate successful models and then engage others to follow. U.S. Supreme Court Justice Louis Brandeis famously called states the "laboratories of democracy" thanks to their ability to innovate and experiment with diverse policy solutions. This is as true of energy and climate today as it was true of leading public policy issues in Brandeis's time nearly 80 years ago.

Cities and counties control city planning, building standards and permits, public transportation, waste management, and zoning, all critically important to climate mitigation. Increasingly they seek to serve their populations by exercising greater influence over such economic factors as the sources and prices of electricity, modes of transportation, and climate resilience. In particular, large cities and counties represent sizable shares of state and regional economies, taxes, and energy demand. Indeed, the 25 largest urban areas in the United States account for 46 percent of total

GDP,[6] 10 percent of the population, and 6 percent of climate emissions.[7]

Businesses do not set public policy; however, they direct, invest in, or influence much of the carbon-emitting asset base (energy, industry, and buildings) across wide swaths of the economy. Business leadership and policy often affect operations across multiple facilities, setting the terms of engagement for complex and multilayered supply chains across a large geographic scope, often spanning many states and even multiple countries. Businesses consume a substantial share of the nation's energy and can make decisions about how to source electricity and heat. They can heavily influence transportation-related CO_2, methane, and hydrofluorocarbon (HFC) emissions as well.

Figure 1-2: States, Cities, and Businesses have a Number of Levers at their Disposal



The importance of real economy actors stepping up to the climate challenge is vital beyond the current American federal abdication context, given that globally, initial NDCs are falling short of the required rate of decarbonization.[8] National governments are realizing that their regions, cities, businesses, and societies are both demanding and driving decarbonization. While this factor was only partly captured in the first round of NDCs, it is now especially timely as Parties to the Paris Agreement prepare to convene in 2020 to re-examine whether they can increase their climate ambition for 2030, both collectively and individually. Rather than viewing climate change as a problem for national governments to solve, the new paradigm must be one of partnership and collaboration across societies.

About America's Pledge and This Report

On June 1, 2017, President Trump announced his intent to withdraw the United States from the Paris Agreement. The response from different sectors and civil society across the United States was swift. Just 72 hours after the announcement, an unprecedented coalition composed of states, cities, businesses, universities, and others declared "We Are Still In," vowing continued climate action consistent with the goals of the Paris Agreement. The list of signatories to this declaration has since doubled in size. In July 2017, Governor Edmund G. Brown, Jr., of California and former New York City mayor and United Nations Special Envoy for Climate Action Michael Bloomberg launched the America's Pledge initiative to enable a diverse set of leaders and groups of actors in the United States to better understand and build the basis for sustained, effective climate action. The America's Pledge initiative played a critical role in the months following the Trump Administration's announcement, showcasing for the world continued U.S. climate leadership from states, cities, and businesses.

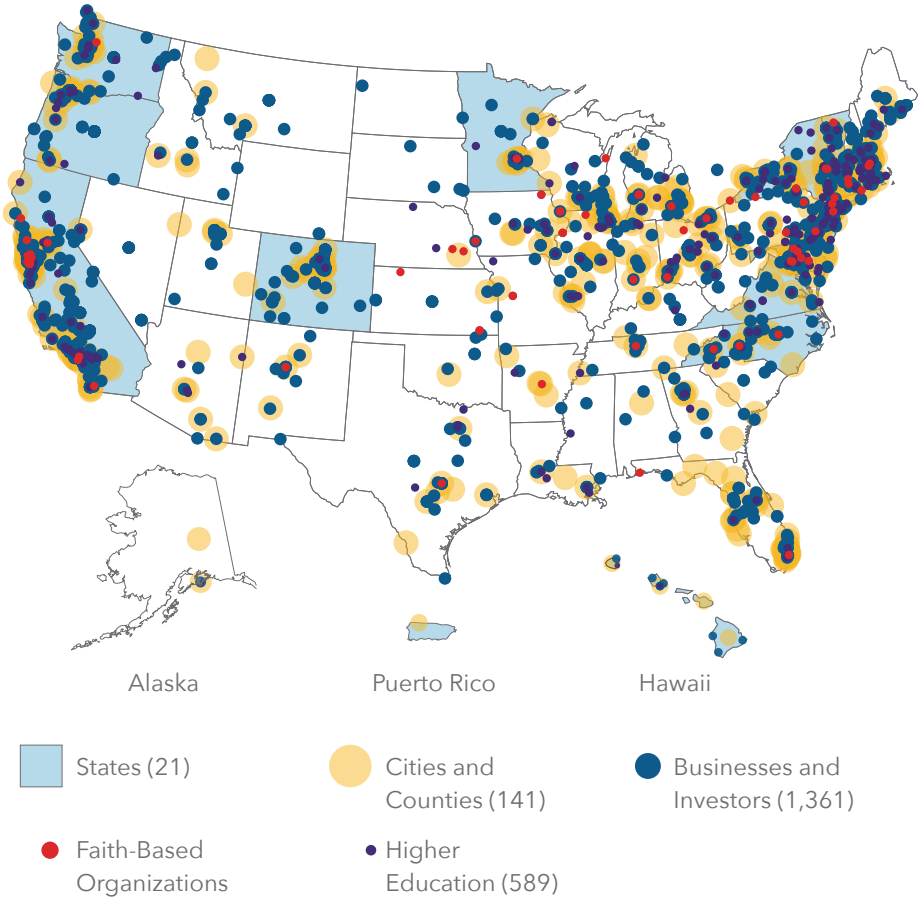
At the November 2017 23rd Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-23) in Bonn, Brown and Bloomberg highlighted the scope and scale of these commitments and actions in *America's Pledge Phase 1 Report: States, Cities, and Businesses in the United States Are Stepping Up on Climate Action*.[9] The report's key finding—that states, cities, and businesses representing over half the U.S. economy, equivalent to the third-largest economy in the world, remain committed to climate action consistent with the Paris Agreement—reverberated in the climate negotiations and around the globe. When presented to the international community, the report helped shift the tone from one of pessimism about U.S. climate efforts to one recognizing and reinforcing the momentum from states, cities, and businesses.

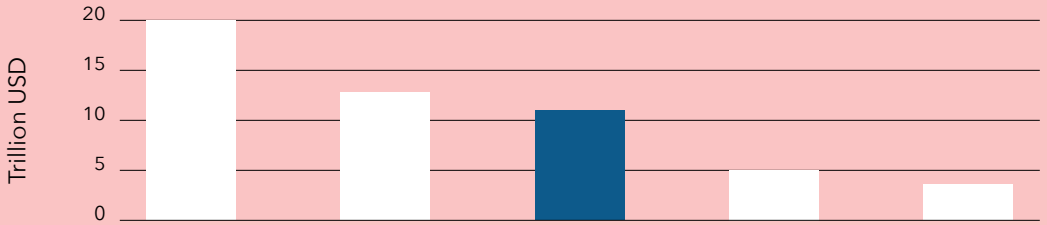
Since President Trump announced his intent to withdraw from Paris, real economy actors have issued a continual stream of ambitious policy changes, investments and decarbonization programmatic initiatives—not just local and regional governments like cities and states, but also businesses,healthcare providers, universities, rural electric cooperatives, investment bankers, community organizations, and religious congregations. Momentum continues to grow—but its aggregate impact on economy-wide emissions has not previously been estimated.

U.S. NETWORKS SUPPORTING THE PARIS AGREEMENT

Since June 2017, the world has witnessed an unprecedented mobilization of U.S. states, cities, and counties; tribal nations; businesses and investors; colleges and universities; and other civil society leaders that have declared their support for the Paris Agreement. Since the launch of the America's Pledge initiative, over 3,000 leaders from regions all across the country have committed to act on climate (see Figure 1-3).[10] The combined gross domestic product (GDP) of U.S. states and cities that remain committed to action in line with the emissions reduction goals of the Paris Agreement would be the third-largest country in the world—larger than the economies of either Japan or Germany—and would account for over 35 percent of U.S. emissions.[11]

Figure 1-3: U.S. States, Cities, and Businesses Supporting the Paris Agreement Make Up an Increasingly Large Footprint





United States
$19.4 Trillion

China
$12.2 trillion

U.S. Non-Federal
$11.4 trillion

Japan
$4.9 trillion

Germany
$3.7 trillion

Population (2018)
173 Million
53% of all Americans

Gross Domestic Product (2018)
$11.4 Trillion
58% of total U.S. GDP

GHG Emissions (2018)
2.4 GT
37% of U.S. GHG Emissions

A number of organized networks have formed to help implement policies and programs consistent with the goals of the Paris Agreement, including those below.

- "*We Are Still In*" is composed of leaders from across all sectors of the United States, including states and tribal nations, cities and counties, businesses and investors, higher learning institutions, faith groups, and cultural institutions. As of August 2018, there were over 2,800 signatories committing to the goals of the Paris Agreement. In aggregate, these leaders represent a population of over 150 million (47 percent) and GDP totaling $9.6 trillion (49 percent).[12]

- *The U.S. Climate Alliance* has grown to include 16 states and Puerto Rico, representing 134 million people (40 percent of the U.S. population) and GDP of more than $9 trillion (46 percent of U.S. GDP), making commitments to meet their share of the U.S. NDC under the Paris Agreement.[13]

- *U.S. Climate Mayors* now include 412 cities, up from 383 cities a year ago.[14] Climate Mayor cities representing more than 70 million Americans and 24 percent of U.S. GDP are committed to upholding the goals of the Paris Agreement and are mobilizing efforts to accelerate U.S. city climate action.

These networks represent the voices of change, demonstrating to the U.S. and global leadership that climate progress will continue. Beyond signing on to these pledges, states, cities, and businesses are enacting policies, making investments, and engaging communities to accelerate the transition to a clean energy economy. It is critical that states, cities, and businesses continue to implement their commitments. This report provides useful examples of current and potential future progress in order to inspire leaders to do more.

In the United States, states, cities, businesses, and other real economy actors have embraced the low-carbon, climate resilient future—helping drive better outcomes for their own citizens and business operations.

This report, *Fulfilling America's Pledge,* builds on our 2017 report and provides the most comprehensive assessment to date of how U.S. states, cities, businesses, and others (often referenced within this report as "real economy actors") are embracing new economic opportunities and technologies to implement climate targets and deliver emissions reductions within their own jurisdictions and operations under their own authority. This report includes an assessment of the impact of their existing commitments on the overall U.S. emissions trajectory, and provides a concise roadmap of 10 broad opportunities for action that together can lay the groundwork for even deeper emissions reductions from the real economy. This report also provides an internationally applicable toolkit to help policymakers and other stakeholders understand how real economy actors can drive more ambitious climate outcomes and serve as implementing partners in the context of other national governments' NDCs under the Paris Agreement.

The information included in this report is the product of a major research and analysis project coordinated by Rocky Mountain Institute and the University of Maryland Center for Global Sustainability, with substantial contributions from a core team that also included experts from World Resources Institute, the American Council for an Energy-Efficient Economy, CDP, the Environmental Defense Fund, and Meister Consultants Group. The analysis benefited from extensive engagement and consultation with a broad group of advisors from industry and civil society, as well as key state, city, business, and other real economy stakeholders (details are included in this report's Acknowledgments page).

The remainder of *Fulfilling America's Pledge* includes the following:

- **Chapter 2** focuses on the impact of *Current Measures*. It updates the survey of existing sectoral commitments from the 2017 report and develops new, bottom-up estimates of the projected impact of these measures. It also presents case studies showcasing concrete examples of these measures in action.

- **Chapter 3** outlines the opportunity for states, cities, and businesses to reach beyond their current commitments through: 1) a discrete set of 10 impactful actions that can be initiated in the next two years, comprising our *Climate Action Strategies* scenario; and 2) the broader, feasible, and even more impactful suite of actions real economy actors can deliver across the major GHG-emitting sectors: our *Enhanced Engagement* scenario. These two scenarios thus estimate the emissions reductions associated with specific, ambitious policies and actions that can be taken by U.S. cities, states, and businesses in the near term, without relying on the federal government. For each sector we lay out a range of potential real-world outcomes, with the discrete *Climate Action Strategies* at the accessible end and the broader *Enhanced Engagement* potential at the more ambitious end. This chapter demonstrates that given the rapid pace of innovation and technological change, and despite the absence in federal leadership, a robust set of attractive-but-as-yet-untapped opportunities to cut emissions remains available to real economy actors.

- **Chapter 4** integrates these current and incremental new commitments within an economy-wide analytical framework to present a novel, integrated synthesis of the quantified impact that state, city, and business actions—both committed and potential—could have on U.S. emissions through 2025. These current and new commitments are modeled as three economy-wide scenarios corresponding to the policies and programs identified in Chapters 2 and 3:

  - *Current Measures*—The impact of current policies and commitments on U.S. emissions;

  - *Climate Action Strategies*—A detailed assessment of the emissions reduction opportunity from 10 near-term, discrete ambitious climate actions led by real economy actors; and

  - *Enhanced Engagement*—A top-end estimate of what can plausibly be achieved through state, city, and business actions.

THE AMERICA'S PLEDGE MODEL AND THE ANALYTICAL APPROACH USED IN THIS REPORT

This report uses a novel approach to quantify the implications of current and potential future state, city, and business actions. It combines the bottom-up and top-down approaches to model the three scenarios discussed above (*Current Measures*, *Enhanced Engagement*, and *Climate Action Strategies*). In addition, we present estimates of the uncertainty of these results created by factors other than climate commitments, such as changes in GDP growth rates.

The immediate application of this approach is to provide an assessment of the implications for climate mitigation in the United States, but the conceptual framework also provides a possible route for similar analyses in other national contexts. The analytical approach integrates three stages:

First, it *tallies individual climate commitments* in key sectors. This report integrates data collected from several sources about current on-the-ground actions in sectors across specific states, cities, and/or businesses.

Second, it *aggregates the impact* of these commitments to the sector level, controlling for overlaps or double-counting (as discussed in the *Technical Appendix*). To understand the combined effects of different actions while more explicitly considering their interactions, World Resources Institute developed a new model, the Aggregation Tool for modeling Historic and Enhanced Non-federal Actions (ATHENA). ATHENA allowed us to quantify the total impact of individual real economy actions and control for double-counting.

Third, it *projects the varying overall impact* these actions might have across the U.S. economy on the national emissions trajectory, depending on the degree of ambition and speed of climate action by states, cities, and businesses. Using an integrated assessment modeling tool, the Global Change Assessment Model for the United States of America (GCAM-USA), the analysis captures the overall GHG impacts of the commitments and actions on the U.S. economy, incorporating interactions between the economy, energy sector, non-CO_2 emissions sources, and land use change. GCAM is an open-source, globally applicable integrated assessment modeling tool, implemented for this study by researchers at the University of Maryland.

As national and international policymakers and other stakeholders around the world seek to understand the potential impact of real economy actors on future emissions outcomes, the GCAM–ATHENA approach taken here can provide both a methodological framework and a conceptual process to guide decision making in other geographies worldwide. Like all models, GCAM and ATHENA have both strengths and limitations and must be interpreted with those in mind. The applications of the combined GCAM–ATHENA framework in this report are not predictions but nonetheless illuminate the potential contribution of real economy actors to the climate solution. More details on the analytical process and the specific tools applied are available in the *Technical Appendix* to this report, which can be found online at www.americaspledge.com.

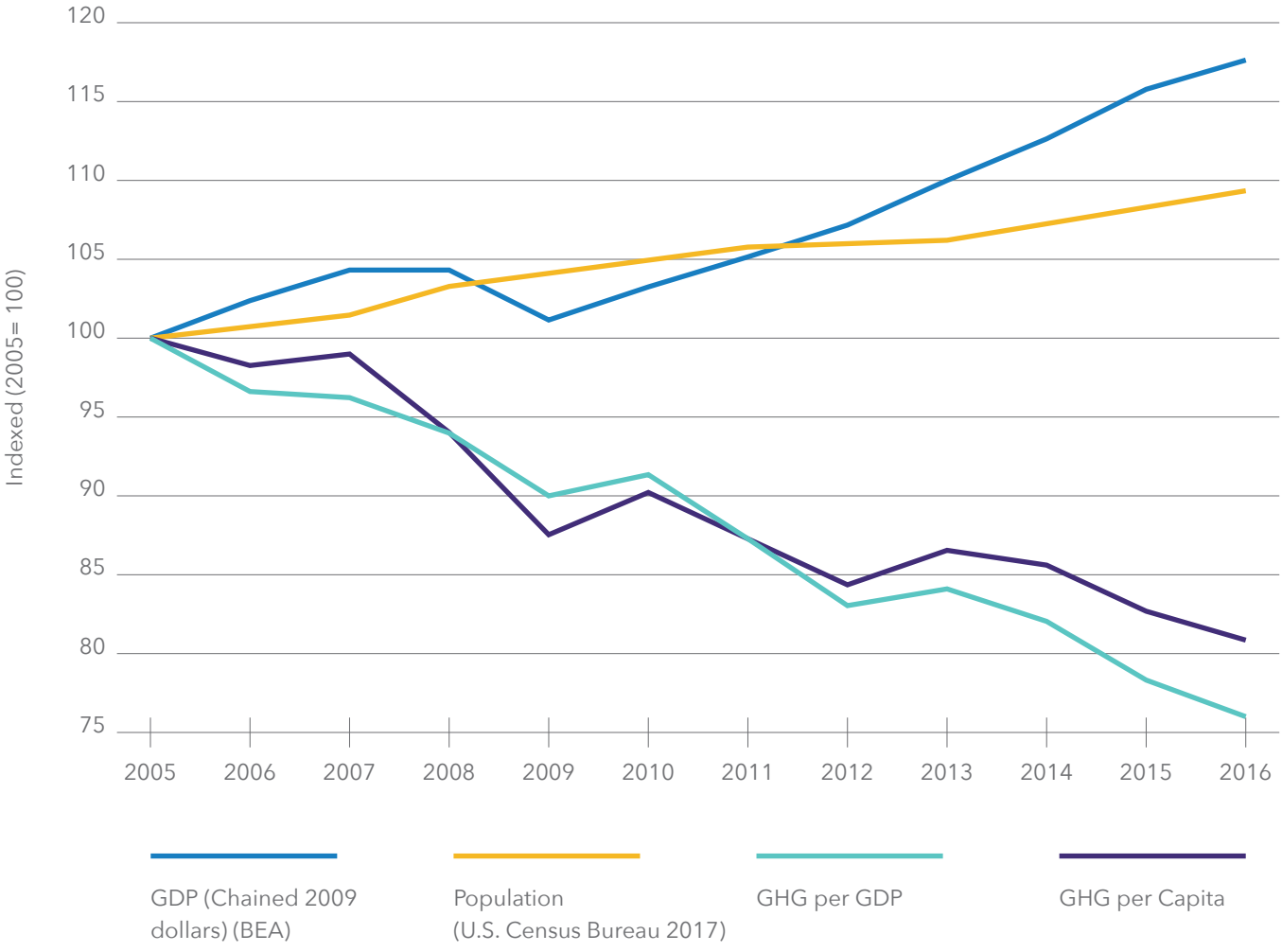
Chapter 2

Current Actions Achieving Emissions Reductions

This chapter provides an update of already committed or pledged state, city, and business actions designed to reduce emissions, building on the set of initiatives documented in *America's Pledge Phase I Report,* released in 2017, and begins to quantify their impact on overall U.S. greenhouse emissions.[15]

The U.S. economy has grown as emissions have been decreasing (Figure 2-1); however, the effort can gain momentum only if more real economy actors embrace opportunities and adopt policies for deeper emissionsreductions. Fulfilling the full potential of the real economy, bottom-up action will require sustained and energetic action on these initiatives from states, cities, and businesses, as well as continued expansion and acceleration of decarbonization efforts.

Figure 2-1: Since 2005, the U.S.has Cut Emissions Even as the Economy Continues to Grow



Source: US EPA "Inventory of GHG Emissions and Sinks: 1990-2016"

This chapter does not detail every climate-friendly activity highlighted in the November 2017 *America's Pledge* report. Instead, we focus on a selection of actions with the highest emissions impact and estimate their current and projected emissions reduction through 2025. Within this chapter, we describe the impact of current, on-the-books policies and actions contributing to greenhouse gas (GHG) abatement. These *Current Measures* include both 1) existing actions that have been formally adopted by local and regional governments and are legally binding and 2) pledged actions that represent clearly defined intentions on the part of real economy actors but that are more aspirational in nature and non-binding. In the sector-specific sections that follow, a broad set of actions and commitments are presented using this categorization to help differentiate the scale and types of policies currently on the ground. The policy categorization, however, does not make assumptions about the likelihood of future implementation. More details on the decision criteria for the policies and actions included in this analysis and their categorization can be found in the report's *Technical Appendix*.

In this chapter, we account for the inherent overlap between the policies assessed within states, cities, and investments from businesses. However, analysis in this chapter does not control for cross-sectoral interactions—such as the impact of transportation electrification or building efficiency on the power sector. To address broader economy-wide interactions, the actions and impacts described in this chapter were input into the integrated analysis presented in Chapter 4, which quantifies their aggregated contribution to GHG emissions. Given this, the impacts described in this chapter are sector-specific and not necessarily 100 percent additive from one type of action to the next. The full details on methods and criteria behind the analysis contained within this section and throughout the report can be found in the *Technical Appendix*.

Sectoral Analysis of Current Actions in the Real Economy

Our 2017 report highlighted 30 state policies, 20 city policies, and 10 corporate policies that have proven to be successful in reducing U.S. GHG emissions. This 2018 report expands our analysis, covering a broader selection of economy-wide and sector-specific actions across all 50 states, cities representing metropolitan areas, and a broader set of businesses.[16]

GHG Reduction Targets

Just as national governments have adopted GHG reduction targets under the Paris Agreement, so too have many U.S. states, cities, and businesses. Twenty-one states have GHG reduction targets adopted under various authorities and with a range of target dates, enforceability, and level of ambition. (Twelve state targets were passed by state legislation; six are executive orders. Three state targets are non-codified goals publicly expressed by governors or included in state climate action plans.)[17]

Similarly, cities have the authority to create and implement their own climate policies, but cities' authority varies depending on state, county, and local statute; revenue sources and allocation; energy regulatory context; and government structure. Since the release of our November 2017 report, 18 additional cities have set quantifiable GHG targets, bringing the total to 142 cities. (This number includes only cities with community-wide GHG reduction goals. Many more cities are part of broader coalitions supporting climate action or have GHG reduction targets for specific sectors such as municipal buildings or commercial buildings.) In total, these states, cities, and counties represent more than 194 million Americans, have a combined GDP of nearly $12.5 trillion, and account for over 40 percent of U.S. GHG emissions (see Figure 2-1). Notably, these actors' share of national emissions is lower than their share of either population of GDP in large part because they have already begun the process of decarbonizing their economies. Their emissions reductions therefore represent a disproportionate share of the 12 percent reduction in U.S. emissions already achieved between 2005 and 2017.

In addition to state and local policies, businesses are similarly setting their own targets to reduce emissions across their operations. As discussed in the 2017 *America's Pledge* report, 1,361 businesses have made voluntary emissions reduction commitments, and a smaller group of corporations have set more ambitious science-based targets.[18] These science-based targets are in line with the reductions necessary to achieve the goals of the Paris Agreement, as discussed in Case Study One. Although a large and ever-growing number of corporate commitments to reduce emissions exist, our analysis focused specifically on 155 GHG reduction targets from businesses that report their progress and implementation plans to the nonprofit data platform CDP. Accounting for their U.S.-based GHG emissions footprint only, our analysis estimates that these

pledges alone, if fully implemented, would result in annual reductions of 26 million metric tons of carbon dioxide equivalent (Mt CO_2e) in 2025.[19] This relatively small sample size suggests that every six U.S. companies making such a commitment might reduce U.S. emissions by an additional million metric ton by 2025, on average, if a larger total number of companies were to engage. Notably, this report has not attempted to estimate such projections for companies not currently reporting to CDP. Furthermore, our analysis here does not account for other types of corporate commitments, such as the voluntary procurement of renewable energy or the management of global supply chains, which themselves present important emissions reduction opportunities for both domestic and multinational firms.

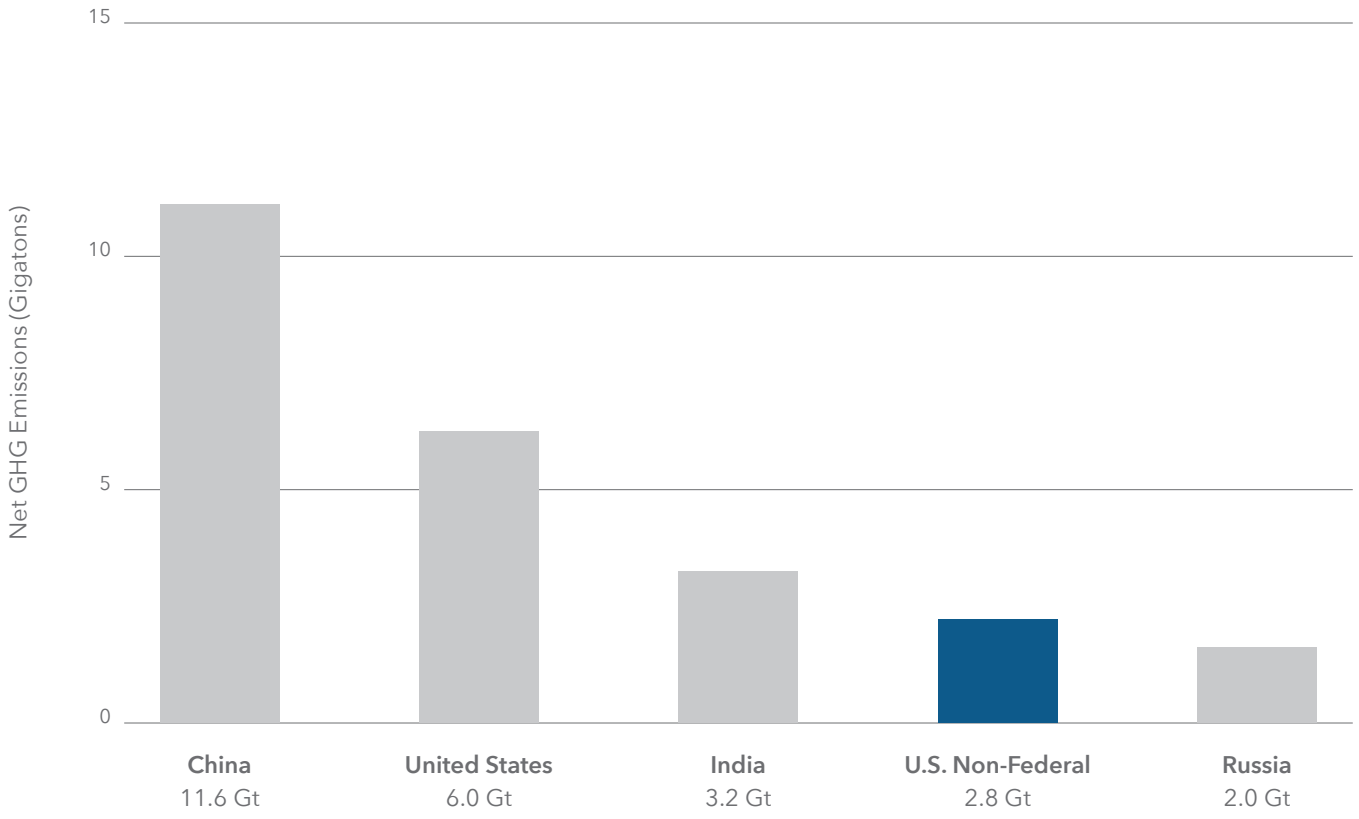
GHG reduction targets established by states and cities are important, but they are effective only if they have strong implementation plans (including monitoring, reporting, and verification) and are backed with binding policies, such as cap-and-trade, clean energy standards, methane standards, vehicle emissions mandates, and other policies covering the sectors discussed in forthcoming sections. Similarly, business pledges are effective only if they are supported by a management plan with concrete goals and timelines that have buy-in throughout leadership. Therefore, states, cities, and businesses need to report transparently on their commitments, receive support in achieving them, and be held accountable to deliver them. If states and cities were to reach these targets, we estimate that it would cut annual emissions by 500 Mt CO_2e from business-as-usual (BAU) levels in 2025—approximately 7.5 percent of 2005 net emissions. A similar analysis by New Climate Institute found that the combination of state, city, and business commitments, if fully implemented, could cut emissions by 360–560 Mt CO_2e in 2025.[20] To ensure our modeling is conservative, we have not included state, city, and corporate GHG targets in the *Current Measures* scenario unless they are backed by binding caps or policies, as in the case of California and the Regional Greenhouse Gas Initiative (RGGI).

21 States

142 Cities

1,361 Businesses

Figure 2-2: States, Cities, and Businesses Accounting for 40 Percent of U.S. GHGs Have Set Reduction Targets



Population (2018)
194 Million
59% of all Americans

Gross Domestic Product (2018)
$12.5 Trillion
63% of total U.S. GDP

GHG Emissions (2018)
2.8 GT
43% of U.S. GHG Emissions

CASE STUDY 01

"Science-Based Climate Targets" for Corporations

Corporations have a critical role to play in driving the transition to a low-carbon economy by tackling GHG emissions in their operations and value chains, driving demand for low-carbon solutions, and signaling to policymakers that greater ambition is possible. One way for corporations to engage meaningfully is to set science-based targets, which are defined as targets that are in line with the level of GHG reductions necessary to keep global temperature increases well below 2 degrees Celsius.

As of May 2018, 74 U.S. companies representing a combined market capitalization of over $2.6 trillion, including 19 companies ranked on the 2017 Fortune Global 500 list, have either set targets or committed to reduce emissions in line with a well below 2 degrees Celsius temperature goal through the Science Based Targets initiative (SBTi).[21] Driven by consumer interests, corporate social governance, and broader economic patterns, this trend is fast becoming a "new normal" in the way businesses operate, and momentum continues to grow; nearly 180 U.S.-based companies have reported to CDP that they intend to set a science-based target by 2019. As of May 2018, the U.S.-based companies that have committed to science-based targets are responsible for an estimated 2 billion metric tons of CO_2e emissions per year across their global operations and value chains, about 4 percent of total global greenhouse gas emissions.[22]

These targets provide a robust and meaningful framework upon which to base corporate climate strategies—helping companies build long-term business value, safeguard their future profitability, reduce regulatory uncertainty, and demonstrate to customers and employees their commitment to sustainability and innovation. For example, in the process of developing its science-based target, Kellogg Company decided to explore fuel cell technology, which is now being used to generate electricity at its waffle-making facility in San Jose, California. Even greater emissions reductions are possible if companies incorporate emissions from their entire value chain, including indirect emissions from electricity, in their targets.

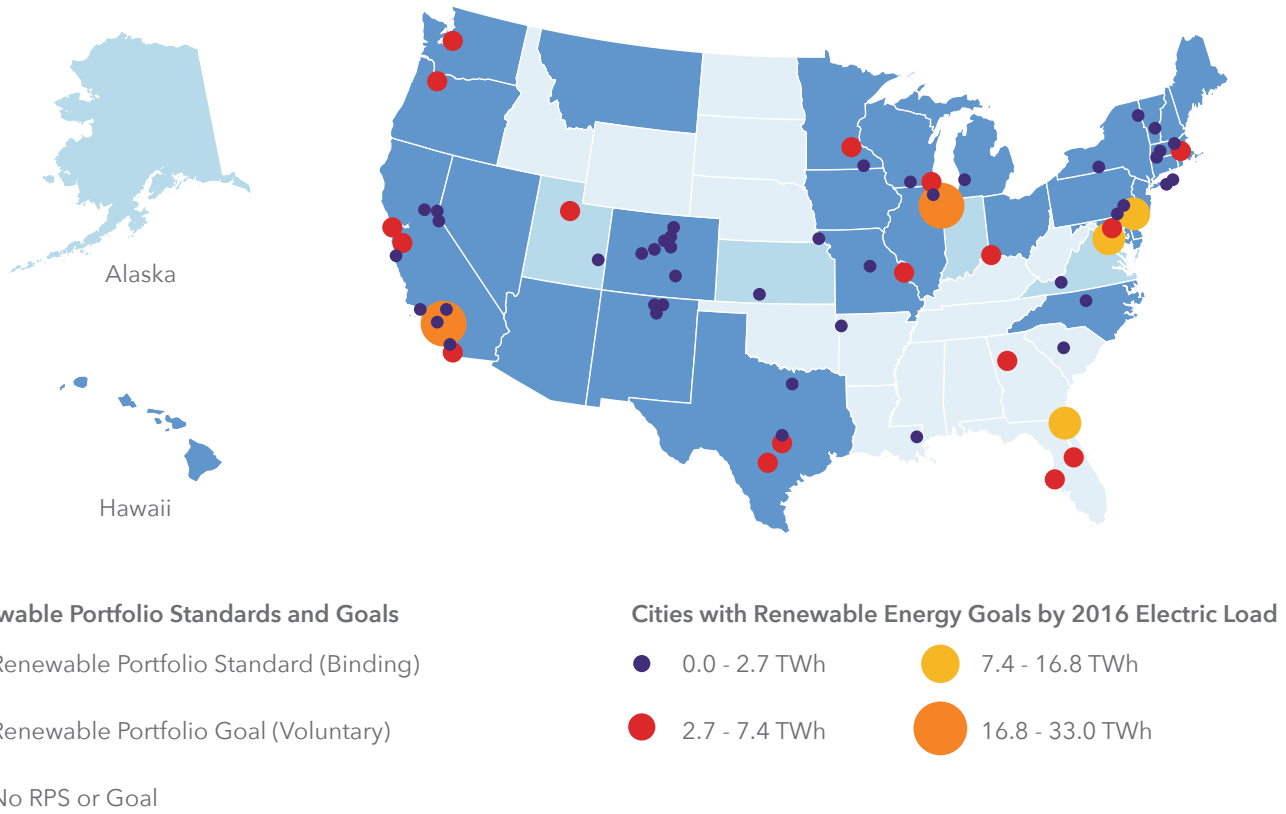
Power Sector

U.S. power sector carbon dioxide emissions have rapidly declined since 2010 after decades of growth.[23] By the end of 2017, annual emissions were 1,744 Mt CO_2e, a reduction of 670 Mt CO_2e, or 28 percent, from 2005 levels and equivalent to taking more than half of all cars off America's roads.[24] This decline is attributable to a combination of policy and market forces. Gains in energy efficiency driven by a variety of policy and market forces have lowered expected growth in demand.

The carbon intensity of the average kilowatt-hour (kWh) of electricity produced in the United States has also declined. Aging of the coal fleet, the Mercury and Air Toxics Standards and other federal public health regulations, and cheaper natural gas led to 15 percent of the U.S. coal fleet retiring between 2006 and 2016.[25] Scaled-up clean energy generation has been an additional influential factor in this trend by providing an alternative as uneconomical fossil fuel units are removed from the grid.[26] By the same token, clean energy options are driving down the demand for (and hence the future economic viability of) coal units that have not yet been retired. In fact, a 2018 retrospective analysis demonstrated that renewable generation between 2007 and 2013 was responsible for nearly a third of the overall 10 percent reduction in U.S. energy-related CO_2 emissions.[27] Increasing availability of renewables is also diminishing the percentage of retired coal that is replaced by natural gas, which has its own substantial global warming footprint.

States, cities, and businesses have undertaken an expanding array of activities to increase clean electricity and cut power-sector emissions. Of these, as previously highlighted in the 2017 *America's Pledge* report, state renewable portfolio standards (RPS) have been most influential in promoting clean energy generation. In 2016, over half of all

Figure 2-3: States and Cities across the U.S. Have Adopted Clean Energy Targets and Goals



Source: American Council for an Energy-Efficient Economy; Lawrence Berkeley National Laboratory; World Resources Institute

non-hydroelectric renewable generation in the United States supplied the RPS market, demonstrating that these policies are creating the demand for investors to install more wind turbines and solar panels in the 29 states (and Washington, D.C.) with RPS mandates.[28] Notably in 2015, Hawaii enacted a bold policy of achieving 100 percent renewable energy by 2045.

Beyond cutting carbon pollution, RPS policies have significant co-benefits. One analysis finds that they have resulted in $5.6 billion in annual health and environmental benefits due to reductions in criteria air pollutants such as SO_2, NO_x, and particulate matter.[29] Other co-benefits include annual savings in water consumption of 27 billion gallons, including in more water-stressed regions such as Texas and California.[30] Finally, a 2017 analysis found that over 250,000 Americans work in the solar power industry, an increase of 168 percent since 2010.[31]

Cities and businesses are also accelerating clean energy deployment by aggregating demand for solar and wind power. More than 80 cities and counties have adopted 100 percent renewable goals (Figure 2-3)—nearly double the number of cities that had committed to this target a year ago.[32] Including Hawaii, jurisdictions pledging to achieve 100 percent renewable energy cover a population of 10.3 million (roughly 3 percent of the U.S. population). In addition, 125 companies with a reported emissions footprint in the United States have adopted goals to either produce or source their electricity from renewables through mechanisms such as power purchase agreements (PPAs), on-site solar, and renewable energy certificates (RECs) purchases.[33]

Our analysis quantifies impact and accounts for overlap across the 29 existing state RPS policies, additional non-binding state pledges, and 104 city-level pledges. Together, these actions can push policy-driven demand for non-hydroelectric renewable energy (i.e., the electricity needed to meet city and state targets only) to over 500 terawatt-hours (TWh) annually by 2025, the equivalent of powering 56 million homes in a year (Figure 2-4).[34] However, additional targets not included in this figure—such as those from corporate actors, counties, and utilities—have the potential to further increase renewable generation in the years to come. For example, current commitments from the 44 U.S.-based RE100 companies could result in an additional 43 TWh of renewable

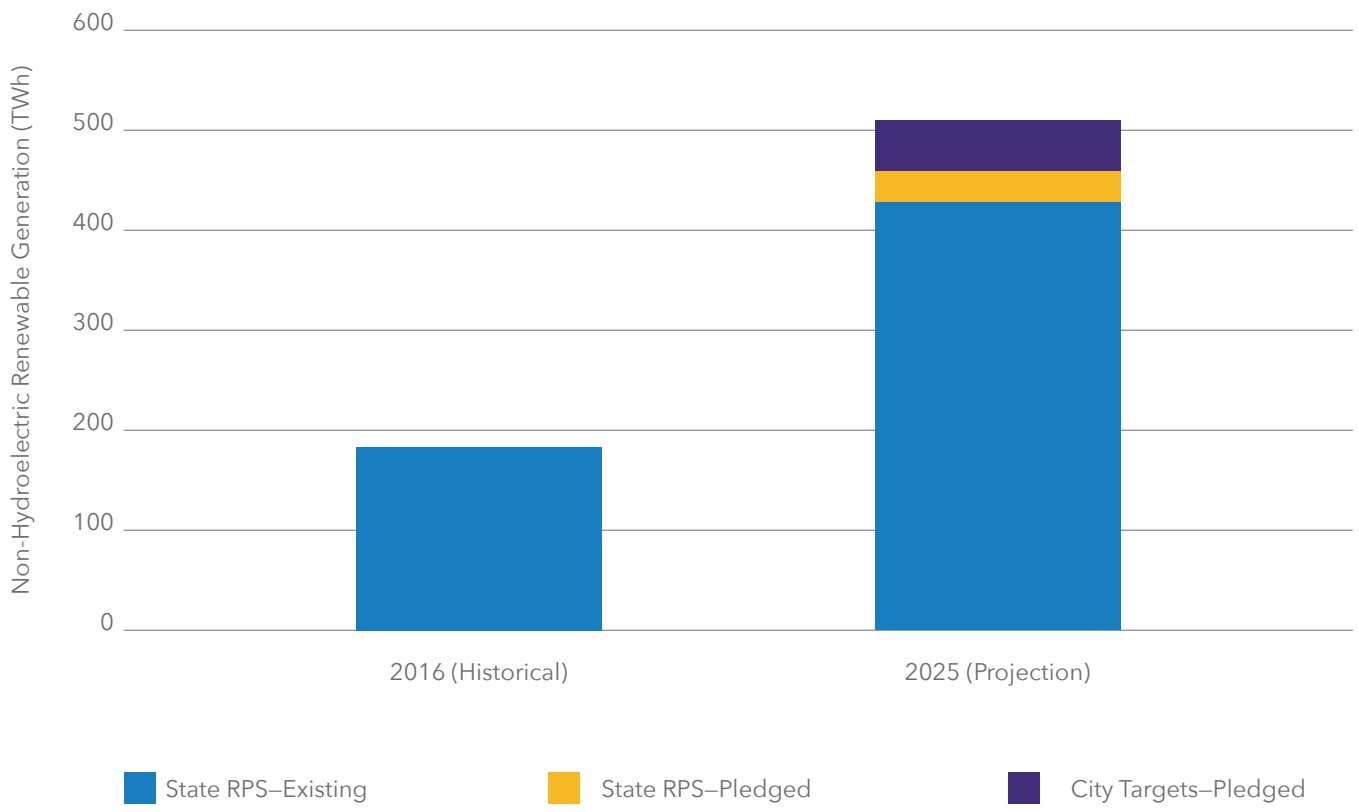
Photo by Dennis Schroeder

State, city, and business clean energy goals can

increase demand for clean energy to over 500 TWh annually by 2025

—enough to power 56 million homes for a year

Figure 2-4: By 2025, State Clean Energy Policies are Projected to Deploy Enough Renewable Generation to Power 56 Million Homes



Source: ATHENA modeling outputs

energy if fully achieved. Such targets may naturally overlap with the goals of cities and states. While they are not modeled in this report, we acknowledge the vital role they will play in helping to reinforce or even drive past the decarbonization measured in this analysis.[35]

Not all renewable generation is driven by the type of explicit policy demand estimated above. Market forces, including falling per-kWh generation costs for wind and solar, mean that a substantial share of renewable capacity will be added to the grid irrespective of top-down goals. In addition, certain types of state actions, such as investment in transmission infrastructure and relaxed siting laws for wind farms, can result in significant shares of increased renewable generation that may not be captured in estimates of RPS demand. In 2016, an estimated 54 percent of non-hydroelectric generation fed into state RPS programs. Voluntary markets—which includes demand from utility green tariff programs and power purchase agreements designed to meet corporate and city demand—represented another 28 percent of renewable energy sales (excluding large-scale hydro) in the same year.[36] These figures indicate that although total future generation will undoubtedly exceed the aggregate demand of non-federal actors– intentional clean energy demand plays a clear role in shaping the market and driving the building-out of new capacity.

At the same time, the reality that climate policy resistant jurisdictions like Oklahoma and Kansas are also among the leaders of renewables deployment signals that the market drives another large segment of renewables demand. Thus, while this section has focused on current policy measures and does not include estimates of projected non-policy or market-based generation occurring in the United States, estimates in the following chapter, as well as the modeling results included in Chapter 4, deal more holistically with the full potential of the U.S. power sector.

CASE STUDY 02

Breaking Barriers to Renewable Energy in Electric Markets

Renewable portfolio standards (RPS) have been a core driver in the shift to renewables, but they are not the only policies that state leaders have at their disposal. State regulators, such as public utility commissions (PUCs), are influential in managing electricity markets and have the opportunity to promote smart rate structures and procurement policies that drive deployment of clean energy and lower prices for consumers. PUCs can also ensure that beneficial low- and zero-carbon generation is deployed by utilities by requiring infrastructure projects to account for either the social cost of carbon or the social cost of abatement. For example, Minnesota requires power companies to evaluate all future investments against the broader social cost of climate change. In general, renewables are often the most cost-effective option. Minnesota's wind industry is at cost parity with natural gas even without subsidies, ranks eighth in the country in terms of generation, and has positioned the state to surpass its existing RPS target a few years ahead of schedule.[37]

States are unlocking potential for large and small consumers to drive greater clean energy deployment on their own initiative by allowing retail choice and community choice aggregation (CCA). To date, seven states (California, Illinois, Massachusetts, New Jersey, New York, Ohio, and Rhode Island) have adopted CCA and another four are considering it. According to analysis by the National Renewable Energy Laboratory, voluntary purchases account for about one-third of total renewable purchases to date, making them an important driver of continued growth.[38] CCA programs sold 7.4 TWh of renewable energy to 1.9 million customers in 2015, enough to power half a million homes for a year.[39]

Large corporate entities are making investments in renewables. More than 100 large companies—including Citi, GM, Johnson & Johnson, Google, and Walmart—have pledged to use 100 percent renewable energy, and many other companies have committed to other renewable energy targets.[40] In 2017 alone, large corporate buyers announced the purchase of 2.78 gigawatts of renewable energy, more than enough to power the state of Rhode Island, marking a 70 percent increase over 2016.[41] Similarly, public utilities in a number of states, including West Virginia, have committed to move toward cleaner generation sources in response to pressures from their customers.[42]

Photo by Dennis Schroeder / NREL

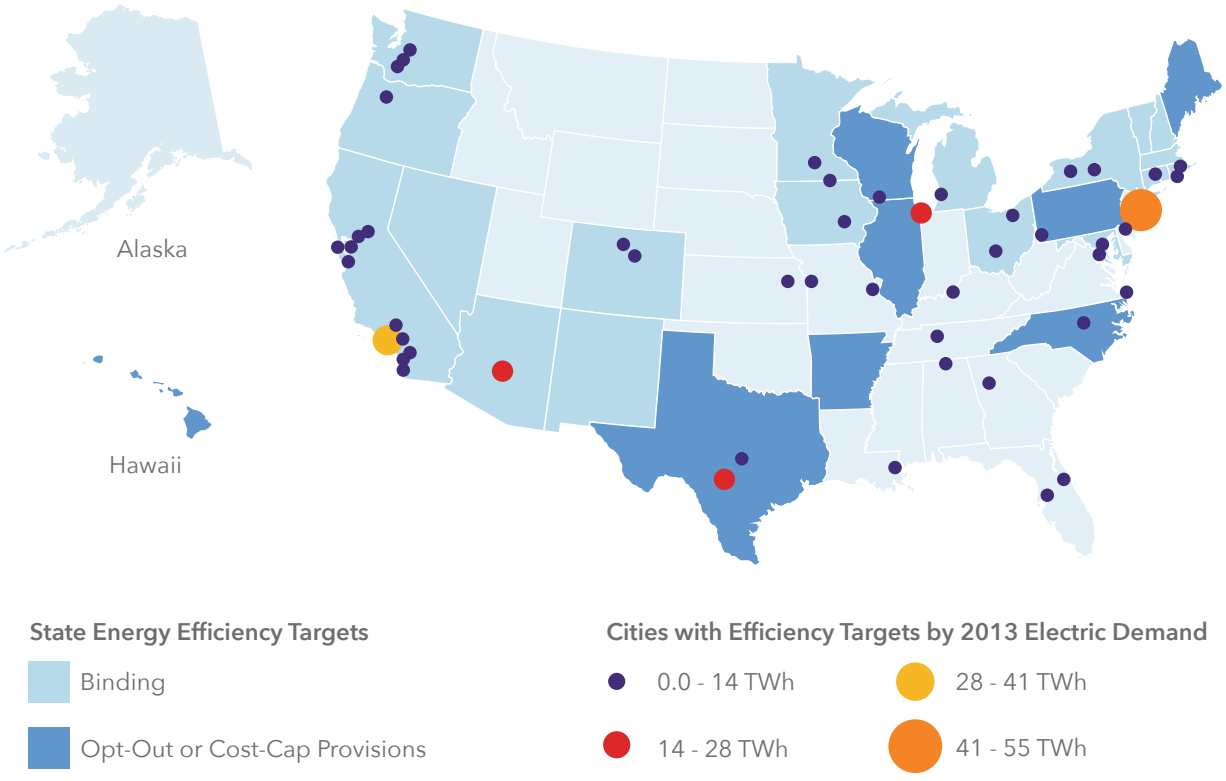
Residential and Commercial Building Energy Use

Residential and commercial building sectors contribute to GHG emissions both directly, through the use of fuels for heating, and indirectly, through the use of electricity. Because much residential and commercial energy use is electrified (e.g., lighting and appliances), this sector closely interacts with the power sector. For example, energy efficiency in the building sector can reduce demand, and hence lessen GHG emissions in the electric sector. Similarly, promoting electrification of end uses—heat pumps, for example—can typically eliminate direct emissions from the use of natural gas and petroleum for heating, hot water, and cooking.

The energy intensity of U.S. residential and commercial sectors has decreased steadily since 1970 as a result of federal, state, and city policies and programs.[43] These include appliance and equipment efficiency standards, building codes, energy efficiency targets, utility regulatory reforms, consumer awareness programs, tax incentives, and other programs.[44] Efficiency measures are one of the most common (and most varied) types of climate actions that real economy actors may implement. At the state level, the analysis of current commitments focuses on energy efficiency resource standards (EERS), a policy that establishes energy savings targets that electricity utilities are required to meet (See Figure 2-5). Twenty-six states have enacted EERS policies, which are typically established through state legislation and refined by PUC rulemaking.[45] Nineteen states have binding EERS, and seven states set a cost cap or allow certain groups of customers to opt out of the program. Sixteen of the 19 also have EERS policies for natural gas utilities. In recent years, a number of states have increased their EERS targets; for example, California, Illinois, Maryland, Michigan, Nevada, New Hampshire, and New York have all set new targets since 2015.[46]

EERS have been demonstrated to improve efficiency and reduce GHG emissions while saving consumers money. In 2016, states with EERS achieved annual electricity savings of 1.2 percent of total electricity sold, compared with 0.3 percent in states without EERS.[47] The savings resulting from state efficiency programs totaled 220 TWh in 2016.[48] An EERS policy is also often paired with complementary policies such as performance incentives or penalty mechanisms to further spur utilities to meet targets. In Case Study Three, we show how utilities can use a range of customer programs to deliver energy savings through EERS.[49]

Figure 2-5: 26 States and 56 of the Largest Cities in the U.S. have set Energy Efficiency Targets



Sources: American Council for an Energy-Efficient Economy and World Resources Institute

Note: This includes Seattle and New York which do not have specific energy efficiency targets but have GHG targets that will include energy efficiency measures

Cities are implementing a wide range of actions that will help utilities meet the state-level EERS goals or have adopted a range of measures on their own to achieve their own energy efficiency targets. Of the 285 most populous U.S. cities, 56 have targets to explicitly reduce energy consumption from residential, commercial, industrial, and/or municipal buildings (see Figure 2-4). These targets are impactful and achievable. But they are only a small portion of the toolkit available to cities to implement efficiency gains, which can work in alignment with, but also in the absence of, top-down targets. These include providing incentives and financing for efficient buildings, setting green building standards and adopting the highest-performance building codes, requiring energy audits, undertaking retrofits, and setting benchmarking and transparency (B&T) standards.[50] These added incentives have proven to be successful. For instance, as discussed in Case Study Four, after Washington, D.C., required commercial and multifamily buildings over 50,000 square feet and municipal buildings over 10,000 square feet to benchmark and report energy use data, these buildings reduced their energy use by almost 6 percent, on average.

Our analysis finds that combined, existing state EERS policies along with city-level goals could achieve over 200 TWh in electricity savings by 2025 after accounting for overlap, or nearly 5 percent of projected electricity demand in the same year. This estimate includes the 26 state-level EERS standards (both binding and non-binding, pledged standards), as well as community-wide targets in 36 cities with a population greater than 100,000.[51] Owing to modeling limitations, this estimate does not capture the full range of efficiency measures currently taking place at the city level, but rather represents a quantifiable subset.[52]

Although these measures are significant, it is notable that only six of the 25 states examined in this analysis have already extended their EERS policies post-2020.[53] Between expanding and extending EERS policies and advancing building and appliance standards, states, cities, and businesses can do far more to drive emissions reductions from improvements in energy efficiency, as discussed in Chapter 3.

CASE STUDY 03

Energy Efficiency Resource Standards in Arkansas

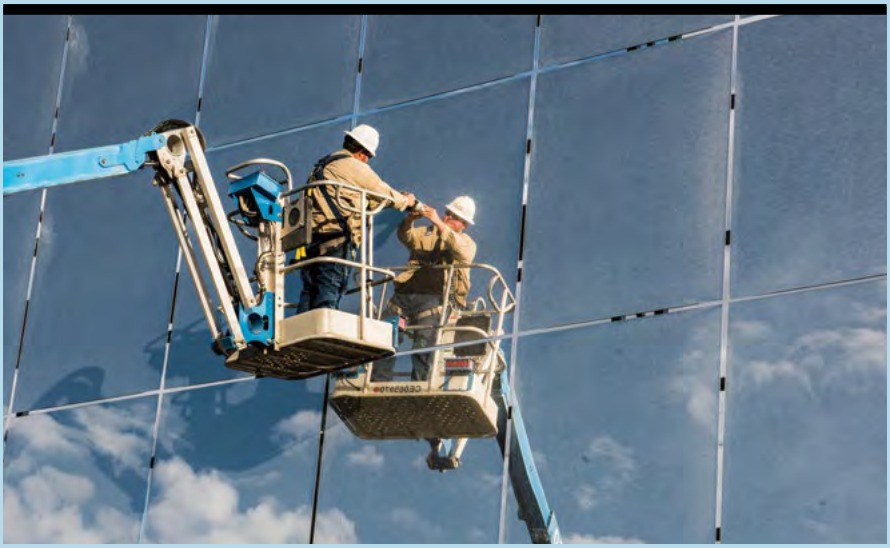
Arkansas is the only state in the Southeast with an EERS, which was first established in 2007, requiring electric and natural gas utilities to propose and administer energy efficiency programs. Arkansas's energy savings targets started out low, initially requiring utilities to reduce annual electricity use by 0.25 percent with respect to sales, ramping up to 0.75 percent in 2013.[54] Natural gas reduction targets were set at 0.2 percent in 2011, increasing to 0.4 percent in 2013. The Arkansas Public Service Commission has strengthened these goals with 1.0 percent reductions to take effect in 2019.

The gradual and deliberate approach to evolving utility programs has allowed Arkansas to achieve and build upon early successes to garner increasing support for energy efficiency. For example, in 2008 the home energy efficiency services market in the state did not yet exist. Utilities worked to improve their understanding of the scope of recruiting and training resources needed and focused on building partnerships with contractors. A significant factor in the success of many of the programs has been ongoing classroom and field training for contractors undertaken in coordination with trade allies and regional technical colleges. Through careful monitoring of program results with the help of a third-party evaluator, utilities have been able to make a variety of adjustments over time to improve program effectiveness. These have included the gradual addition of new measure offerings, such as incentives for heat pump water heaters, behavioral benchmarking through home energy reports, and measures targeting multifamily property. Other refinements have included making programs easier for customers to access, studying new technologies, and making more concerted efforts to reach certain customer segments that might have more difficulty accessing utility efficiency programs.

Taken together, Arkansas electric utilities have increased energy savings more than fivefold over the past decade through these programs, raising savings from 60,000 megawatt-hours (MWh) in 2009 to more than 300,000 MWh in 2016, or enough to power more than 28,000 homes for a year.[55] Through these efforts, Arkansas has emerged as a Southeast energy efficiency leader, and an example to its neighbors of the diverse benefits achievable when a state and its utilities come together to value and pursue efficiency as an energy resource on the same level as other fuel sources.

According to the American Council for an Energy-Efficient Economy (ACEEE), if states were to continue to meet savings targets and legislators and regulators were to extend expiring targets in the years leading up to 2020, the combined annual electricity savings from the 26 states with EERS policies would be equivalent to 6.2 percent of overall electricity sales in the United States in 2020.[56] As noted below, existing policies and pledges described in our *Current Measures* scenario, which accounts for standards that could expire, are expected to reduce annual electricity demand by as much as 200 TWh by 2025.

Photo by Rachel Renaud



CASE STUDY 04

Benchmarking and Transparency Policies for Buildings

Buildings account for about 50 percent of carbon dioxide emissions from cities (including indirect emissions from electricity use); in some large cities, the portion could be as much as 75 percent.[57] However, given the variety of buildings, including their age, use, and ownership, it has been difficult to achieve this sector's full energy savings potential.

To better incentivize building efficiency improvements, cities have adopted new innovative benchmarking and transparency (B&T) policies that improve knowledge of energy use and aid in planning and implementing energy-saving measures. By increasing building owners' understanding of their asset's energy performance, these policies create market value for energy-efficient buildings.

Most B&T policies set by local officials call for property owners of large buildings—typically commercial and/or multifamily buildings—to benchmark their buildings' energy using ENERGY STAR® Portfolio Manager, through which building owners can understand how much energy their buildings are using in relation to buildings of a similar type and size in a similar climate. B&T policies also generally call for owners to disclose their annual energy consumption to local governments on a regular basis.

These policies have gained traction across the United States. As of December 2017, 26 municipalities, including many of the largest, had a B&T policy for public, commercial, and/or multifamily buildings.[58] Nearly 10 percent of the U.S. population across 17 states lives in a municipality with a B&T policy.[59]

In 2008, Washington, D.C., adopted the Clean and Affordable Energy Act of 2008 (CAEA). The CAEA amended the city's Green Building Act of 2006 and required that owners of commercial and multifamily buildings over 50,000 square feet benchmark their energy use annually and share that data with the

Photo by Dennis Schroeder / NREL

city for public release. The law also required that the city annually benchmark its own buildings that are greater than 10,000 square feet and report results to the public.[60] After a multiyear stakeholder process, local electric and gas utilities provided building owners with the whole-building aggregated energy data that was necessary to comply with CAEA. Washington, D.C., also adopted legislation requiring utilities to provide this data in 2014.[61]

Washington, D.C., commissioned a third-party evaluation of benchmarking data submitted voluntarily between 2009 and 2012 by a sample of office property owners. Although it was not representative of all district buildings, the analysis revealed that energy use in these benchmarked buildings decreased by 5.8 percent (124 billion Btu) and led to carbon emissions reduction of 5.2 percent (13.8 thousand Mt CO_2e). The average ENERGY STAR score for these buildings also increased from 73 to 81.[62] Recently the city used reported benchmarking data along with data obtained from partners to model potential greenhouse gas emissions reductions from lowering the energy use of buildings. Compared with a BAU scenario, the plan's building-related actions are forecast to reduce 11.8 percent of community-wide greenhouse gas emissions by 2032. These actions account for more than a quarter of the city's anticipated greenhouse gas emissions reductions.[63]

If the 26 municipalities with policies experienced a 5 percent energy savings due to their benchmarking policies, it would avoid nearly 5 Mt CO_2e and save over 35 million MMBtu.[64] The impact is even clearer when looking at the potential effect if the largest cities in the United States' largest metro regions pursued benchmarking. If these cities adopted a policy that saved 5 percent of large building energy, it would avoid 8.8 Mt CO_2e—roughly equivalent to the CO_2 emissions from 950,000 homes' energy use in a year—and nearly 60 million MMBtu.[65]

Transportation Sector

The transportation sector accounts for nearly a third of net annual emissions in the United States. In 2016, it surpassed the power sector to become the largest sectoral source of emissions.[66] Within the transportation sector, passenger cars, light-duty trucks, and medium- and heavy-duty trucks are, by a substantial margin, the largest sources of GHG emissions (though ships, aircraft, and rail transport also emit significant levels of greenhouse gases).[67] Transportation emissions declined during the 2008–12 period but have started to increase again as low gasoline prices, increasing vehicle sizes, and expanding economic activity outpace efficiency gains from federal fuel economy standards.

In 2010, the Obama Administration worked with the State of California and the auto industry to begin the process of establishing new fuel economy and GHG standards. These were projected to achieve a fleetwide fuel economy average of 54 mpg by 2025 and were projected to reduce climate pollution by a cumulative 6 billion metric tons of carbon dioxide—equal to a year's worth of emissions for the entire United States.[68] However, the Trump Administration is moving to dismantle or roll back these standards for model years 2021 through 2025,[69] despite public, state, and industry resistance to such a move.[70] States, cities, and businesses are playing a crucial role in defending these standards, challenging the administration's attempts to place corporate profits over public health and consumer savings. They can also act independently of federal rules. For instance, California has the authority (granted through a waiver by the EPA) to set its own air emissions standards for motor vehicles, provided they are more stringent than federal standards.[71] Other states with air pollution problems can adopt California's standards (13 states already have, and Colorado has an executive order in place and is developing a rule that would make it the 14th).[72] In early May 2018, California led an 18-state coalition (representing over 40 percent of the U.S. car market) to sue the EPA to preserve the nation's light-duty vehicle emissions standard.[73]

States and cities are enacting policies in addition to GHG emissions standards. Two states—California and Oregon—have low-carbon fuel standards (LCFS), which require fuel suppliers to reduce the carbon intensity of fuels at all points through the fuel supply chain.[74] California's standard requires a 10 percent reduction in the carbon intensity of transportation fuels sold into California markets by 2020 and 20 percent by 2030.[75] LCFS promote alternatives such as electric vehicles, hydrogen vehicles, and carbon-beneficial forms of biofuels, and if a number of states copied California and Oregon, the fuels market might change quite dramatically in the coming years.

States and cities are promoting zero-emissions vehicles (ZEVs) through a range of actions, including statewide ZEV regulations and government fleet procurement goals.

California's ZEV policy requires vehicle manufacturers to produce an increasing number of light-duty ZEVs through the year 2025.[76] In January 2018, California set a goal of having 5 million ZEVs on the road by 2030 and identified a number of actions to help it achieve that goal.[77] Nine other states have joined California in a ZEV program requiring automakers to sell electric cars and trucks: Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont. These states, with the exception of Maine, are also part of a Memorandum of Understanding that commits the states to coordinating actions to ensure successful implementations of programs that support ZEV adoption in each state.[78] It is expected that the ZEVs will account for approximately 15 percent of new vehicle sales in these states by 2025 in part due to these regulations.[79] This analysis suggests that this would likely lead to approximately 4 million new ZEVs on the road by 2025, with annual sales reaching 1.2 million by 2025 (Figure 2-6).

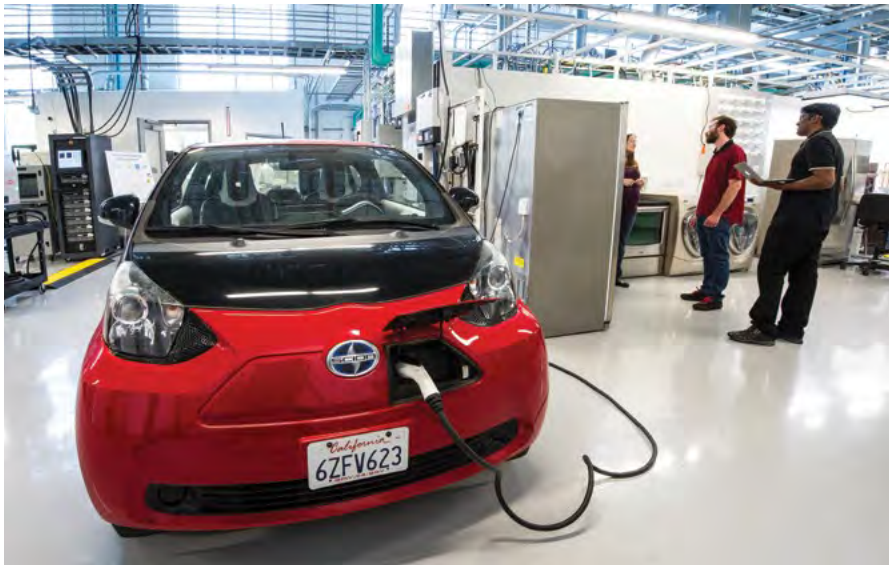
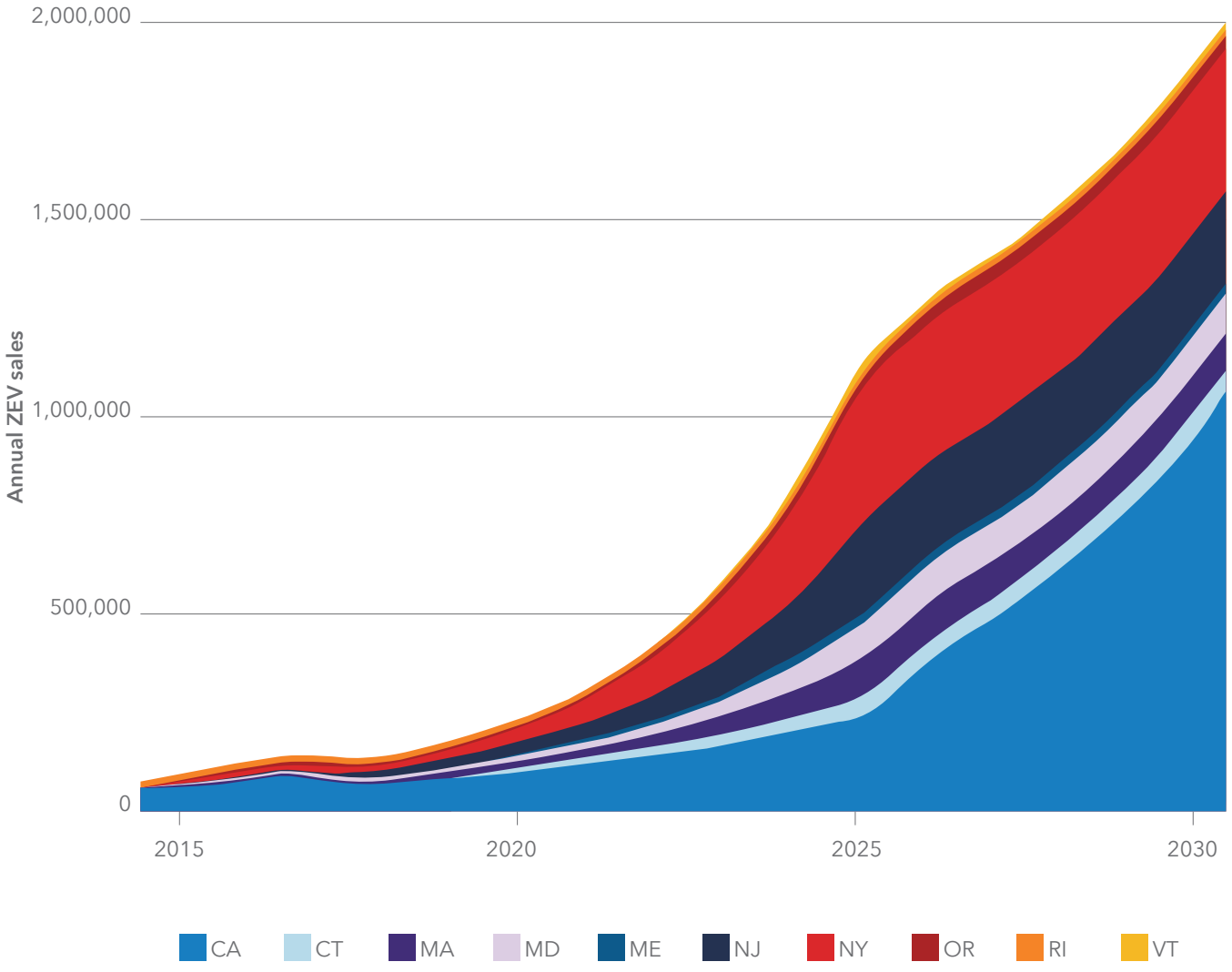


Photo: U.S. Department of Energy, 298 031 005

Figure 2-6: State ZEVR Targets Increase Steadily with Annual EV Sales Reaching a Projected 1.2 Million Vehicles in 2025 and Growing to 2 Million by 2030



Source: ATHENA modeling outputs.

Five states (California, Illinois, Maryland, Rhode Island, and Vermont) have fleet procurement goals that are aimed at increasing the number of ZEVs owned and managed by the state government.[80] Fleet procurement creates a reliable demand for electric vehicles, which in turn helps EV technologies achieve economies of scale. At least 34 out of the 285 most populous U.S. cities have goals to procure alternative fuel vehicles (AFVs) such as hybrids, electric plug-in vehicles, and vehicles that run on biodiesel or renewable natural gas that can lower the emissions of city-owned buses, cars, and trucks. Our analysis specifically included eight goals from major U.S. cities (Atlanta; Austin, Texas; Chicago; Denver; Indianapolis; Los Angeles; New York; and Portland, Oregon) to procure light-duty ZEVs for their municipal fleets, as well as electric bus procurement targets in Madison, Wisconsin; Los Angeles; and New York. Taken together, these fleet procurement goals will promote investment in advanced vehicle technology including developing efficient batteries for buses that could have applications in other transportation subsectors (e.g., other medium-and heavy-duty vehicles).[81]

Finally, real economy actors are promoting sustainability and working to reduce emissions by cutting the total number of miles that citizens drive each year. Vehicle miles traveled (VMT) have been increasing since 1990 (after a brief plateau following the recession in 2008, growth has picked back up again).[82] Strategies that involve mode-shifting—encouraging people to use public transit, bike, or walk—will not only decrease air pollutants from vehicle emissions but also improve human health through physical activity and reduce the incidence of motor vehicle accidents.[83] Three states (California, Vermont, and Washington) have targets to reduce VMT explicitly, and 32 cities (out of the 285 most populous in the United States) have goals to reduce VMT either directly or indirectly through the promotion of non-automobile modes of transportation.

Despite the importance of VMT-related policies, the direct impact of these policies is difficult to measure, owing to the long lead times for the interventions to take effect and the complexity of estimating more indirect goals to shift traffic patterns. Our analysis—which focuses more narrowly on the three current state-level targets and quantifiable goals from 15 cities (including Boston; Los Angeles; Louisville, Kentucky; Pittsburgh; Portland, Oregon; San Antonio; and Seattle)[84]—finds that if these targets alone are achieved, annual VMT would fall by over 36 billion miles compared with BAU projections. Case Study Five, featuring mechanisms used to motivate behavior change designed to reduce VMT in Portland, Oregon, shows how such actions could have multiple benefits. Finally, although these actions are undoubtedly significant, broader adoption of such strategies could have much greater impact on the total number of miles driven by Americans.

CASE STUDY 05

Developing Low-VMT Planning in Portland, Oregon

In the 1990s, the Portland metro area adopted a comprehensive system-wide approach guiding transportation policy. The Transportation Planning Rule requires transportation and land use planning to be explicitly linked with the ultimate goal of reducing the community's reliance on automobiles.

Portland's Transportation System Plan (TSP), which guides transportation investments, contains mode share targets aimed at increasing the percentage of trips taken using non-automobile modes of transportation. Out of 51 of the largest cities in the United States, 25 have some sort of mode share target.[85] By 2014, residents of the Portland metro area were driving 14 percent fewer miles per capita than they had 20 years earlier, compared with other metro areas in the United States, where driving rates increased by 8 percent on average in that time. Portland also tops U.S. cities for bicycle commuting and scored the highest in ACEEE's 2017 City Energy Efficiency Scorecard for transportation.[86] Between 1994 and 2011, the Portland region also saw a reduction in drive-alone mode share of approximately 4 percent, while the VMT fell by 7 percent in the region.

If Portland were to achieve a combined drive-alone and carpool 2035 target of 42.5 percent by 2035, the city could save a cumulative 47 million gallons of gasoline, or 422,000 metric tons of CO_2, by 2035. However, there is potential for greater energy savings from a combined package of strategies and interactions between approaches in addition to multimodal targets. Other city, regional, and state policies that can support further ambition include the city's Urban Growth Boundary policy, which encourages the creation of denser communities with access to multiple modes of transportation, and investment in infrastructure that supports walking and biking.

If the 24 other cities in ACEEE's 2017 City Energy Efficiency Scorecard with mode share targets were to strive for the same reductions in single-occupancy drives and carpool rides as Portland by 2035, the amount of gasoline saved would increase to 1.3 billion gallons, or 11,505,000 metric tons of CO_2.

Hydrofluorocarbons

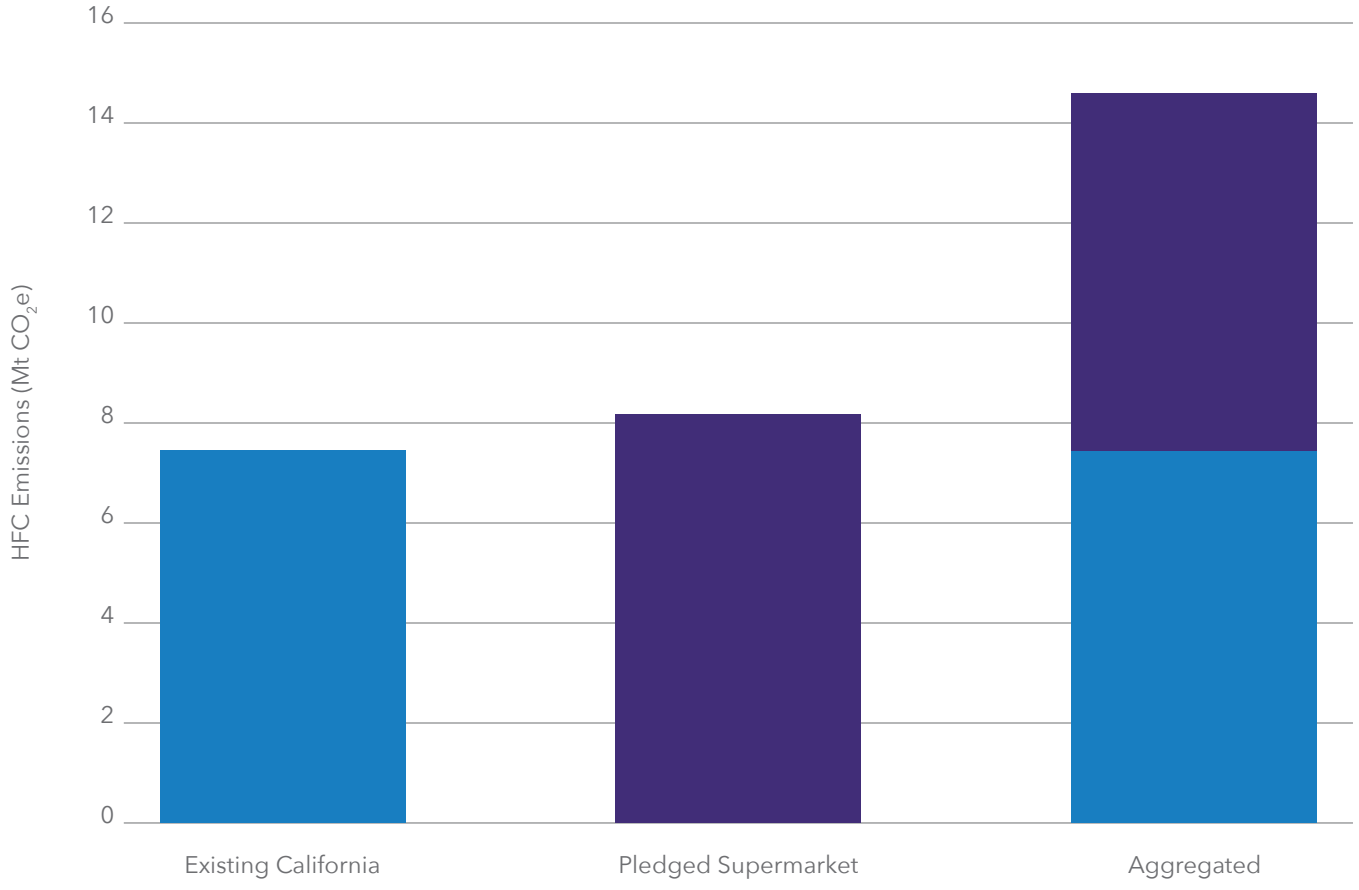
Hydrofluorocarbons (HFCs), chemicals commonly used in industrial applications including air conditioning, refrigeration, insulation, aerosol propellants, and flame retardants, remain a significant threat to the goal of keeping global warming well below 2 degrees Celsius. Although HFCs make up a relatively low percentage of emissions by volume, they are up to 12,000 times more potent a greenhouse gas than carbon dioxide. Without immediate regulatory action, HFC emissions are projected to grow rapidly in the coming decades. The parties to the Montreal Protocol, the international treaty originally established to address ozone-depleting substances, agreed to the landmark Kigali Amendment in October 2016. This amendment calls for a global phasedown of HFCs starting in 2019 and has a strong backing from industry. Developed countries are to begin ramping down production and consumption starting in 2019–20, with an 85 percent total reduction achieved by 2036.[87] Developing countries are required to freeze their HFC production by 2024, with an 80–85 percent reduction achieved in the mid-2040s. In keeping with this international ambition, the EPA originally sought to phase down HFCs for certain uses; however, these restrictions on HFCs have been partially blocked by courts.[88] This ruling is currently being challenged by a coalition of industry and nonprofit groups. Meanwhile, the Trump Administration's EPA has issued new guidance that further dismantles restrictions on HFC production and use. This rollback is also facing legal challenges from NGOs and states.[89]

While federal efforts are stalled, states, cities, and businesses are moving forward with their own actions, most recently with the commitment by the U.S. Climate Alliance—a coalition of states representing approximately 30 percent of U.S. HFC emissions—to phase down HFCs along with other short-lived climate pollutants.[90] In 2011, California established the first regulations addressing HFCs (including the Refrigerant Management Program [RMP]), requiring leak inspections, registration, and reporting to the Air Resources Board. [91] In March 2018,

Existing state, city, and business initiatives could cut HFC emissions by

6% from 2015 levels by 2025

Figure 2-7: State and Corporate Actions Designed to Reduce HFC Emissions Are Projected to Cut Emissions by 15 Mt CO_2e in 2025



Source: ATHENA modeling outputs.

Note: Figure relies on a potentially conservative estimate of BAU HFC emissions. Given the uncertainty of future HFC emissions, the abatement impact of non-federal actions may be larger than represented in this figure. More information on baseline projections used in this analysis can be found in this report's technical appendix.

California adopted regulations requiring a 40 percent reduction in HFC emissions below 2013 levels by 2030. California's guidance is also broadly consistent with the EPA's original rules that were vacated, thus creating a backstop against current federal inaction.[92] Together California's RMP and 2018 regulations are projected to significantly cut HFC pollution. The RMP is estimated to avoid 5 Mt CO_2e each year, and the 2018 regulations are projected to reduce emissions by 13.2 Mt CO_2e in 2030 compared with BAU.[93]

Businesses, including large supermarkets, are also taking action by signing voluntary agreements to reduce their HFC impact (Figure 2-7). According to the 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 percent.[94] Through the EPA's GreenChill program, 43 supermarket chains have committed to reducing their HFC emissions. This represents over 10,000 individual stores or about 28 percent of all stores in the United States.[95] GreenChill partners have, on average, reduced their leakage rate about 44 percent compared with a typical supermarket.[96] As of March 2018, 215 stores were certified as having achieved even greater emissions reductions. These stores have taken a wide range of actions to reduce their emissions, including addressing leaks, upgrading equipment, and switching to refrigerants with lower global warming potential (GWP).

Oil and Gas Methane Emissions

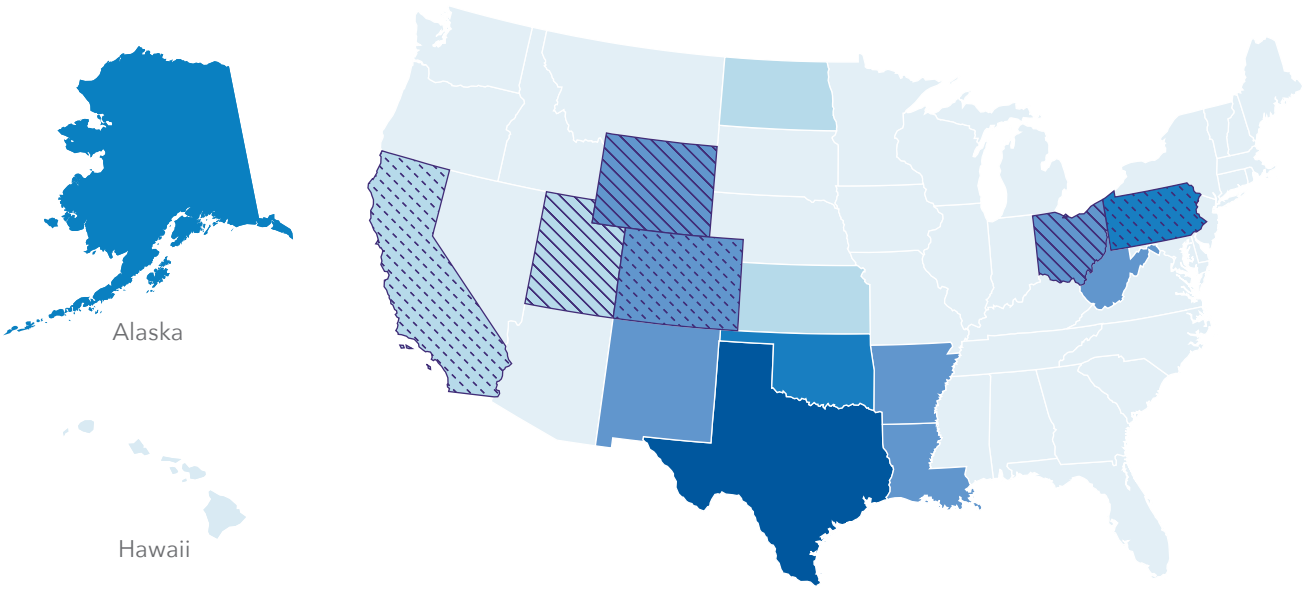
Oil and natural gas systems leak large amounts of methane to the atmosphere throughout the entire supply chain, from well site to end-user, due to poor extraction practices, aging infrastructure, and leaky components. In 2016, methane emissions from oil and gas systems reached roughly 200 Mt CO_2e (about 4 percent of total U.S. GHG emissions).[97] As the United States continues to increase its oil and gas production, methane emissions will grow.[98] Moreover, a 2018 peer-reviewed analysis found emissions to be 60 percent higher than the EPA's official estimate, suggesting that the real numbers are much larger, and underscoring the urgency in addressing these sources.[99] Notably, the numbers used in this report are based on official EPA estimates, so the real-world benefits of methane emissions reduction efforts are likely to be significantly greater than estimated herein.

Under the Obama Administration, the federal government enacted performance standards to reduce methane and other harmful air pollution from new oil and gas production and processing equipment.[100] While the Trump Administration is seeking to roll back federal standards, a coalition of states have sued successfully to keep these rules on the books.[101]

Yet states do not have to wait for federal standards to take effect, nor are they prevented from adopting more ambitious policies on their own. Colorado was the first state to establish methane pollution standards, in 2014, and California followed suit by adopting similarly rigorous standards in 2017. These state-level standards go beyond federal standards by covering not only new and upgraded equipment, but also existing, high-emitting sources, and thus are particularly impactful in the near term. They require operators to conduct periodic reviews of equipment to catch and repair methane leaks (referred to as Leak Detection and Repair [LDAR]). Moreover, the list of states with oil and gas pollution standards is growing, with New Mexico, Ohio, Pennsylvania, Utah, and Wyoming in the process of adopting or expanding commonsense standards and monitoring requirements that will further reduce these emissions (Figure 2-8).[98] If successfully implemented, these rules will not only reduce methane emissions, but also reduce smog-forming pollution, thereby improving public health while creating jobs and preventing revenue losses.

Beyond mandatory policies, natural gas producers and distributors have adopted voluntary measures through the EPA's Natural Gas STAR program. The program currently is composed of 105 domestic corporate partners

Figure 2-8: Some of the Highest Oil and Gas Producing States have Enacted Policies to Address Methane Leaks but Significant Opportunities Remain



Source: World Resources Institute, Environmental Defense Fund, Energy Information Administration

and 25 international partners making commitments across the natural gas supply chain that have avoided an estimated 15 Mt CO_2e of potential CH_4 emissions annually (average of 2012–16 reported reductions).[102]

Taken together, we estimate that current state policies and corporate actions will yield a national reducton in oil and gas methane emissions of 17 percent, relative to 2005 levels, by 2025.[103] This estimate includes the projected impact of standards that will lower methane emissions in California, Colorado, New Mexico, Ohio, Pennsylvania, Utah, and Wyoming, and assumes maintained ambition of voluntary measures based on historical EPA reporting. Although these figures are significant, more will need to be done to bend the curve and avoid a net increase in national emissions from increased oil and gas production. Recent scientific evidence shows that emissions from this sector may be significantly underestimated, suggesting that the potential for abatement—and necessity of further action—may in fact be much greater.[104] Additional priority policies and programs for oil and gas emissions will be discussed in Chapter 3.

Current state policies and corporate actions to address fugitive methane leaks could cut emissions from national oil and gas operations by

17% from 2005 levels by 2025

Landfill and Wastewater Methane

Landfills and wastewater treatment were responsible for approximately 123 Mt CO_2e of methane emissions (about 2 percent of total national GHG emissions) in 2016.[105] This methane is generated when organic materials decompose in the absence of oxygen. Rather than winding up in the atmosphere as potent GHGs, these emissions can be captured as a source of renewable natural gas (RNG) to be used for power generation, heating, and vehicle fuel.[106] Combustion of RNG for such uses can result in net GHG reductions on a life-cycle basis, particularly if the gas would not otherwise have been captured or flared, is transported efficiently (without leakage), and is used to displace more carbon-intensive fuels such as diesel.[107] The RNG market has significant potential to expand. Federal policy has helped incentivize RNG in recent years; following a 2014 EPA update[108] to the classification of RNG, production increased nearly sixfold from 2014 to 2016.[109] RNG can also be used to meet California and Oregon's low-carbon fuel standards. Finally, 632 operational landfill gas projects across the United States have resulted in 14 Mt CO_2e in avoided emissions in 2018 so far.[110]

Better yet, states, municipalities, and businesses can help prevent the generation of methane in the first place by promoting policies that divert waste before it can go to a landfill. Our 2017 report documented the fact that 12 out of the 51 largest U.S. cities have waste methane reduction goals[111] and have enacted organic waste diversion and recycling programs as a strategy to achieve this target. For instance, Austin, Texas, aims to divert 75 percent of its solid waste from landfills by 2020 in order to prevent methane emissions.[112] Rhode Island, New York, Massachusetts, California, Vermont, and Connecticut have similarly set statewide goals.[113]

A final bottom-up opportunity available to non-federal real economy actors is curbing methane emissions from wastewater facilities. In 2015, Washington, D.C., installed biodigesters at its Blue Plains water treatment facility and used the captured methane to supply 50 megawatts of power.[114]

Natural and Working Lands

America's natural lands, including forests, grasslands, and wetlands, serve an important function in absorbing and sequestering carbon. In 2016, these ecosystems sequestered 755 Mt CO_2e—more than 10 percent of U.S. GHG emissions.[115] Achieving long-term climate goals will require bolstering America's natural carbon sink, especially by protecting, managing, and expanding existing forests and integrating trees into urban and agricultural landscapes. To date, mitigation opportunities in this sector have suffered from a lack of finance. Persistent challenges in measurement and monitoring also affect prospects for deployment at a large scale. Modest investments in these capabilities (improved land-sector monitoring, inventories, and mapping programs) combined with public and private finance could unlock significant untapped potential from the nation's natural and working lands on the order of hundreds of millions of metric tons of carbon storage.

While forests and other lands sequester carbon, some land uses are large sources of emissions. Agricultural production results in methane and nitrous oxide emissions. In 2016, methane emitted from livestock and manure accounted for 240 Mt CO_2e, and nitrous oxide from agricultural soils emitted nearly 285 Mt CO_2e.[116] It is possible to cut methane and nitrous oxide through more efficient climate-smart agricultural practices that have added benefits to farmers. For instance, typically half of nitrogen fertilizer is not absorbed by plants but instead volatizes or is washed into waterways—adversely impacting air and water quality.[117] More efficient application of nitrogen fertilizer (using precision agriculture techniques or slow-release fertilizer) could maintain crop yields while decreasing fertilizer expenses and saving farmers money.

To date, despite the large share of emissions from this sector, few initiatives have attempted to address them, underscoring the need for enhanced ambition, as is discussed in Chapter 3. One example is California's SB 1383, which, along with HFC targets, established a target to cut methane emissions by 40 percent, including methane from manure management, and direct funds to programs that support installation of dairy digesters and other methane reduction tools and strategies.[118] Furthermore, California credits methane abatement as an offset under its cap-and-trade program,[119] and credits renewable natural gas from manure methane under its LCFS regulation.[120]

A second example is a voluntary program run through the EPA's AgSTAR program. Under the program, U.S. farms share basic information on anaerobic digesters installed, including the farm's location, operational date, and estimated methane emissions reductions in Mt CO_2e per year.[121] It is estimated that the United States has 265 digesters either operating or under construction on livestock farms.[122] Assuming that each digester continues to avoid the same amount of methane each year after its reported operational date, and that no new digesters are installed and none are retired, U.S. livestock farms will avoid about 5 Mt CO_2e of methane emissions annually by 2025. This would amount to about 9 percent of 2005 methane emissions from manure management.

GHG Emissions Limits and Market-Based Policy Frameworks

Compared with the sector-specific actions outlined above, a cross-sector approach to reducing emissions can be taken. Economy-wide prices on GHGs can be set through mechanisms such as cap-and-trade, and a carbon tax or fee. Ten states are implementing some form of emissions limit and pricing, including California's economy- wide cap-and-trade program and the RGGI, a cooperative effort of nine states to reduce power- sector CO_2 emissions. California phased in its GHG emissions pricing regulation in 2012, mandating the adoption of a comprehensive strategy to reduce GHG emissions to 1990 levels by 2020.[123] Senate Bill 32 (2016) mandated a statewide goal to reduce GHG emissions by at least 40 percent below 1990 levels by 2030. Legislation passed in July 2017 clarified the role of California's Cap-and-Trade Program as a key part of the strategy to achieve the 2030 limit.[124] The RGGI program caps CO_2 emissions from large power plants and creates a market where emissions allowances are auctioned. The resulting revenue is then reinvested into public programs focused primarily on energy efficiency. Since the program was first adopted, New Jersey withdrew, but has subsequently announced its intent to rejoin in 2018. Similarly, Virginia is considering creating a GHG limits program that would be compatible with the RGGI system.[125] RGGI's market has been effective at reducing emissions in the power sector. Because it applies only to the power sector, RGGI states have not made progress in reducing emissions from other important sectors, such as transportation (although states in the Northeast are in active discussions about developing a program for the transportation sector). By using a cap-and-trade system, RGGI states and California allow for flexibility and help achieve GHG reduction targets in the most comprehensive manner.

Photo: ENMAX

Finance as a Key Driver of a Low-Carbon Economy

Installing new solar panels, retrofitting existing buildings, and deploying clean all-electric buses and passenger vehicles will all require access to new capital. Fortunately, markets are responding, with private-sector clean energy or climate finance totaling over $270 billion per year globally in 2015–16, according to Climate Policy Initiative.[126]

States and cities can issue bonds to either fund projects directly or help attract private capital. They can also set policies or regulations that enable new and innovative finance models. Property Assessed Clean Energy (PACE) financing is one example of how states are facilitating clean energy investments through policy. As of July 2018, 33 states and the District of Columbia had enabled PACE legislation to support the deployment of energy efficiency and renewable energy.[127] As of January 2016, PACE models supported more than $3.6 billion in clean energy investments.[128] States and cities are also contributing to the financing of clean energy through the use of publicly owned, commercially operated green banks. These institutions specifically target clean energy and climate mitigation projects by helping to decrease project risk and attract additional private capital. Case Study Six provides a more in-depth look at how New York's green bank is sparking new clean energy markets and encouraging private investment in clean energy.

The private sector is continuing to identify innovative approaches to clean energy finance, often in collaboration with the public sector. Several

third-party ownership models have been deployed that allow investment groups to provide the up-front funding in exchange for a portion of the savings over time. Examples include energy performance contracts (EPCs) commonly used to support investments in energy efficiency, the solar lease model that helped unlock the residential and commercial rooftop solar market, and the use of power purchase agreements (PPAs) or virtual PPAs (VPPAs) that has led to significant scaling of the utility solar market.

CASE STUDY 06

New York's Green Bank: An Innovative Approach to Mobilizing Private Capital

The largest state green bank in the country, NY Green Bank (NYGB) was created in 2013 as a division of the New York State Energy Research and Development Authority (NYSERDA) with a $1 billion capitalization.[129] Funding comes from utility ratepayers as well as revenues from carbon trading under the RGGI. Whereas some green banks have focused on individual households or businesses, NYGB addresses gaps in wholesale markets by providing wholesale financing to large-scale developers and projects that require investments in the range of $5 million to $50 million. All potential transactions must meet key investment criteria, which include investments on commercial terms that mobilize private capital contribution to financial market transformation and greenhouse gas emissions—all in support of New York's clean energy policies. Proposed investments are also assessed to ensure they are additional to, and do not "crowd out," private capital providers and investments.

As of March 2018, NYGB had invested $457.5 million toward energy efficiency, solar power, sustainable transportation, and fuel cell projects, which has helped leverage a total project value of $1.39 billion to $1.63 billion in public and private funds. This means that the NYGB is currently mobilizing at least $3 in total project value for every $1 of NYGB funds.[130] NYGB is able to reinvest not only its original capital as individual investments mature and repay, but additional retained earnings. At this rate, NYGB is expected to recycle its $1 billion initial capital almost twice by 2025, meeting its 10-year investment goals.[131] This is expected to result in 29 million tons of greenhouse gas emissions reductions over financed projects' lifetime, equivalent to taking 6.2 million cars off the road for a year.[132]

In October 2017, New York Governor Andrew M. Cuomo announced that NYGB would seek to raise an additional $1 billion in capital from third-party investors, as well as expand its activities nationally. NYGB is also working with the United States Climate Alliance and the Coalition for Green Capital to establish local green banks in other states, and will potentially provide financing for sustainable infrastructure as well as leveraging NYGB's existing credit underwriting abilities and infrastructure.[133] As federal initiatives to create a green bank are deadlocked in Congress, NYGB's nationwide expansion is an innovative example of how state-led climate initiatives can fill the gap.[134]

Alongside NYGB's moves to expand nationwide, Nevada and the District of Columbia passed legislation creating their own green banks in 2017 and 2018, respectively; Massachusetts has a green bank bill under consideration in its legislature; and more than six other states are looking at establishing their own green banks, including Colorado, Missouri, and Pennsylvania.[135] By addressing perceived risks and demonstrating new financing models, states can build confidence in the private sector, sparking independent investment in clean energy, allowing a self-sustaining green economy to flourish.

Chapter 3

Accelerating Progress: State, City, and Business Opportunities

Existing commitments, policies, and programs lay the groundwork for achieving America's current 2025 target under the Paris Agreement and drive the deep reductions necessary to avoid the most dangerous impacts of climate change over the long term.

Ultimately, successful decarbonization will require full implementation of existing and more ambitious policies and greater engagement from all institutions and sectors, including the federal government. However, in the immediate future, real economy actors have direct control and influence over the bulk of U.S. climate emissions through bottom-up action, wielding a diverse and growing toolbox of levers.

This chapter outlines the opportunity for states, cities, and businesses to reach beyond their current commitments and promote a faster transition to a clean and prosperous economy. We present the potential for continued real economy leadership under two nested scenarios: *Climate Action Strategies* and *Enhanced Engagement*.

Climate Action Strategies

Climate Action Strategies provides a detailed assessment of 10 near-term, discrete climate leadership opportunities for states, cities, businesses, and other real economy actors. The strategies represent opportunities that can be initiated in the near term, can build on momentum under way in key sectors of the economy, and can deliver meaningful impact by 2025.

The 10 *Climate Action Strategies* were developed through a collaborative process with experts from industry and civil society using the following criteria:

- **Impact:** Substantial, quantifiable emissions reduction potential by 2025
- **Technical viability:** Technology exists and is deployable at scale in the near term
- **Cost-effectiveness:** Economically attractive; existing business models
- **Political feasibility:** Likely political support in the near term
- **Progress under way:** Similar action is taking place, momentum is building, and one or more standard-bearers exist
- **Innovation and excitement:** Innovative approaches to emissions reduction

Using these criteria, we identified the following *Climate Action Strategies*:

#1: DOUBLE DOWN ON RENEWABLE ENERGY TARGETS

#2: ACCELERATE THE RETIREMENT OF COAL POWER

#3: ENCOURAGE RESIDENTIAL AND COMMERCIAL BUILDING EFFICIENCY RETROFITS

#4: ELECTRIFY BUILDING ENERGY USE

#5: ACCELERATE ELECTRIC VEHICLE (EV) ADOPTION

#6: PHASE DOWN SUPER-POLLUTING HYDROFLUOROCARBONS (HFCS)

#7: STOP METHANE LEAKS AT THE WELLHEAD

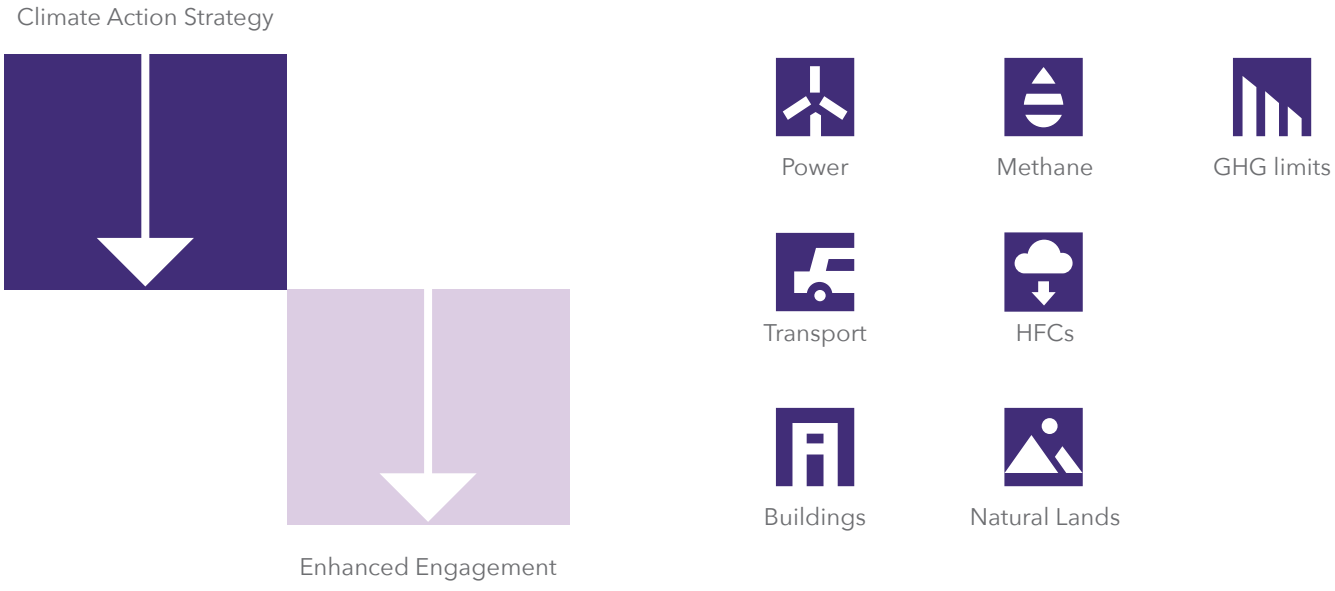
#8: REDUCE METHANE LEAKS IN CITIES

#9: DEVELOP REGIONAL STRATEGIES FOR CARBON SEQUESTRATION ON NATURAL AND WORKING LANDS

#10: FORM STATE COALITIONS FOR CARBON PRICING

For each of the seven sectors, this chapter presents one or more Climate Action Strategies to accelerate progress and Enhanced Engagement to go even farther.

Figure 3-1: Illustrative Depiction of Scope of Climate Policies and Impacts in *Ten Climate Action Strategies* and *Enhanced Engagement* Scenarios



Enhanced Engagement

Enhanced Engagement captures the impact if real economy actors are highly ambitious in adopting a broader, feasible suite of actions across each major GHG-emitting sector. This scenario envisages more states, cities, and companies joining those already acting to cut emissions, as well as accelerated and more aggressive actions by those real economy actors who have already started down the decarbonization trajectory. Building on both the *Current Measures* and the *Climate Action Strategies* scenarios, the *Enhanced Engagement* scenario presents a top-end estimate of what can reasonably be achieved through state, city, and business actions. It takes into consideration limitations, including legal barriers to scaling up some specific policies as well as the political unwillingness of local governments in some regions of the U.S. to take up climate policies.

These two scenarios are presented in this chapter as a range of potential real-world outcomes with the discrete *Climate Action Strategies* at the accessible end and the broader *Enhanced Engagement* potential at the more engaged end. Moving from the low to the high end of potential requires both more actors undertaking commitments defined in the *Climate Action Strategies* and an expanded range of actions across the economy, defined as levers of change under *Enhanced Engagement*.

This chapter demonstrates that given the rapid pace of innovation and technological change, and despite the absence in federal leadership, a robust set of as-yet-untapped opportunities to cut emissions remain available to real economy actors. Such opportunities can be seized immediately, at low cost, while also creating jobs and growing the economy.

The complete GHG implications of the *Climate Action Strategies* and the overall opportunity for *Enhanced Engagement* is modeled and presented in Chapter 4, where we account for the complex linkages between the various sectors.

Power Sector

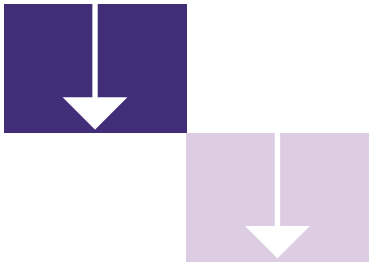
The power sector is undergoing rapid change and cutting emissions faster than any other sector.[136] At the same time, the United States must expand electric generation to absorb increasing demand due to electrification of end-uses (such as vehicles, building heating and cooling, and industrial processes).[137] Decarbonizing the electric grid will require both the retirement of aging fossil units, such as coal, and the ambitious scale-up of clean energy technologies and electricity services (including wind, solar, demand response, energy storage, improved efficiency, and, eventually, carbon capture and sequestration technology). In the case of nuclear power, it will also require retention efforts. According to the U.S. Energy Information Administration, 14 gigawatts (GW) of renewable energy capacity came online in 2017.[138] This is impressive but insufficient. The U.S. Mid-Century Strategy (MCS) estimates that the United States would need to deploy roughly 30 GW of new renewable energy per year between 2016 and 2035, with this pace accelerating to 50 GW per year thereafter.[139]

Despite the proposed rollback of federal policies such as the Clean Power Plan, declining federal tax incentives for renewables, and ongoing discussions of federally mandated subsidies for uneconomic coal plants, U.S. states, cities, and businesses have many powerful tools at their disposal to significantly scale up renewable power generation and accelerate the retirement of coal-fired electricity generating units, two of the most important changes needed for continued emissions reductions from the power sector.

Motivation to take action is not solely environmental reasons; economic reasons are also compelling. Low-carbon electricity is cheaper in many cases, it is better for public health, and it provides a competitive edge in attracting business.

Compared to the reference case scenario and *Current Measures*, the outlook under the *Enhanced Engagement* scenario foresees the retirement of coal power plants and scales up renewable energy (see Figure 3-2). We estimate that state, city, and business leadership implementing *Climate Action Strategies* could drive 990 terawatt-hours (TWh) of total renewable generation and 94 gigawatts of coal retirements by 2025 (130 TWh and 25 GW beyond *Current Measures*). Full uptake of the *Enhanced Engagement* scenario would see the deployment of 1,050 TWh of renewable generation (Figure 3-2) and 128 GW of incremental coal retirements. In addition, the Enhanced Engagement scenario reflects retention of 6,500 MW of existing nuclear capacity otherwise scheduled to retire within the next decade.

ACCELERATING PROGRESS



We estimate that state, city, and business leadership could drive

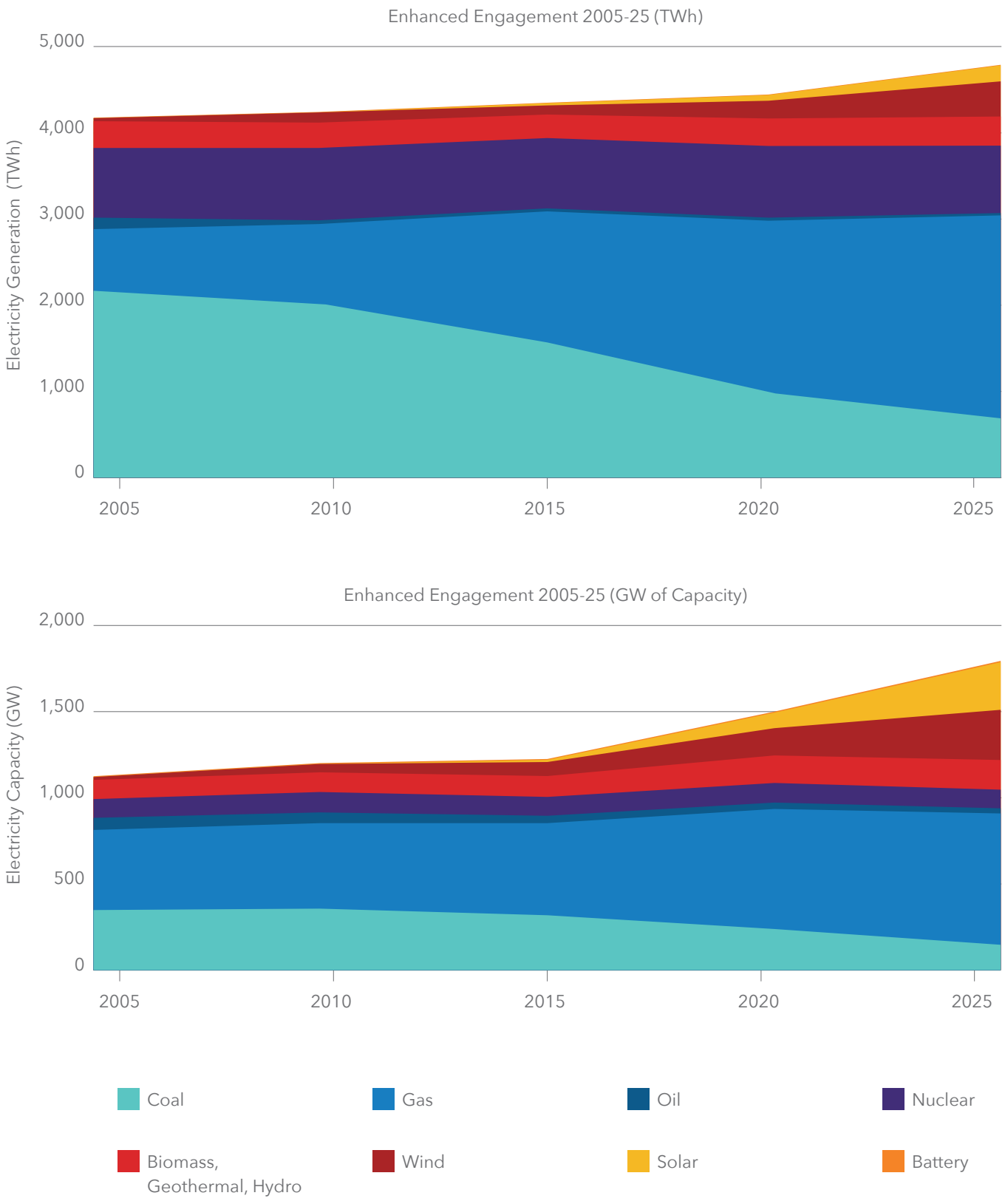
990-1,050 TWh

of total renewable generation and

94-128 GW

of coal retirements by 2025 (through implementation of the *Climate Strategies* and *Enhanced Engagement*).

Figure 3-2: Ambitious Action by States, Cities, and Businesses and Significantly Increase Renewables and Retire Coal by 2025



Source: America's Pledge modeling outputs

Levers of Change

States, cities, and businesses can achieve the ambitious outcomes outlined above by supporting implementation of the following interventions.

- Foster broad coalitions of support in favor of clean energy programs by highlighting the full range of climate, economic, health, and equity benefits to help reduce political barriers to clean energy standards, tax incentives, net metering, and retail choice (see Climate Action Strategy #1 for additional details);
- Pursue policies to source electricity from clean energy sources, such as wind and solar, and that support increasingly at-risk nuclear generation (see Climate Action Strategy #1 for additional details);
- Work collaboratively with states, public utility commissions (PUCs), utilities, and affected communities to phase out uneconomic and environmentally damaging coal generation (see Climate Action Strategy #2 for additional details);
- Promote innovative utility business models and rate structures (such as variable time-of-use rates) that can help optimize grid load, promote flexibility, and otherwise incorporate smart grid technology (such as demand response, distributed generation, and energy storage);
- Collaborate to improve transmission corridors that will allow for the transport of renewable energy from generation sources to demand markets; and
- Identify and take advantage of opportunities to cost-effectively deploy carbon capture and storage (CCS) technology in order to capture emissions from remaining fossil sources and from industry (although not yet economically viable at scale, certain CCS activities are subject to recently passed federal tax incentives).

Economic and Health Benefits of Climate Action

Mitigation and economic growth go hand in hand, as demonstrated by the continued growth in the U.S. economy as emissions have fallen steadily. At the state level, California GHG emissions peaked in 2004, and in 2016, the state's GHG emissions fell below 1990 levels, meeting California's 2020 target four years ahead of schedule. California law requires that emissions return to 1990 levels by 2020 and reach 40 percent below that marker by 2030. California has reduced its emissions by over 13 percent since the state's peak in 2004, while also growing the economy by 26 percent during the same time period.[140]

Transitioning to a clean electric grid will shift valuation of assets and create jobs in new and different industries. Real economy actors must ensure that public policies adequately promote new employment opportunities for their citizens. States and cities would reap the benefits of promoting clean energy industries in their region, either through promoting local residential or commercial energy policies that spur project development, or through attracting clean energy manufacturing. By attracting these viable new business models, states and cities are all able to support job creation for their citizens.

In addition to the climate benefits, closing coal plants can improve the air and water quality of local communities. Estimates vary, but between 7,500 and 52,000 people in the United States meet early deaths because of small particles resulting from power plant emissions.[141] The Sierra Club's Beyond Coal campaign has helped prevent at least 7,000 premature deaths every year.[142]

CLIMATE ACTION STRATEGY #1

Double down on renewable energy targets

States, cities, corporations, and utilities all have proven tools at their disposal to promote clean energy through renewable energy targets, and the approaches they have pursued to date hold promise for accelerated deployment. When cities, state policymakers, corporate renewable energy buyers, and utility companies work together to develop integrated strategies across stakeholder groups, they can drive progress even faster.

We estimate that this Climate Action Strategy could readily lead to the deployment of an additional 130 TWh of renewable energy beyond what is assumed under the *Current Measures* scenario by 2025—reaching 990 TWh of total renewable energy annually—while also saving consumers money on their energy bills and improving public health.

The Opportunity

- **States** enact new commitments that put states with an RPS on track toward 25 percent renewables by 2025 and bring new states on board by adding an RPS.
- **Cities and businesses** can leverage ambitious city and corporate renewable targets and develop integrated strategies across the state/city/corporate/utility stakeholder groups to drive faster progress. Cities and businesses can also build coalitions of support for higher state RPS, for more ambitious clean energy commitments from utilities, and for policies that enable cities' renewable energy goals. Cities can partner with one another and with corporations and universities to aggregate energy demand and facilitate bulk purchasing of renewable energy.

Example of This Approach at Work

The Renewable Energy Buyers Alliance (REBA) is a collaborative effort led by four nonprofit organizations to accelerate and scale up procurement of renewable energy. REBA exists to help energy buyers such as corporations, cities, and public institutions power their operations with clean energy by helping them understand the benefits of moving to renewables, connecting large buyer demand to renewable energy supply, and helping utilities better understand and serve the needs of all energy buyers. REBA brings together all market actors through annual gatherings and monthly calls to collectively overcome the largest barriers to meeting ambitious renewable energy targets. Today, over 250 companies and institutions participate in REBA to accelerate the transition in the energy sector toward a low-carbon future. Since 2013, these organizations have announced over 12 GW of new renewable energy capacity.

Salesforce, one organization participating in REBA, is more than halfway toward its goal of matching 100 percent of its global electricity use with renewable energy. The majority of that progress has come from virtual power purchase agreements in West Virginia and Texas, as well as renewable energy tariffs. The company is focused on building a diverse portfolio of renewable energy projects that minimize risk and maximize emissions reductions. However, company leaders recognize that matching electricity use is only an initial step toward the long-term goal of shifting the world's power supply completely to clean energy resources. To pursue that long-term goal, Salesforce relies on collaboration through groups like REBA to effect change on a global scale.

CLIMATE ACTION STRATEGY #2

Accelerate the retirement of coal power

Coal was an important engine of American economic growth 100 years ago, but its prime has passed for both economic and environmental reasons. According to recent analysis by the International Energy Agency, to avoid 2 degrees Celsius of warming, advanced economies like the United States would need to phase out all conventional coal generation and capacity by 2035. Between 2009 and 2017, 60 GW of U.S. coal capacity was retired, and a further 45 GW will be closed by 2025. These retirements are the result of local, state, and citizen action and the eroding economics of coal against clean energy. Now, the economics alone are more compelling than ever, as renewable cost reductions in recent years have made the majority of the remaining U.S. coal fleet uneconomic relative to regional wind and solar resources.

Yet the pace of phaseout remains too slow for U.S. and global climate goals. Even as utilities face increased shareholder and ratepayer pressure to phase out coal, PUC policies, utility planning, and local priorities do not always align. Working together, we estimate that states, cities, businesses, advocates, and other stakeholders can accelerate the retirement of coal capacity by an additional 25 GW beyond what is assumed under Current Measures, resulting in 94 GW of total reductions, which would equate to almost 30 percent of the total installed capacity in 2005. Adding up retirements to date, the assumed retirements under Current Measures, and what could be accomplished through the additional actions outlined in this *Climate Action Strategy,* 45 percent of the 2005 coal fleet could no longer be polluting in 2025.[143]

The Opportunity

Environmental and consumer advocates are already deeply engaged in many of the venues that affect decisions about the remaining coal plants and have played an important role in securing the progress to date. States, cities, and businesses have not yet seized their full potential in accelerating the transition from fossil fuels to clean energy and shaping the evolution of the electricity grid. Specifically, they can map out where decisions are pending on existing coal-fired power units and:

- Participate actively in PUC meetings, utility resource planning processes, rate structuring, and other public proceedings to shape decisions in favor of clean, cost-effective alternatives;
- Work with investors and other stakeholders to develop novel financial, regulatory, and tariff structures that provide customers with the opportunity to take advantage of falling renewable costs to achieve their carbon and clean energy goals while reducing their rates from day one;
- Work directly with utilities to actively plan how electricity demand and reliability criteria can be met by improving efficiency, scaling renewables, and promoting demand response when fossil fuel generation retires;
- Make choices in electricity procurement at the municipal and corporate level as outlined in Climate Action Strategy #1 above; and
- Collaborate with coal plant owners, workers, and local communities to promote employment opportunities as the grid transitions from coal (and gas) to a clean grid.

Example of This Approach at Work

Colorado's Xcel Energy announced plans in June 2018 to implement the single largest national proposal to replace retiring coal power with renewable energy in American history. Xcel plans to accelerate retirement of one-third of its coal fleet, replace that with major new additions of wind, solar, and battery storage, and add no new utility-owned gas builds, bringing the utility's portfolio to 55 percent renewable energy. In its request for proposals for this plan, thanks to falling renewable costs and federal tax credits, Xcel received the lowest bids for wind and solar ever received by any U.S. utility, and this shift will save its customers an estimated $215 million. The utility is also investing in an economic transition pathway for the community that is home to the coal units. The utility was pushed toward this pathway by sustained, multiyear engagement by key stakeholders and grassroots advocacy that included thousands of its customers sending comments and attending hearings to demand this change. The cities of Pueblo, Aspen, and Boulder have all declared their commitment to meet 100 percent of their electricity needs with the low-cost clean energy sources that already employ more Coloradans than coal and gas combined. Xcel's plan by the numbers includes:

- Constructing 1,131 megawatts (MW) of new wind, 707 MW of new solar, and 275 MW of new battery storage;
- Accelerating retirement of 660 MW of its coal fleet (about a third of its Colorado fleet);
- Purchasing 383 MW of existing gas plants, but beginning no new gas construction;
- Increasing its share of renewable energy in Colorado from about 29 percent to more than 50 percent by 2026;
- Reducing carbon emissions by 59 percent as compared with a 2005 baseline; and
- Achieving at least $213 million in savings as compared with continued operation of all Comanche coal units.

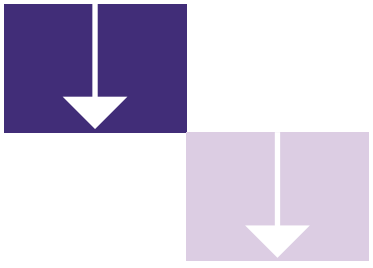
Residential and Commercial Energy Use

Energy efficiency has been a cornerstone of the decoupling of energy use from economic growth and recent reductions in U.S. GHG emissions.[144] This has been achieved by reducing overall energy demand through energy efficiency—and increasingly through dynamic demand management—and complemented with low-carbon energy generation (as discussed above in the Power Sector section, 3.2). Energy efficiency continues to be one of the more cost-effective mitigation options compared with other interventions,[145] and if counted alongside generation assets it would be the third-largest electricity resource.[146] If the country is to achieve its near- and mid-term climate goals, additional action on building energy use is needed, and luckily there is significant low-cost potential for greater efficiency (Figure 3-3).

We estimate that implementing the policies described in the *Climate Action Strategies* would lead to an additional 13 TWh in energy savings by 2025 beyond current measures. Scaling these actions to full potential in the *Enhanced Engagement* scenario could help drive total 58 TWh in energy savings by 2025 beyond current measures. In these scenarios consumers would also save 800-1,050 tera British thermal units (TBtu) by transitioning from direct fossil fuel use for end-uses to electricity by 2025.

Photo: David Dodge, GreenEnergyFutures.ca

ACCELERATING PROGRESS



We estimate that implementing policies would lead to an additional

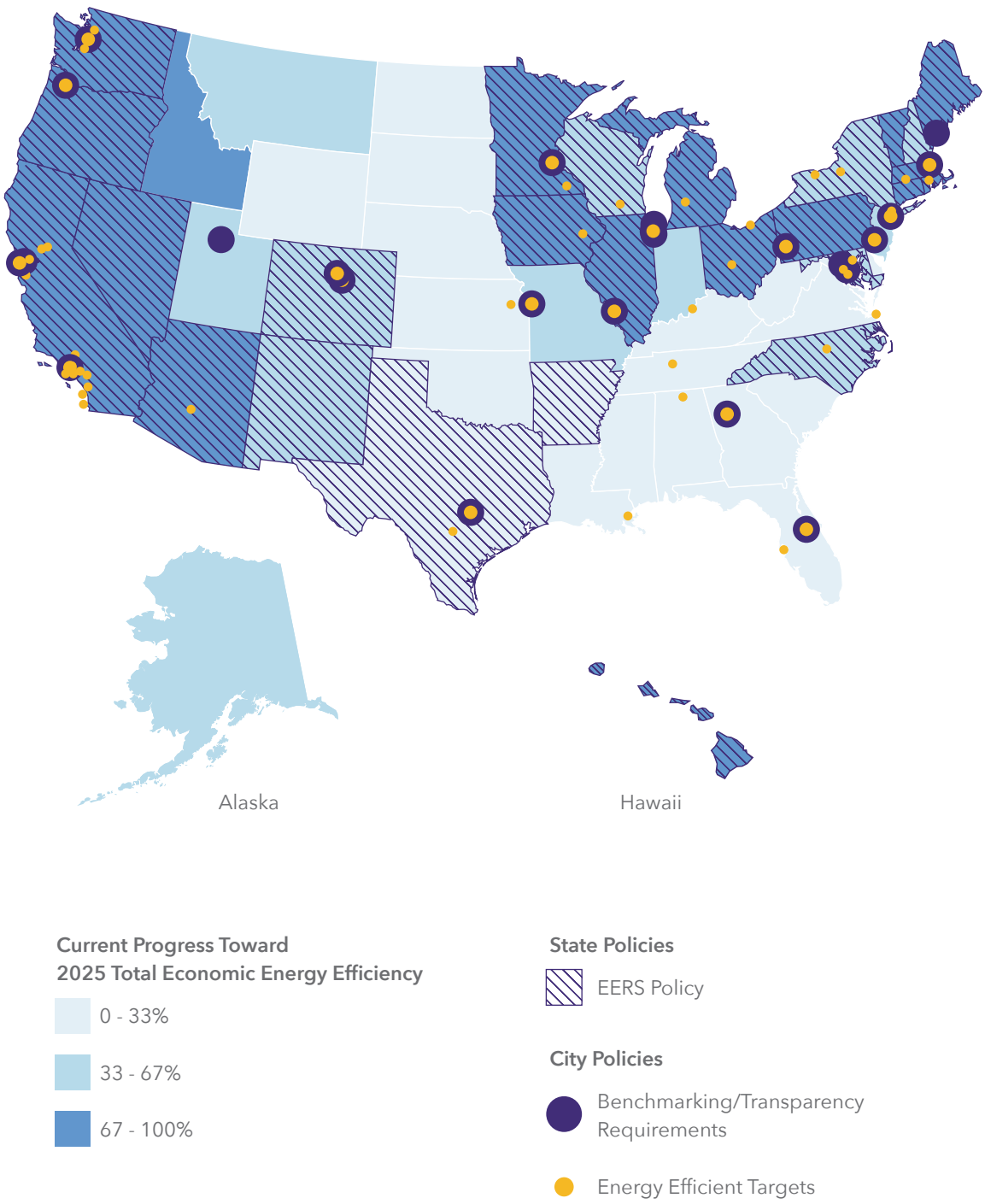
13 TWh-58 TWh

in energy savings by 2025 beyond current measures (through implementation of the *Climate Action Strategy* and Enhanced Engagement). Additionally, under these scenarios, consumers would also save

800-1,050 TBTU

by transitioning from direct fossil fuel end-uses to electricity by 2025

Figure 3-3: Many Areas of the U.S. are Making Progress on Energy Efficiency, but there is Signficant Opportunity for Additional Ambition



Source: Electric Power Research Institute's "State Level Electric Efficiency Potential Estimates" (May 2017) report; Institute for Market Transformation; World Resources Institute

Levers of Change

In order to meet the goals of the Paris Agreement, the United States will need to: 1) make new and existing buildings more efficient and grid connected and responsive; 2) switch heating systems from fossil fuels to clean electricity generated from renewable sources; and 3) ensure that any remaining fuel used comes from clean sources. State and city levers can prove even more effective than federal leadership in achieving these goals, particularly because states and cities regulate building efficiency codes, implement city planning and zoning, set state-level appliance standards, and control utility efficiency programs. Businesses can also electrify and improve the efficiency of their buildings. Key levers include:

- Requiring retrofits for residential and commercial buildings at key trigger points during structures' life cycle, including when changing ownership and during major renovations (see Climate Action Strategy #3 for further details);
- Setting and enforcing advanced building and appliance codes that vastly improve energy efficiency, promote smart, grid-connected end-uses, and promote electrification of fossil-based end-uses, such as water heating (see Climate Action Strategy #4 for further details). This includes adopting the latest minimum codes determined appropriate by DOE but ideally reaching beyond that to match stretch targets;
- Working with utilities and PUCs to adopt time-based electricity rate pricing to promote demand response and load shifting that will save utilities and ratepayers money;
- Setting state, city, utility, or business energy efficiency targets that drive improvements to existing residential and commercial buildings, including utility EERS programs; incentivizing the adoption of system-wide efficiency certifications such as "ISO50001 Ready"; adopting ENERGY STAR goals; or committing to state, municipal or business-owned retrofits;
- Enhancing energy efficiency programs that provide resources to support home and business energy upgrades and ensuring that these programs are available for all socioeconomic levels;
- Launching private-sector challenge programs to promote innovation and growth in energy efficiency in buildings (such as the Advanced Rooftop Unit [RTU]) campaign to save cities and building owners money on cooling[147]); and
- Creating and standardizing benchmarking, audit, and retro-commissioning policies for existing buildings.

Economic and Health Benefits of Climate Action

Beyond emissions and environmental benefits, investing in building energy efficiency yields significant economic benefits. The American Council for an Energy-Efficient Economy (ACEEE) estimates that residential households each save as much as $460 per year on electricity due to energy efficiency programs and policies.[148] According to a 2018 U.S. Energy and Employment Report, employment in the energy-efficient technologies and related services sector grew by just over 3 percent from 2016 to 2017, employing approximately 2.25 million workers.[149]

When properly structured, energy efficiency programs can reduce energy burdens for renters and low-income households. The amount spent on energy costs as a percentage of income, also known as the energy burden, is approximately three times as high for low-income households, due to building inefficiencies.[150] Energy efficiency programs that address traditional barriers for low-income households can improve indoor air quality while bringing older building stock up to code.

CLIMATE ACTION STRATEGY #3

Encourage residential and commercial building efficiency retrofits

New homes and commercial properties are getting more energy efficient, but addressing the carbon footprint of existing buildings is challenging. Fortunately, advances in technology and business models have opened up new opportunities to implement building retrofits in cost-effective ways. And federal policy is not needed to achieve major progress: local governments, real estate companies, and utilities can come together to implement new programs and policies in order to maximize carbon savings achievable through retrofits.

Over 40 cities have set ambitious energy efficiency targets and are implementing policies and programs in support of these stated targets. Looking at the U.S. cities with a population over 100,000 that are engaged in existing climate coalitions or clean energy efforts, we see a realistic potential to double the number of cities with building-specific energy targets and associated programs. We estimate that new cities recruited into this Climate Action Strategy could achieve a target similar to those set by existing participants, which would reduce overall annual building electricity use alone by 13 TWh by 2025 in addition to what is outlined in our *Current Measures* scenario.

The Opportunity

Cities can collaborate with the real estate industry, utilities, and state regulators to set policies and implement ambitious building energy efficiency programs. Several cities have begun to explore new approaches to scaling energy efficiency within their own buildings and across their communities. An assessment of innovative actions highlights several opportunity areas for additional action:

- **Require energy disclosure** to create market value for energy-efficient buildings. As discussed in Case Study Four in Chapter 2, 26 cities currently require building energy benchmarking and transparency policies to improve knowledge of energy use and aid in planning and implementing energy-saving measures. Cities without a benchmarking and transparency policy can implement one; cities with a current policy can build on existing policies with additional programs, including rating systems, energy disclosure for all buildings, and retrofit requirements.
- **Require upgrades at key trigger points in the building life cycle,** including through minimum efficiency standards for residential rental units and policies to retrofit residential and/or commercial buildings at time of sale. In the United States, rental properties make up more than 50 percent of all residences, and because owners can pass along energy costs to renters, there is a lack of incentive for both owners and renters to invest in efficiency upgrades. Cities can lead the way in overcoming this barrier by requiring rental units to achieve efficiency standards at the point of rental licensing. Today, two cities have implemented rental efficiency standards, and several others plan to launch similar policies.
- **Scale up retrofit incentive programs,** which are often a direct collaboration between local governments and utilities, providing financial incentives and additional resources with which to implement energy efficiency. These programs are particularly effective when pairing utility financial incentive programs with city challenge programs or retrofit requirements. Best-in-class programs provide models others can follow when considering additional opportunities to scale up building energy efficiency.

Example of This Approach at Work

Retrofit Chicago is a voluntary program that encourages and promotes energy efficiency in buildings. The program includes all building types—from small residential properties to larger properties such as offices, hotels, college buildings, large multifamily residences, nonprofits, and houses of worship. Under Retrofit Chicago, the City is also improving the efficiency of its own buildings and has reduced energy use by approximately 18 percent across 60 City-owned properties. The portion of the program addressing large buildings has also achieved approximately 18 percent energy reduction in 88 participating buildings spanning more than 56 million square feet of space.

Building on the success of this program, as well as the City's mandatory energy benchmarking requirement for large properties, Chicago will begin assigning a building energy rating of between zero and four stars to all properties over 50,000 square feet, starting in 2019. Property owners will be required to post their rating in a prominent location and to share it at time of listing for sale or lease. The new Chicago Energy Rating System is expected to increase the transparency and simplicity of energy information reported under the Chicago Energy Benchmarking Ordinance.

CLIMATE ACTION STRATEGY #4

Electrify building energy use

Homes and commercial buildings burn fossil fuels (natural gas, propane, and oil) for end-uses such as heating and hot water—resulting in over 500 million tons of carbon pollution per year. Electrifying the primary end-uses that consume fossil energy, such as space heating, water heating, and cooking, would result in significant climate and public health benefits, particularly when combined with decarbonizing the electricity grid itself.

Targeting collaborative action by states, cities, utilities, and industry organizations in regions where electrification retrofits are most cost-effective today, we estimate that this Climate Action Strategy could save over 800 TBtu of building energy use by 2025—enough energy to power 20 million homes for a year—as well as leading a significant transition away from fossil fuels.

The Opportunity

Utilities, cities, and states can each contribute to achieving the full potential of this opportunity. Utilities primarily control the design and implementation of energy efficiency programs, including incentives for implementation of new technologies. Cities direct policies and regulations for building standards and, in particular, codes that set the bar for new construction and in many cases for major retrofits of existing buildings. States set energy policy and strategy, appliance standards, and building codes. Yet there is significant work to be done. It is estimated that over 70 million homes and businesses across the United States use natural gas, oil, or propane to heat their space and water.[151] Turnover of existing systems is slow, retrofitting existing homes and businesses to support all-electric equipment can be costly, and consumers lack awareness of the more efficient electric systems.

States, cities, and utilities can therefore collaborate to electrify building energy use by:

- **Evaluating local or regional potential** from a technical and economic standpoint prior to setting a goal and implementing a specific strategy. While building electrification is broadly applicable, an assessment of the local or regional economic and technical potential for electrification can help tailor a strategy to the existing fuel mix, climate zone, and composition of the building stock.
- **Setting an electrification target or goal,** and backing it up by implementing policies or regulations that address new appliances and building standards. Setting a target or goal can signal to a broader set of stakeholders the intent to take action, as well as engaging with other actors with similar goals (see the multi-city initiative example below).
- **Coming together through regulatory processes** to advocate for rules and requirements that support electrification goals. These include establishing fuel switching rules; promoting smart, grid-responsive appliances and buildings; implementing cost-effectiveness requirements; adjusting rate structures; and providing financial performance incentives for utilities.
- **Implementing programs** to encourage electrification, in particular in existing buildings where the financial challenge is the greatest. Potential options include providing incentives, establishing new or innovative financing models, and running outreach and education campaigns.
- **Identifying funding opportunities,** including the nearly $10 billion in demand-side management funding from utilities to encourage electrification.[152]

The regions of the country with the biggest opportunity to electrify existing residential and commercial buildings are in areas that have not already begun to address this, where there is a meaningful heating load (i.e., colder climates), and where fuel costs for direct fuels are higher, particularly propane and oil. The Northeast and Midwest regions are well poised to electrify residential and commercial buildings for these reasons. In addition, all regions of the United States should consider opportunities to encourage policies to support electrification of new construction and where there are significant industrial sectors.

Example of This Approach at Work

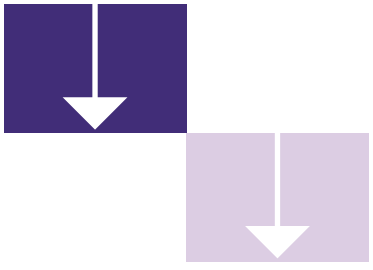
Boulder, Colorado, has helped launch a multi-city initiative to rapidly wean buildings off their dependence on natural gas for space and water heating by replacing existing units with high-efficiency heat pumps—with the goal of transitioning 80 percent of residential building stock to heat pumps by 2050. A consortium of over 20 cities including Boulder; New York City; San Francisco; Seattle; Salt Lake City; Palo Alto, California; Burlington, Vermont; Washington, D.C., and others have initiated a broad public–private collaboration working with most of the world's major heat pump manufacturers as well as suppliers and installers in the HVAC industry to develop policy, market development, and financial mechanisms to facilitate this rapid transition.

Transportation

Although transportation surpassed electricity generation as the largest source of GHG emissions in the United States in 2016,[153] there is significant innovation under way. The cost of electric vehicles continues to decline as their range increases and the variety of electric vehicles available to consumers expands.[154] Battery and hybrid electric vehicles could reach cost parity with gasoline vehicles by 2025—even when not considering the lifetime benefits of fuel savings associated with electric vehicles versus gasoline-powered alternatives.[155] Cities are implementing multifaceted approaches to support alternative transportation modes; states are adopting policies such as zero-emissions vehicle (ZEV) mandates; and companies are ramping up their commitments to low-carbon vehicles. If such trends are harnessed, real economy actors can help transition the United States away from a fossil fuel–based transportation system to the low-carbon transportation system of the 21st century.

We estimate that states, cities, and businesses could take actions that would help boost annual new electric vehicle sales from 128,000 in 2017 to 1.9 million in 2025, resulting in over 8.4 million EVs on the road (see *Climate Action Strategy #5*). Through broader engagement, the real economy can accelerate deployment to 2.2 million new electric vehicle sales in 2025, or over 9 million EVs on the road (*Enhanced Engagement* scenario) (Figure 3-4). We also project that real economy actors could reduce annual passenger and freight vehicle miles traveled by 1 to 2 percent nationally relative to our current measures case in 2025 (a modest and achievable estimate compared with the significant progress some leading cities and states are currently targeting).[156]

ACCELERATING PROGRESS



We estimate that states, cities, and businesses could help boost annual new electric vehicle sales to

1.9-2.2 million

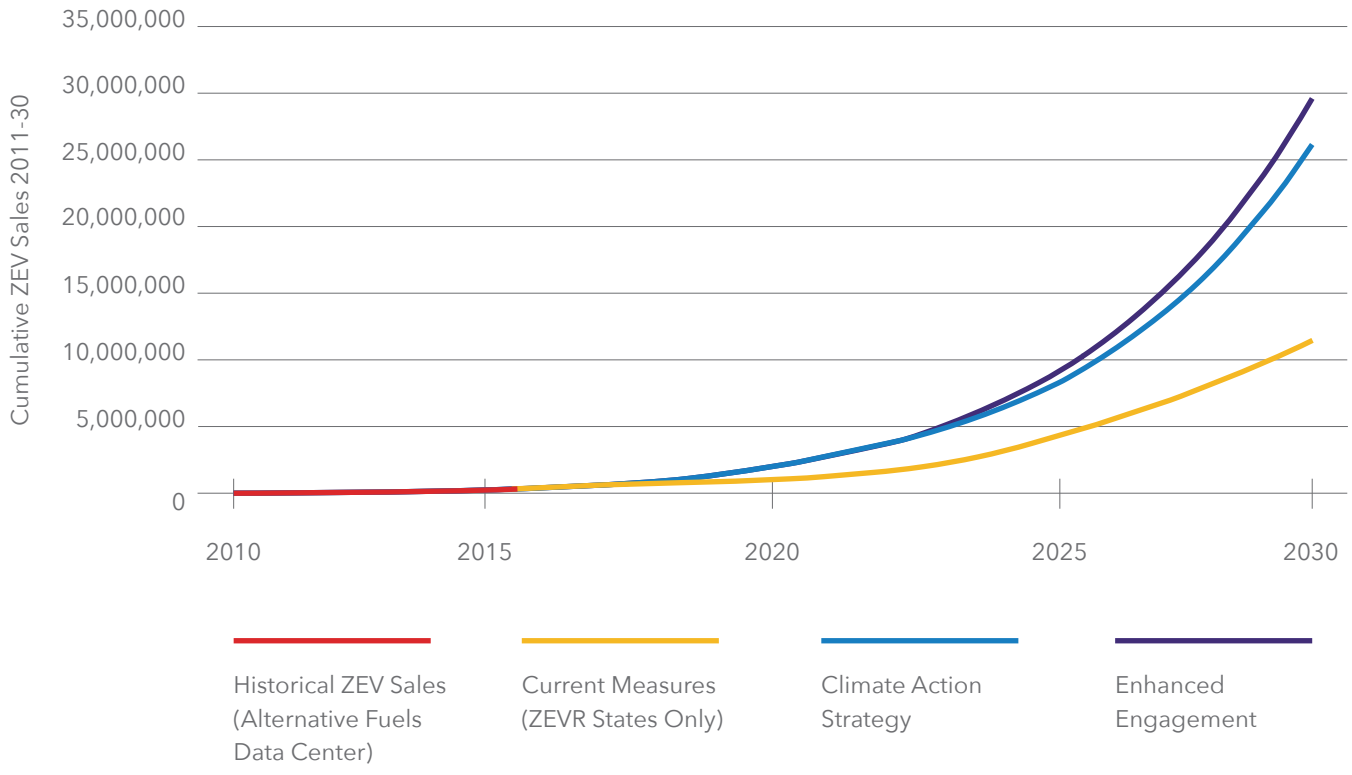
in 2025, resulting in

8-9 million EVs

on the road (through implementation of the Climate Action Strategies and Enhanced Engagement).


Electric Vehicle Infrastructure
WARNING!
DO NOT USE AN
EXTENSION CABLE TO
CHARGE THIS CAR

Figure 3-4: Through Accelerated Ambition by Real Economy Actors, the U.S. could Achieve as much as 9 million ZEVs on the Road by 2025



Source: Historical ZEV sale data from Alternative Fuels Data Center; projections based on America's pledge modeling output (using BNEF 2018 EV Outlook data)

Levers of Change

Key strategies for reducing transportation emissions: 1) increased adoption of ZEVs and other low-carbon vehicles; 2) reductions in emissions from vehicles attained by reducing the carbon intensity of fuel production and fuel combustion; 3) the densification of urban development; and 4) the expansion of public transportation networks, ride-sharing, and non-vehicle modes of transportation. Fortunately, states, cities, and businesses have many tools to help them achieve all four goals, including the selection listed below.

- Commit to procuring EVs for state, city, and business fleets and accelerate efforts to electrify medium- and heavy-duty vehicles, including municipal vehicles, that serve or transit through underserved communities, which often suffer disproportionate health impacts from diesel and gasoline pollution.

- Enable greater EV penetration by building infrastructure, adjusting regulatory structures to enable greater private investment in charging infrastructure, and encouraging public acceptance of these vehicles. This includes providing public access to EV charging at multifamily apartment buildings and in municipally owned or business-owned parking lots; expanding EV education and incentives; and promoting community-scale transition to EVs with commercial fleets and carsharing programs.

- Adopt statewide policies such as GHG standards for cars and trucks, ZEV regulation (ZEVR) mandates, or low-carbon fuel standards (such as California's and Oregon's low-carbon fuel standards [LCFS]).

- Reduce vehicle miles traveled in the short, medium, and long term by prioritizing investments in public transit, including deployment and cost-effective rapid transit, and by promoting compact, dense, walkable development through land-use planning.

As discussed in Chapter 2, states recognize the co-benefits that accompany strong policies addressing transportation emissions and are acting accordingly. However, the need for higher ambition in addressing transportation emissions is coupled with a need to counter the Trump Administration's regressive fuel economy policies and recent challenge to California's ability to set its own standards. Additional states could join the 13 states that are moving forward with California's rigorous GHG standards for cars and trucks or could join California's ZEV regulation program. In addition, states can engage the Transportation Climate Initiative, a collaboration of states and the District of Columbia working together on accelerating clean vehicles and fuels.[157] State, cities, businesses, community organizations, and universities can also concurrently enact programs that expand the accessibility and range of ZEVs, as discussed in Climate Action Strategy #5.

New mobility solutions are on the horizon, in particular the predicted growth of shared and autonomous vehicles. Autonomous vehicles have the potential to significantly change the transportation system by making roads safer, limiting congestion, and reducing overall vehicle ownership, but they also run the risk of increasing overall vehicle miles traveled (VMT).[158] Regulators are working to keep pace with the development of autonomous vehicles; four U.S. states (Nevada, California, Florida, and Michigan) plus the District of Columbia have legalized the testing of driverless vehicles on their roads, in order to better understand these potential opportunities and challenges.[159] It is critical that autonomous vehicles be all-electric (and ideally shared) to ensure that growth in this mobility solution does not result in backsliding on GHG emissions.[160]

States, cities, and businesses can also pursue policies to promote non-vehicle-based transportation and reduce VMT, as highlighted in Case Study Five. Among these strategies are advantageous pricing, particularly of parking and travel; infill development and additional land use or zoning decisions; regional and local transportation investments, including pedestrian, bike, and transit; and transportation demand management.[161]

Economic and Health Benefits of Decarbonizing Transportation

Transitioning from traditional gas-powered or diesel-powered vehicles to clean vehicles will result in significant public health benefits. Within the transport sector, diesel engines emit especially high quantities of short-lived pollutants that cause global warming, such as black carbon, a major component of PM2.5, a particularly harmful type of particulate matter.[162] A study by MIT found that 53,000 premature deaths annually in the United States can be attributed to road transportation–related PM2.5, and it disproportionately affects the most vulnerable populations, such as children, the elderly, the chronically ill, and people in low-income communities.[163] In addition, slowing down progress in efficiency and electrification would increase oil demand and make the United States more exposed to foreign oil suppliers.

Furthermore, low-income communities in particular face transportation barriers, such as inadequate access to affordable transportation.[164] Innovative clean energy transportation programs can benefit disadvantaged communities (see the example in Climate Action Strategy #5 below).

CLIMATE ACTION STRATEGY #5

Accelerate electric vehicle (EV) adoption

U.S. light-duty electric vehicle sales are steadily growing, from 50,000 in 2012 to more than 187,000 in the U.S. market in 2017. The number of EV models on the market is on track to double between 2016 and 2020, and the offerings are expanding to all vehicle classes and market segments—light-duty trucks, commercial delivery vehicles, transit buses, and even semi trucks. This growth and expanded vehicle availability is impressive, but market penetration is still tracking well below the rate needed to put a dent in the greenhouse gas emissions of the U.S. transportation sector.

We estimate that real economy actions taken through this Climate Action Strategy can accelerate uptake of EVs such that an estimated 8.4 million EVs will be on the road by 2025—with annual sales of over 1.9 million in 2025—4 million EVs beyond what is anticipated to happen under current commitments. This would represent 4 percent of all light-duty vehicles across the United States in 2025.[165]

Photo by Felix Kramer, CalCars

The Opportunity

States, cities, corporate fleet owners, utilities, vehicle manufacturers, transportation network companies, and other private-sector innovators have the power to substantially increase the rate of EV deployment, particularly when they work together.

- **State ZEV targets:** States can set and expand proactive ZEV policies and regulations. As discussed in Chapter 2, 10 states have already adopted the ZEV regulation program goals to enhance vehicle availability and support overall ZEV deployment. Additional states can follow in the footsteps of these leading states to adopt the same goals. States with ZEV program goals can collaborate with cities and businesses to complement state-level programs and accelerate deployment of EVs.
- **Group procurement can drive down EV costs:** Cities and counties can work directly with manufacturers to organize a "group buy" in which public-sector organizations or residents of their areas are able to take advantage of a large discount on EVs if they go through a certain dealer, typically within a specific window of time. This approach can save up to 25 percent on the price of a ZEV.[166]
- **Educate and promote:** Cities and states with substantial EV incentives and outreach activities often have higher rates of EV penetration.[167] Education and advertising programs, opportunities to test-drive electric vehicles, and carshare programs can address common customer concerns such as range anxiety and demonstrate the benefits of EVs to potential consumers. By gathering around a common cause, these organizations can share the program costs, pool resources, and expand reach and influence.
- **Expand charging infrastructure:** To scale up EVs, the 38 percent of Americans who own or rent units in multifamily buildings will need the ability to charge their vehicle. This can be achieved on-site by requiring developers of new or renovated multifamily buildings to install charging stations. More generally, states and cities have a major role to play in working with private developers and utilities to build out public charging infrastructure access points, especially direct current fast charging (DCFC), which charges EVs at a much higher speed than other options, as well as incentivizing workplace charging options.

An Example of These Approaches at Work

Los Angeles Mayor Eric Garcetti pioneered BlueLA, the nation's first all-electric carshare program designed to serve low-income residents. BlueLA exemplifies a successful public–private partnership with a comprehensive community outreach and engagement process. The program is a unique blend of leveraged funds from California's cap-and-trade program, a local city match, and the backing of a committed carshare operator identified through a competitive solicitation to the private sector. Stations are located throughout some of LA's most disadvantaged neighborhoods, and members of the local community are employed by BlueLA to lead on outreach and education. The program is expected to take at least 1,000 vehicles off the road by 2020 while saving Angelenos money and giving them high-quality, affordable, and clean mobility options.

HFCs

HFCs have been the fastest-growing greenhouse pollutant, growing by more than 50 percent between 2005 and 2017.[168] HFCs are such potent greenhouse gases that the landmark 2016 Kigali Amendment to the Montreal Protocol to phase them down could prevent as much as 0.5 degrees Celsius of warming by the end of the century. But stalled federal policy places greater importance on real economy actors to fill the ambition gap and forge ahead on key actions to cut these harmful pollutants.

We estimate that increased real economy actions could cut 2025 HFC emissions an additional 5 percent below 2015 levels (through implementation of *Climate Action Strategies*) and an additional 16 percent (through implementation of full *Enhanced Engagement*) below 2015 levels (see Figure 3-5).[169]

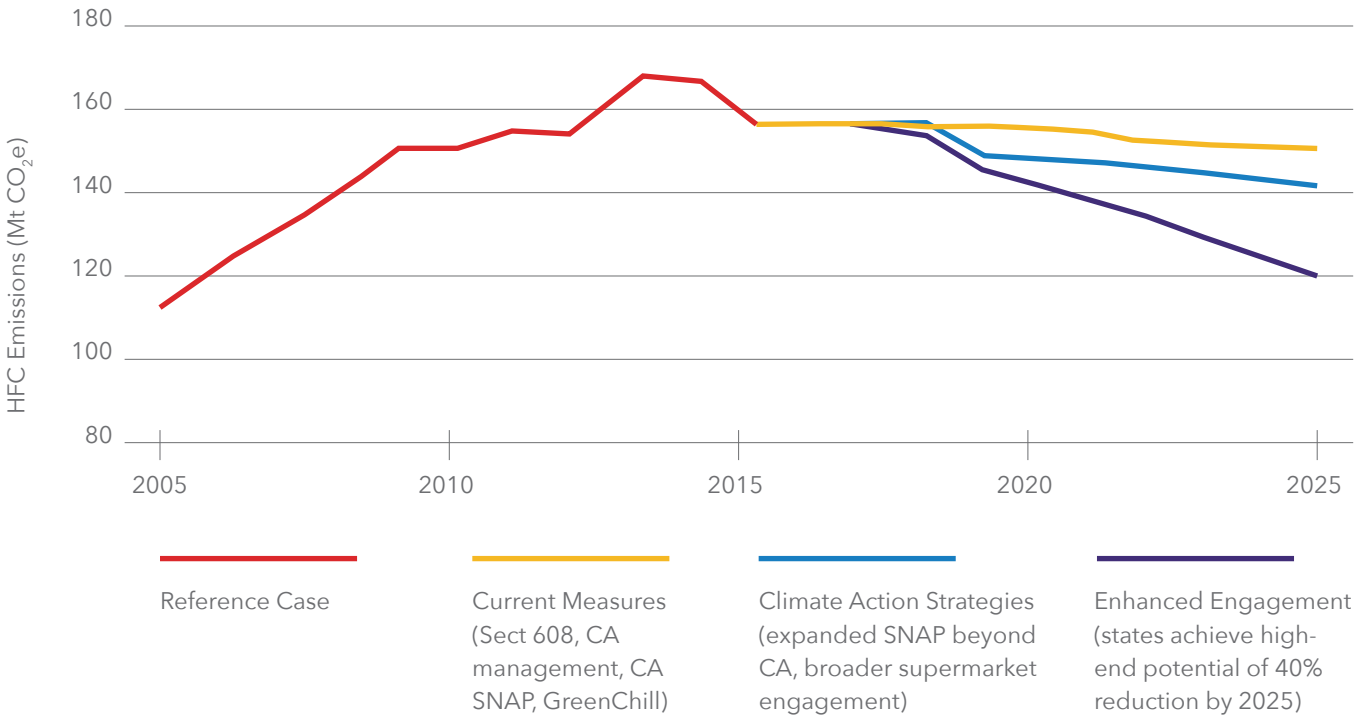
ACCELERATING PROGRESS

We estimate that increased real economy actions could cut 2025 HFC emissions an additional

5-16% below 2015 levels

(through implementation of *Climate Action Strategies* and *Enhanced Engagement*)

Figure 3-5: Through the Climate Action Strategies and Enhanced Engagement, Real Economy Actors could cut HFC Emissions an Additional 5-16 percent below 2015 levels by 2025



Source: ATHENA modeling outputs

Note: Figure relies on a potentially conservative estimate of BAU HFC emissions. Given the uncertainty of future HFC emissions, the abatement impact of non-federal actions may be larger than represented in this figure. More information on baseline projections used in this analysis can be found in this report's technical appendix.

Levers of Change

State and business actions can set the United States back on track to meet its obligations under the Kigali Amendment and achieve even greater reductions by expediting the phasedown of harmful HFCs across the full range of end-uses and capturing legacy pollutants from leaks and end of life. Specifically, these levers include:

- Adopting state HFC standards (such as California's Significant New Alternatives Policy [SNAP] program) and partnering with businesses and manufacturers that are already transitioning away from super-polluting HFCs to remain competitive in international markets (discussed in Climate Action Strategy #6 below);
- Working with businesses, including supermarkets, to expand participation in voluntary refrigerant-leak management programs by providing technician training and education of co-benefits (discussed in Climate Action Strategy #6 below);
- Incentivizing businesses and residences to switch to HFC alternatives; and
- Improving HFC inventories and monitoring, reporting, and verification of emissions.

Although the actions included in Climate Action Strategy #6 highlight significant potential and build on existing efforts, up-front costs for alternative refrigerants remain high, and there is a general lack of familiarity and training in key sectors. Real economy actors will have to work collaboratively across sectors to identify alternative options and build capacity in order to achieve greater emissions reductions for HFCs. However, if all states set more ambitious policies similar to the California SNAP rule and achieve a 40 percent reduction from 2013 levels by 2030, the United States could reduce HFC emissions by an additional 15 million metric tons of carbon dioxide equivalent (Mt CO_2e) beyond current measures by 2025.

Economic and Health Benefits of Phasing Down Use of HFCs

The HFC industry is already headed toward a low-GWP future. American companies have brought many low-GWP alternatives to market, and the Kigali phasedown schedule has strong industry backing.[170] In 2015, the Air-Conditioning, Heating, & Refrigeration Institute (AHRI, which represents 90 percent of related U.S. manufacturing) committed $5 billion through 2025 in R&D and capital investment to commercialize efficient equipment that uses next-generation refrigerants.[171] Moreover, a recent analysis commissioned by AHRI and the Alliance for Responsible Atmospheric Policy found that 1,400 jobs and $1 billion in capital investment could be at risk if Kigali is not ratified and the United States cedes its leadership in this space.[172] The same analysis found that implementing the HFC phasedown schedule outlined under the Kigali Amendment would lead to the creation of 33,000 jobs and $38.3 billion per year in economic impact.[173] In addition, transitioning to low-GWP alternatives and reducing refrigerant leaks not only reduces HFC emissions, but also increases efficiency and helps save on energy costs.

CLIMATE ACTION STRATEGY #6

Phase down super-polluting hydrofluorocarbons (HFCs)

California's actions, including the March 2018 SNAP rule, demonstrate the opportunity for states to drive progress themselves. California has set out to reduce HFC emissions by 40 percent from 2013 levels by 2030 in supermarket refrigeration and other refrigeration uses. Its recent ban on the use of HFCs in certain sectors would prevent 2.7 million Mt CO_2e emissions annually by 2025, but its rules can also be expanded to cover additional end-uses, including aerosol propellants.

Expanding the California SNAP program to include aerosols, growing this program to include additional U.S. states (including all U.S. Climate Alliance states) representing roughly 54 percent of U.S. HFC emissions, and expanding the EPA's GreenChill program could reduce HFC emissions below 2015 levels an additional 5 percent beyond current policies in 2025. In addition to addressing a potent greenhouse gas, the phasedown of HFCs could lead to increased energy efficiency for end-use products. As stated in a California Air Resources Board (CARB) analysis, transitioning to low-GWP equipment could improve the efficiency of refrigeration systems by 10–18 percent.[174] These efficiency improvements would save money on energy bills and lead to additional reductions of GHG emissions as a result.

The Opportunity

The U.S. Climate Alliance, which released a statement of its commitment to reducing short-lived climate pollutants in June 2018, could adopt the California SNAP standards on HFCs. These states make up more than 30 percent of the U.S. HFC market.

Supermarket chains and associated suppliers are also key actors. Collaborative campaigns involving states, cities, and supermarket chains can encourage additional commitments across the supermarket industry. These efforts can complement existing or new state and city policies, which may include updating building codes and providing incentives for converting to new or retrofitted HFC-free air conditioning systems. These policies can be enhanced by programs that support training and education on HFC alternatives and their co-benefits (as the EPA's GreenChill program has done). The Consumer Goods Forum established an initiative to reduce HFCs associated with refrigeration, and to date its members have installed low-carbon refrigeration systems in over 4,000 supermarkets.[175]

Example of This Approach at Work

After a federal court blocked a portion of the EPA's authority to regulate HFCs, CARB was left in a bind because of its reliance on the EPA's Significant New Alternatives Policy rules to help meet California's preexisting emissions reduction goals for HFCs, which in turn are important in ensuring California ultimately meets its larger climate goals. "As a result of the recent court decision, California had to pass its own regulation to ensure it could meet these goals," CARB said in a statement.

The regulation CARB promulgated in March 2018 affects certain stationary refrigeration and foam end-uses. It preserves emissions reductions from specific sectors with past or shortly upcoming compliance deadlines and will "prevent manufacturers from backsliding or [starting to use] high-global warming HFCs again," according to the CARB statement. The regulation applies mainly to equipment manufacturers, which cannot use prohibited HFCs in new refrigeration equipment or foams.

Prohibited HFCs cannot be used in new equipment and materials in California for the following end-uses:

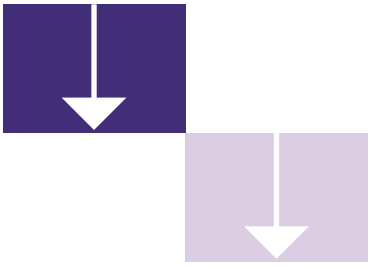
- Supermarkets and remote condensing units used by convenience stores;
- Refrigerated food processing and dispensing equipment, such as Slurpee machines and frozen yogurt dispensers;
- Stand-alone or small self-contained refrigeration units;
- Refrigerated vending machines; and
- Foams used in buildings and other places.

Oil and Gas Methane

Oil and gas operations are responsible for more methane emissions than any other source in the United States.[176] Methane emissions originate from both the wellhead and throughout the distribution system, and recent analysis indicates that we may be underestimating the full emissions impact.[177] As highlighted in Chapter 2, real economy actors have already begun to address these sources by enacting policies to upgrade equipment and limit fugitive methane leaks. In addition, recent advancements in technology, led by collaborations between industry, local policymakers, and technology providers, are making leak detection cheaper and more effective.

Through these measures alone, we estimate that real economy actors could go beyond current state and federal-level policies to reduce emissions by an additional 6-14 percent (through implementation of *Climate Action Strategies* and *Enhanced Engagement* scenarios respectively), relative to 2005 levels (see Figure 3-6).

ACCELERATING PROGRESS

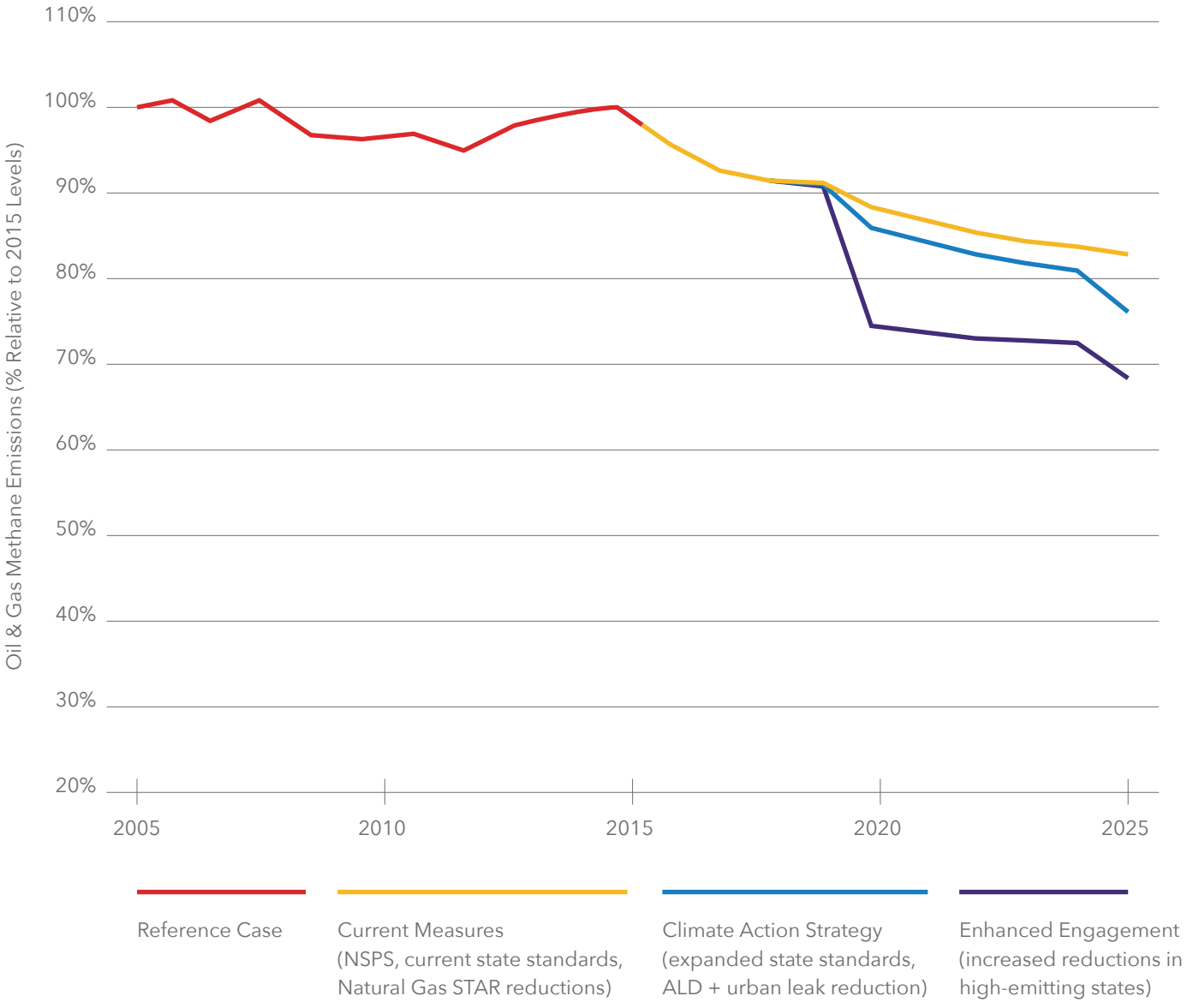


We estimate that real economy actors could reduce oil and gas methane emissions by an additional

6-14%

(through implementation of *Climate Action Strategies* and *Enhanced Engagement* scenarios respectively), relative to 2005 levels by 2025.

Figure 3-6: Real Economy Action can cut Oil and Gas Methane Emissions an Additional 6-14 percent below 2005 levels by 2025



Source: ATHENA modeling outputs

Levers of Change

Monitoring for fugitive methane leaks is one of the most powerful and low-cost interventions with which to mitigate emissions; it is a cornerstone of existing oil and gas standards in states such as Colorado and California. In addition to setting equipment and leak detection and repair (LDAR) standards, we explore two commonsense solutions for cutting methane emissions at different points along the supply chain in Climate Action Strategies #7 and #8 below. In addition, improved leak monitoring, which can be performed using satellite imaging, is critical to detecting and rapidly repairing these leaks early. This is a tool that real economy actors can readily ramp up in the coming years. For instance, a NASA pilot program helped California pinpoint 300 major sources of methane across the state.[178] States, academic institutions, utilities, and businesses can build on this blueprint to advance research and develop better tools that effectively measure and monitor methane leaks.

Economic and Health Benefits of Cutting Oil & Gas Methane Emissions

Addressing oil and gas operations will have an immediate impact on criteria and climate pollutants. Mitigating gas leaks has safety benefits and improves environmental welfare. Furthermore, adopting technologies to prevent methane leaks can provide oil and gas businesses with a competitive advantage by decreasing inefficiencies that affect sales.[179] According to the EPA, voluntary measures taken to reduce emissions have already led to an increase of over $264 million in revenue from natural gas sales for businesses.[180] In 2017, the Environmental Partnership was launched by American Petroleum Institute, with 26 other companies such as BP and Shell, to reduce methane leaks from operations. Participating companies began implementing the voluntary program as of January 1, 2018. A 2012 Natural Resources Defense Council (NRDC) study of the cost savings opportunity if legislation or standards moved the entire industry to use best practices found that it would generate revenue of more than $2 billion annually (at gas prices of $4 per thousand cubic feet).[181]

CLIMATE ACTION STRATEGY #7

Stop methane leaks at the wellhead

Recent scientific studies have shown that methane leaks associated with the exploration, production, and distribution of oil and especially natural gas are far higher than initially estimated. But those studies also show that because of the value of the natural gas recovered, simple leak detection and repair strategies can cut over 40 percent of these emissions. **California, Colorado, New Mexico, Ohio, Pennsylvania, Utah, and Wyoming** plan to put in place regulations or permitting programs to address emissions from oil and gas production facilities. There is an opportunity for other states to follow in their footsteps and drive action on methane now. In addition to reaping the climate benefits, such states can increase the efficiency of natural gas production, with the royalties and tax revenue that it brings. In support of adopting state-level standards, collaborations among real economy actors can develop and pilot innovative approaches in order to detect and repair leaks at oil and gas exploration and production sites.

We estimate that this Climate Action Strategy can reduce methane emissions in these states by an additional 6 percent beyond *Current Measures* in 2025. In addition to addressing methane emissions, these actions will help remove other harmful pollutants that are released into the atmosphere contributing to poor air quality and public health issues.

The Opportunity

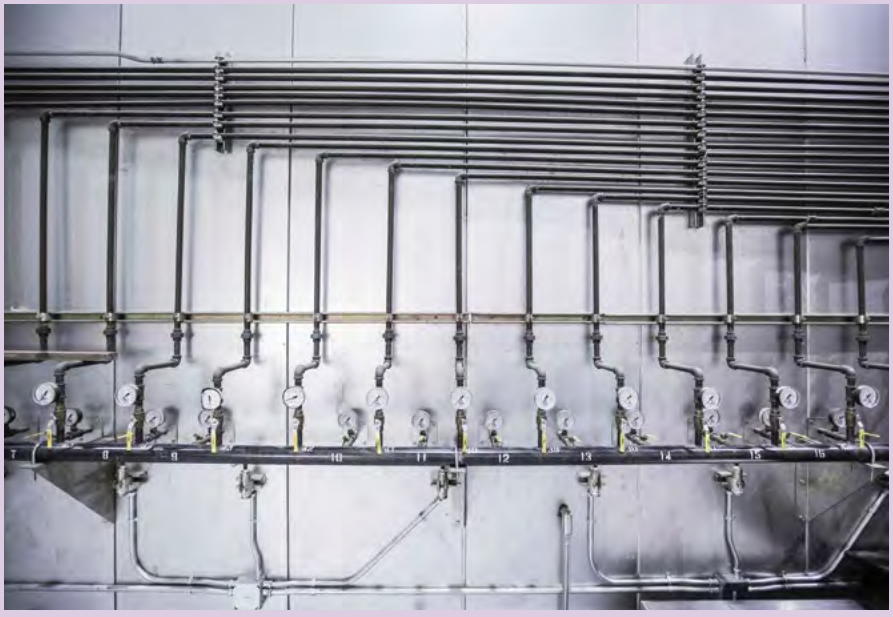
States, supported by industry, environmental groups, and broader campaigns, can:

- Put in place important regulations and/or permitting programs to manage methane emissions from oil and gas facilities.
- Collaborate to develop and scale up new technologies and approaches to detecting and repairing methane leaks. The Methane Detectors Challenge (MDC) is a partnership between the Environmental Defense Fund, oil and gas companies, technology developers, and other experts with the goal of accelerating the development and commercialization of methane detection technologies. The collaboration has developed several new technologies, has performed field testing, and is now working to pilot them at scale.
- Commit through regional initiatives to address methane emissions. Recently, the Western Governors' Association—made up of governors from 19 Western states—announced a policy resolution recognizing the benefits of taking action to address methane pollution from oil and gas facilities. State collaborations can encourage additional action and help apply existing policies and programs to a broader set of actors.

Example of This Approach at Work

Last June, Pennsylvania Governor Tom Wolf delivered on a key promise, enacting general permit conditions for new well sites and major emissions sources in the midstream sector. Pennsylvania plays a critical role as the second-largest gas-producing state in the nation. This move is vital not only for the tons of pollution it will prevent from escaping into the atmosphere but also for its value in demonstrating that methane solutions are both cost-effective and politically feasible. Governor Wolf has also committed to proposing new rules for existing sources in 2018, protections that are sorely needed to ensure that pollution from the roughly 70,000 wells already operating in the Commonwealth does not go unaddressed.

CLIMATE ACTION STRATEGY #8



Reduce methane leaks in cities

Methane leaks not only at the wellhead, but from pipes throughout communities. Between 173,000 and 519,000 Mt CO_2e leaks from natural gas distribution systems each year. Much of this infrastructure exists underground in large cities and is controlled by local utilities supplying natural gas for heating, cooking, and other energy uses. Detecting and repairing leaks in this vast system can be difficult and costly. But through the use of innovative technologies, improved partnerships, and advanced analytic methods, including leak quantification, real economy actors can revolutionize the way utilities repair and abate leaks—driving down the cost of detection and repair while achieving greater reductions.

By using innovative, data-driven approaches to identify and prioritize the repair of the top 20 percent of leaks in the eight states with the highest leakage, we estimate that this Climate Action Strategy could cut nationwide distribution system emissions by 30 percent by 2025. This would equate to 3 Mt CO_2e in avoided urban methane emissions each year.

The Opportunity

Working with urban gas distribution utilities in the eight states that account for 85 percent of leak-prone pipe (California, Michigan, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, and Texas), cities, utilities, and commercial service providers can develop and implement plans to use advanced leak detection and data analytics (ALD+) to identify and abate the largest leaks. The ALD+ approach provides benefits to ratepayers, utilities, regulators, and the environment by allowing smarter and more cost-effective utility leak abatement programs. It also improves the rationale for utility expenditures and state approvals for utility leak-prone pipe replacement programs. This approach has been piloted with several utilities, with proven results, and is now being offered by commercial utility leak service providers.

Example of This Approach at Work

EDF developed and piloted this approach working in collaboration with New Jersey's largest natural gas utility, Public Service Electric & Gas (PSE&G). Using leak data collected by EDF and Google Street View vehicles equipped with advanced leak detection sensors, PSE&G was able to prioritize leakage repairs as part of a large-scale $905 million pipe replacement program. PSE&G achieved an 83 percent reduction in leakage and replaced one-third fewer miles of gas lines than would have been needed to achieve the same result using industry standard approaches for leak detection.

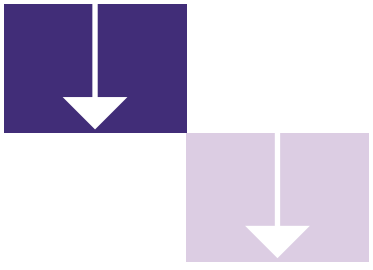
Natural and Working Lands

Maintaining and enhancing a strong land-sector sink is essential to cost-effectively achieving long-term climate goals. Yet the role of the land sector to serve as a carbon sink is increasingly threatened by drought, disease, wildfire, invasive species, and urban development. This challenge is compounded by the fact that land uses vary across ecosystems and are owned and managed by millions of individual farmers, ranchers, foresters, and public and private institutions. Furthermore, land-sector monitoring and measurement tools are grossly inadequate to provide the precision necessary to track changes in this sector with confidence.

Land-sector strategies offer mitigation, adaptation, and sequestration benefits in the same low-cost investment. These mitigation opportunities provide added benefits to farmers and rural communities by improving productivity and cutting down on waste while also improving environmental conditions, including enhancing biodiversity, water quality, and air quality. For these reasons, these opportunities may be attractive to states, cities, and businesses for climate as well as non-climate purposes. However, this sector also illustrates the urgency of bringing the federal government back as a positive partner in curbing climate change; federal farm policy, particularly poorly managed disbursement of agricultural subsidies, significantly impedes improvements in landscape carbon storage.

In total, we estimate that through state, city, and business actions, it is possible to bolster the land carbon sink by 60 Mt CO_2e through implementing the *Climate Action Strategies* scenario and 100 Mt CO_2e by 2025 through the *Enhanced Engagement* scenario. Realizing the full sequestration potential of the land sector is a long-term endeavor requiring immediate scale-up to allow forests and soil carbon sequestration the decades needed to mature and to allow land managers the opportunity to learn and adopt new strategies. In addition, roughly tripling the number of farmers and ranchers who have installed methane digesters from nearly 300 to 1,000 could realize an additional reduction of 10 MT CO_2e by 2025.

ACCELERATING PROGRESS



We estimate that through state, city, and business actions, it is possible to bolster the land carbon sink by

60-100 Mt CO_2e

and reduce emissions from farms and feedlots by

0-10 Mt CO_2e

through implementing the *Climate Action Strategies* and *Enhanced Engagement*

Levers of Change

To date, few actions have focused on this sector, resulting in a significant amount of untapped potential—in part owing to challenges associated with measuring and monitoring carbon flux in the land sector. Achieving land-sector targets requires building strong coalitions across local, state, and regional levels. These levers include:

- Establishing state-level programs that engage state and local governments, businesses, and communities in improving forest management, tree cover expansion, and soil health;
- Preserving forestland by increasing conservation designations and pursuing smart-growth development policies aimed at addressing development pressure;
- Investing in natural and working lands' GHG inventories and other measuring and monitoring programs, including remote sensing, to track progress;
- Collaborating with city officials and residents to preserve and expand urban forests through planting and tree-retention ordinances;
- Enhancing opportunities for land-use and natural resources management at the landscape and watershed level by enabling multi-jurisdictional planning and regulation; and
- Working with farmers by providing incentives and education to promote emissions reductions and sequestration through fertilizer management, crop changes, conservation tillage, and waste reduction.

Much of the potential for impact lies in innovative forest-based interventions, which provide significant carbon storage both above and below ground. States can provide incentives and tools to cities and landowners to help them improve forest management—increasing the carbon productivity of existing forests by managing them for forest health and resilience in the face of inevitable climate change, increasing rotation age in timberlands, actively replanting with resilient, native species after harvest, changing species composition, and other measures. Reforestation of lands threatened by conversion could provide similar increases in carbon sequestration.

Improved agricultural practices such as planting cover crops, converting marginal croplands to grasslands, adopting no-till policies, and improving the productivity of rangelands can

increase the carbon stored in soils (with a technical potential of 200-300 Mt CO_2e of incremental storage per year).[182] Additional measures such as planting higher-residue crops and perennials, adding manure or compost to soils, avoiding burning agricultural slash, and planting legumes in pastures can support GHG reduction goals and sequester carbon. Integrating trees into agricultural systems by establishing forested riparian buffers and wind breaks could sequester several hundred million tons of carbon dioxide per year without significant displacement of food production. Finally, actions by farmers and livestock managers involving better application of fertilizer and treatment of livestock manure can curtail nitrous oxide and methane emissions.

CLIMATE ACTION STRATEGY #9

Develop regional strategies for carbon sequestration on natural and working lands

States and businesses, nurtured with support from coalitions of philanthropies and NGOs, can spark regional initiatives appropriate to the variety of ecosystems that span the American continent. If successful, these regional initiatives could become a focal point for future federal policy, while providing significant benefits for rural economies, agricultural productivity, water resources, habitat, and recreation.

California's existing natural and working lands policy goals are designed to increase carbon abatement within the state's forests, crops, other lands, and soils, resulting in an additional emissions reduction of 15–20 Mt CO_2 by 2030.[183] Through additional action as outlined in this strategy, we conservatively estimate that actions on natural and working lands by California and other states could reasonably drive additional carbon sequestration of 60 Mt CO_2 by 2025. This is an ambitious, but achievable, estimate of this strategy's potential, based on focused studies: In 2005, the EPA's nationwide modeling found that afforestation, reforestation, and forest and agricultural soil carbon management could increase sequestration in 2025 by nearly 90 Mt CO_2 at a nominal carbon price of $1 per ton, and approximately 260 Mt CO_2 at a price of $5 per ton; in addition, a 2016 study found that land management strategies in California alone could bolster carbon sequestration by an incremental 40 Mt CO_2 by 2030.[184]

The Opportunity

Deploying carbon-beneficial practices across a large majority of U.S. forestlands, croplands, and grazing lands will require improved data, new monitoring systems, and scalable incentive mechanisms to elevate deployment from one-off transactions at the farm level or forest level to efficient landscape-level programs. States, local governments, and businesses can lay the foundations for this vision by:

- Establishing state-level programs for forest management, tree cover expansion, and soil health;
- Committing to science-based targets for GHG emissions and removals in agricultural for forest product supply chains; and
- Investing in measurement and monitoring systems to target efforts and track progress.

These actions have the potential to force policy transformations that extend beyond state boundaries. For instance, by increasing the availability of agricultural products meeting climate-related corporate purchasing standards, first-mover states can enable broader adoption of such standards while boosting the competitiveness of in-state producers.

Philanthropies and NGOs can catalyze and support these efforts by conducting outreach and providing technical assistance for policy and program development, engaging landowner groups, developing public–private partnerships for incentive delivery mechanisms, and seed-funding innovative incentive programs with grants and program-related investments.

Example of This Approach at Work

Forests present the largest opportunity for carbon sequestration in the North American land sector, and currently absorb and sequester roughly 10–15 percent of total U.S. carbon emissions each year. Of the 750 million acres of forest in the United States, over half is privately owned; 61 percent of private ownership (265 million acres) is in the hands of individuals and families in tracts over 10 acres in size. Unfortunately, the United States is slowly losing its forests, and many remaining forests are in a degraded state due to unsustainable harvesting, forest health issues including fires, and expanding development.

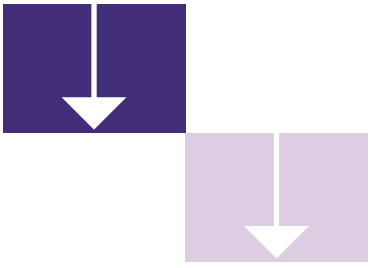
In partnership with a wide range of private landowners, The Nature Conservancy (TNC) of Pennsylvania launched a new program, Working Woodlands, in 2009 to accelerate large-scale forest protection and sustainable management by offering a new value proposition to forest landowners through forest certification and carbon markets. The program targets key landowner segments with a value proposition to protect forests through a working forest easement and agreement, Forest Stewardship Council (FSC) certification, and access to carbon markets. This model can help landowners achieve higher-performing forests, with better growth rates that produce higher-value wood products. Meanwhile, the forest is able to capture and store more carbon through improved forest practices. The additional carbon is quantified, verified, and sold to organizations or companies that wish to offset their carbon footprint, and the majority of the benefits flow to the landowner.

To date, in Pennsylvania alone, over 62,000 acres have been protected, restoration has been accelerated on 5,000 acres, and almost 3.5 Mt CO_2e of carbon will be sequestered over the life of the projects. Now, the model has been implemented in Tennessee, Michigan, and New York; eight other states are in early stages of project development. TNC aims to have 1 million acres in the program by 2025, sequestering an estimated 50 million tons over the life of the projects.

Emissions Limits and Market-Based Policy Frameworks

In concert with other policies and actions described above, states and other real economy actors, where appropriate, should seek to establish comprehensive and binding carbon pricing policies. Not only are such pricing-based frameworks the most comprehensive way to reduce emissions across an entire economy, but they can also ensure that major industrial sectors not otherwise covered by specific |policies contribute meaningfully to climate progress. If optimally designed, these frameworks can constitute effective complements to other, more targeted climate and energy policies. Evaluating existing emissions limitation policies, aspirational targets, and the potential for additional states to take action in the coming years, we estimate that establishing state caps on GHGs could reduce emissions 350 Mt CO_2e under the *Climate Action Strategies* scenario, and 390 Mt CO_2e in our *Enhanced Engagement* scenario by 2025.

ACCELERATING PROGRESS



We estimate that establishing state caps on GHGs could

reduce emissions 350-390 Mt CO_2e

by 2025 (through implementation of the *Climate Action Strategies* and *Enhanced Engagement*).

Levers for Change

A nationwide GHG emissions limit and pricing system would ultimately be more efficient than a patchwork of separate market-based mechanisms, but states can and must step up in the near term to create and scale carbon markets that could grow to encompass additional sectors and larger geographic regions over time. By helping to achieve near-term reductions with the maximum flexibility and the greatest coverage, programs such as emissions caps and trading can demonstrate their effectiveness and value, building political support for economy-wide pollution limits. Real economy actors can:

- Establish statewide, city-wide, or business-wide science-based emissions reduction targets with concrete plans of action for how to deliver on these goals;
- Develop "trading ready" programs that can link up with programs in other states and provide for broader and more cost-effective reduction opportunities;
- Put a price on GHG emissions within specific sectors or across multiple sectors of the economy; and
- Account for the social cost of carbon when making policy and investment decisions.

Photo by Dennis Schroeder / NREL

Market-based policies with enforceable limits on pollution offer the assurance that emissions targets will be met. Failure to accurately and fully account for the costs of carbon pollution is the single broadest market failure contributing to climate disruption. Many other market failures will need to be directly resolved to enable the effective decarbonization of the economy. GHG pricing is not a silver bullet—and in many cases it may be of greatest value when used in conjunction with other policies, for instance, to advance research and development, particularly for relatively costly-to-deploy important early-state technologies. The distribution of revenues generated from GHG pricing also represents a politically and economically efficient tool to accelerate other reforms that reduce emissions and yield co-benefits, as California's experience with its AB 32 program revenues demonstrates.

CLIMATE ACTION STRATEGY #10

Photo by Anthony Zboralski

Form state coalitions for carbon pricing

We estimate that through this Climate Action Strategy, if a set of politically plausible states put into place a binding limit and implementation plan for GHG pollution consistent with U.S. targets under the Paris Agreement, the United States could reduce emissions by more than 350 Mt CO_2e by 2025.[185]

The Opportunity

States, cities, and businesses can aim to establish legally enforceable economy-wide limits on carbon pollution in geographically diverse states, with emissions targets consistent with the near- and long-term reductions necessary to achieve the goals of the Paris Agreement. These policies may be implemented through caps with emissions trading or tax and should look to existing successful policy frameworks such as California's cap-and-trade and Regional Greenhouse Gas Initiative (RGGI) as model policies to replicate. Today eight states have mandatory economy-wide GHG targets, and another eight states and the District of Columbia have aspirational GHG targets (e.g., set by executive order).

Additionally, regions with existing GHG markets can link with new emerging markets or broaden their markets to cover new sectors. For instance, RGGI covers only emissions from electric utilities, but some policymakers are looking at opportunities to expand the protocol to include transportation or establish a cap on transportation emissions under another program.

Finally, these real economy actors have the opportunity to increase the stringency of their existing emissions limits and pricing policies. As a result of the low price of natural gas and the declining costs of renewable energy, as well as policy drivers including federal clean air standards, power companies are on a much lower carbon trajectory than they were even five years ago. That reality creates new opportunities for utilities to make the transition from coal to clean energy while providing cost savings to their customers and setting even more ambitious targets than could have been imagined just a few years ago.

Example of This Approach at Work

Demonstrating how quickly a state can advance ambitious executive action, then Virginia Governor Terry McAuliffe deployed available air pollution control tools and issued an executive directive (on May 16, 2017) to the Department of Environmental Quality (VADEQ) requesting the development of a "trading-ready" regulation to limit carbon pollution from the power sector. After broad stakeholder outreach, a draft regulation awas formally proposed to the state's Air Pollution Control Board (APCB) in the fall of 2017. Governor Ralph Northam continued this climate leadership, shepherding the regulatory process along through his first year in office. A final regulation is expected to be compatible with the successful RGGI program and completed in time to facilitate compliance beginning in 2020.

Summary

As demonstrated in this chapter, states, cities, and businesses have only begun to approach the opportunities to cut emissions while growing the economy. Ambitious actions aimed at cleaning the energy system, restoring natural lands, and targeting non-CO_2 emissions have the potential to put the United States within range of its near- and long-term climate targets. And specific strategies oriented around discrete objectives can help lay the groundwork for increasingly ambitious targets over time.

Ultimately, meeting the goals of the Paris Agreement will require new investment in innovative technologies; rapid deployment of wind, solar, and electric vehicles; expanded policies covering all sectors of the economy; and a broadening of coalitions in support of ambitious climate action. It will require transformations of major sectors, such as the U.S. electric grid, urban buildings, and transportation infrastructure at an unprecedented pace. Leaders must challenge conventional wisdom and identify new strategies that will allow the United States to go farther faster while also inspiring others to heed the call to action. Actions such as those discussed in this section can enable the coalition-building necessary to begin to address the climate challenge.

Photo by Ken Oltmann/CoServ | U.S. Department of Energy, 431 024 010

Chapter 4

Pathways to America's Low-Carbon Future

As detailed in Chapter 2 of this report, on metric after metric (whether electric vehicle sales, coal plant closures, renewable energy deployment, or methane leaks), more actors than ever in the real economy are taking innovative, ambitious, and replicable steps to cut greenhouse gas emissions.

Impressive as these efforts are, it has always been clear that commitments to date will neither ensure that the United States meets its 2025 Paris target nor establish a sufficient foundation for long-term deeper decarbonization. Holding global warming to well below 2 degrees Celsius will require renewed engagement from all stakeholders and across all sectors, including the U.S. federal government. It is equally clear that actors in the real economy have a wide range of opportunities to greatly accelerate decarbonization in ways that will drive U.S. emissions steadily toward meeting both the country's 2025 pledge under the Paris Agreement and the long-term, science-based decarbonization goals. Most of these *Climate Action Strategies* and opportunities for enhanced ambition also deliver substantial public health and economic benefits, such that pursuing them is not only vital for climate security, but beneficial for the organizations that lead the way to a low-carbon future. But change is always difficult; incumbent players with substantial equity in fossil fuel supply chains will resist those assets being stranded and seek to influence national politics to defend their interests.

This puts the United States at a critical juncture. Dedicated leadership from

citizens, governors, mayors, and businesses, combined with the cumulative impact of previous and remaining federal policies, has helped achieve significant emissions reductions to date and set the stage for even greater ambition in the years ahead. Using a novel method to estimate the emissions reductions from real economy actors, we project that through sustained state, city, and business leadership, the United States could come within striking range of meeting the U.S. climate target under the Paris Agreement. Central projections find that the 10 *Climate Action Strategies* and the broader *Enhanced Engagement* scenarios would drive emissions 21 and 24 percent, respectively, below 2005 levels by 2025 (see Figure 4-1). Given the uncertainty that attends all projections of future emissions, the actual potential from real economy actors could be either higher or lower than these central estimates, and these uncertainties are discussed in more detail in this chapter. Moreover, the scenarios indicate that these real economy actions would accelerate the decarbonization of the U.S. economy between 2025 and 2030.

Photo by Dennis Schroeder/ NREL

Discussion of Results

The analysis for this report modeled three scenarios reflecting different pathways of climate ambition and broadly aligned with the levels of ambition discussed throughout this report: *Current Measures, Climate Action Strategies,* and *Enhanced Engagement*. In this analysis, we generated central estimates for these three pathways (or scenarios) that reflect the outcome of one plausible set of core assumptions. We also generated a range of outcomes for each scenario reflecting plausible alternative assumptions about many key uncertainties that could influence future emissions—energy prices, technology costs, economic growth, and land sector sinks.

Modeling of the three scenarios yields central estimates of emissions reductions as follows (see Figures 4-1 and 4-2):

- *Current Measures:* 17 percent below 2005 levels by 2025 (range of 12–22 percent) and 20 percent by 2030 (range of 13–27 percent)
- *Climate Action Strategies:* 21 percent below 2005 levels by 2025 (range of 16–26 percent) and 26 percent by 2030 (range of 18–32 percent)
- *Enhanced Engagement:* 24 percent below 2005 levels by 2025 (range of 20–30 percent) and 32 percent by 2030 (range of 23–38 percent)

Note that economy-wide emission reduction estimates throughout this report have been rounded to the nearest percentage point.

2016 Emissions

Between 2005 and 2016—the latest EPA U.S. GHG inventory—U.S. emissions declined by 12 percent, or nearly halfway to the lower bound of the emissions target under the Paris Agreement.[186] This emissions reduction occurred in tandem with overall economic growth of more than 18 percent during that same period.[187]

Economic Growth 2016–25

Between 2016 and 2025, overall emissions would be expected to grow by some range, with the center of the band at roughly 200 Mt CO_2e, driven by economic expansion and population growth. As discussed in detail below, we assume 1.9 percent annual economic growth and 0.8 percent annual population growth, in line with the April 2018 U.S. Congressional Budget Office (CBO) analysis.

Between 2005 and 2016

U.S. emissions declined by 12%

nearly halfway to the U.S. NDC

Current Measures:

17% below

2005 levels by 2025

Climate Action Strategies:

21% below

2005 levels by 2025

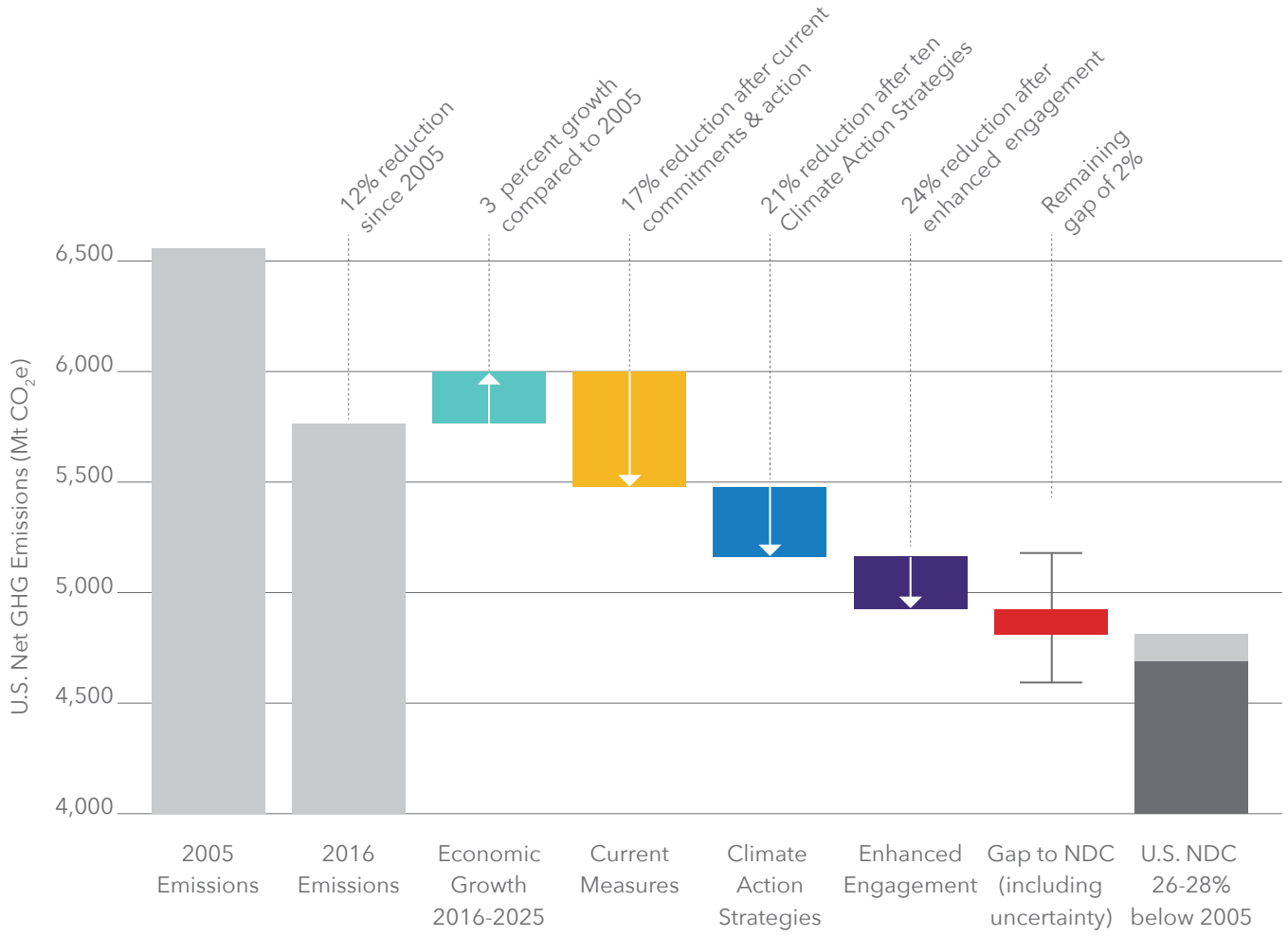
Enhanced Engagement:

24% below

2005 levels by 2025

Photo by Sameer Halai, Co-Founder of SunFunder Solar Company: Gigawatt Global

Figure 4-1: America's Pledge Analysis Demonstrates that States, Cities, and Businesses Can Significantly Cut U.S. Emissions in 2025 (Mt CO_2e)



Climate Action Strategies:

#1: Double down on renewable energy targets

#2: Accelerate the retirement of coal power

#3: Encourage residential and commercial building efficiency retrofits

#4: Electrify building energy use

#5: Accelerate electric vehicle (EV) adoption

#6: Phase down super-polluting hydrofluorocarbons (HFCs)

#7: Stop methane leaks at the wellhead

#8: Reduce methane leaks in cities

#9: Develop regional strategies for carbon sequestration on natural and working lands

#10: Form state coalitions for carbon pricing

Source: Historical emissions data is from the U.S. EPA "Inventory of GHG Emissions and Sinks: 1990-2016"; projected emissions based on modeling from the America's Pledge research team

Current Measures

The *Current Measures* scenario reflects state, city, and business commitments announced as of June 2018. Factoring in this future economic and population growth, current federal, state, city, and business climate actions are projected to result in a 17 percent reduction in U.S. GHG emissions by 2025 compared with 2005, or an additional 5 percent reduction beyond 2016. This outcome would be roughly two-thirds of the way to the Paris Agreement pledge, but would fall short by roughly 600 Mt CO_2e. Plausible alternative assumptions about key factors such as future energy prices, technology costs, economic growth, and land sector sinks create uncertainty in the projections. Considering many of these key uncertainties, we find a broader range of possible reductions in the *Current Measures* scenario, from 12 percent to 22 percent.

Previous modeling exercises have already (and usefully) attempted to project the impact of U.S. actions to date on emissions through 2025 and 2030.[188] Our approach goes one step further. In creating the *Current Measures* scenario, the modeling team incorporated the policies, incentives, and public commitments listed in Chapter 2 as well as several additional existing policies. Because the *Current Measures* scenario assumes full compliance with all existing policies and concrete city and business commitments (including pledged targets), this underscores the importance of ensuring that real economy actors hold true to their pledge, continuing to implement on these policies and targets.

Falling GHG emissions in the power sector have been the primary factor in the reductions to date. Existing policies, such as federal incentives, the Regional Greenhouse Gas Initiative (RGGI), California's cap-and-trade, state renewable portfolio standards (RPS), and technology-based factors (such as growth in natural gas and renewables) continue to drive a substantial reduction (7 percent) from the power sector through 2025 in the *Current Measures* scenario. Owing to the relatively slow pace of fleet turnover, current policies will have a relatively small impact in transportation emissions by 2025. *Current Measures* also deliver modest levels of emissions reductions from non-CO_2 sources (e.g., methane, hydrofluorocarbons), which currently account for 21 percent of net emissions in the United States.

Climate Action Strategies

The *Climate Action Strategies* represent early-start actions that could be readily adopted by already motivated and engaged actors. The *Climate Action Strategies* alone would cut emissions by an additional 4 percent below 2005 levels compared with the *Current Measures* scenario, reaching 21 percent below 2005 levels in 2025 (16–26 percent range). This analysis assumes fully successful implementation of the *Climate Action Strategies* laid out in Chapter 3 while also assuming continuing full implementation of the policies in the *Current Measures* scenario. These actions could lay the groundwork for greater ambition (consistent with *Enhanced Engagement*) in the coming years.

Enhanced Engagement

Expanding from the *Climate Action Strategies* in terms of both the number of engaged real economy actors and the range of their interventions, the *Enhanced Engagement* scenario presents a top-end estimate of what can plausibly be achieved within realistic political and legal limits through state, city, and business actions in the 2025 time frame. Modeling the overall opportunity in the *Enhanced Engagement* scenario, including the broader set of actions defined in Chapter 3, indicates that real economy actors can put the United States within striking range of achieving the original Paris Agreement target. The central projection for the *Enhanced Engagement* scenario leads to a reduction of more than 24 percent below 2005 levels in 2025.

Current federal and real economy commitments, combined with market forces, will

drive U.S. emissions to 17% below 2005 levels by 2025, roughly 2/3 of the way to the original U.S. target

Gap to NDC

The gap between the *Current Measures* scenario and the lower bound of the U.S. nationally determined contribution (26 percent) would be substantial—9 percent of total U.S. emissions, or approximately 600 Mt CO_2e. The actions led by real economy actors in the *Enhanced Engagement* scenario narrow that gap substantially, to 100 Mt CO_2e (see Figure 4-2). This would be within striking distance of the Paris pledge, making the 26 percent threshold achievable shortly thereafter. Any number of combinations of federal actions could resolve the remaining gap, though time is short to 2025 and national political outcomes are difficult to predict. One significant finding of the modeling is that these actions will continue (and even accelerate) emissions reductions through 2030.

This result is compatible with the emissions projections presented by the Obama Administration to the global community in its 2016 Biennial Report to the United Nations Framework Convention on Climate Change (UNFCCC). They demonstrate that the U.S. target for 2025 is a stretch goal, but achievable with concerted effort. But whereas the Obama Administration's 2025 projections assumed continued, and indeed enhanced, federal engagement in the period from 2017 through 2025, our analysis demonstrates that during the current hiatus in federal leadership, real economy actors can maintain the momentum of the nation's decarbonization trajectory for 2025 and beyond.

Furthermore, the annual rate of decarbonization in the *Enhanced Engagement* scenario is 1.6 percent between 2016 and 2025, accelerating to 2.1 percent for 2025–30. This is substantially higher than the historical 1.1 percent rate for the period 2005–2016.

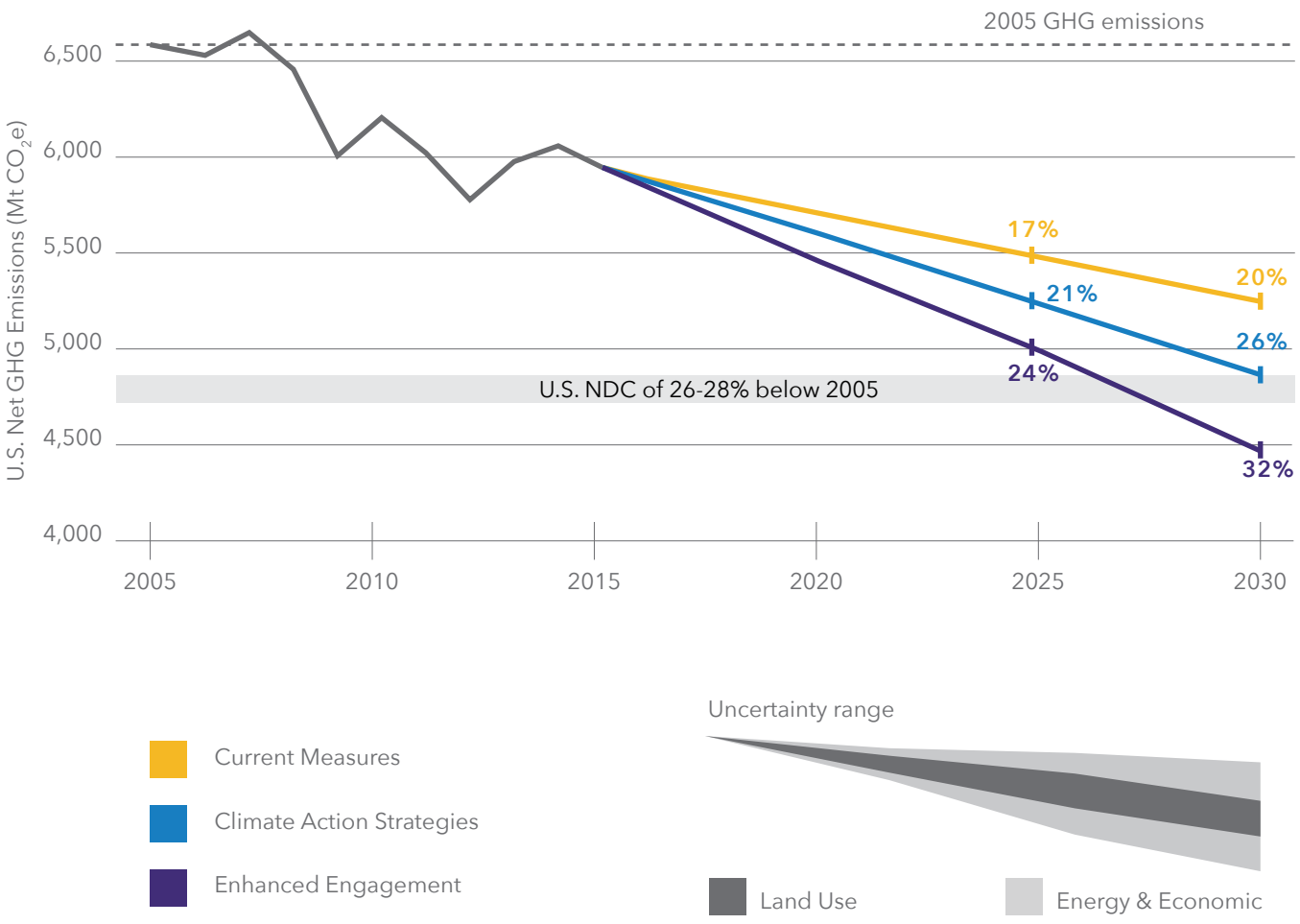
Photo by Michael Nothum

The post-2025 trajectory approaches the rate of decarbonization needed to hit 80 percent below 2005 levels by 2050 (2.3 percent).[189] This accelerated rate of decarbonization is attributed to the fact that several sectors of the economy—transportation and buildings, for example—have long lead times for capital turnover. Policies put in place between now and 2025 will deliver the bulk of their emissions reduction benefits only after 2025, and will continue to have an effect after 2030 as buildings, fleets, industrial processes, and other infrastructure components are modernized.

Federal reengagement undertaken as rapidly as possible will be essential in sustaining and accelerating the needed breadth and depth of emissions reductions across all sectors of the U.S. economy, both to close any remaining gap in 2025 and for long-term decarbonization.

As we move onward from the Paris pledge, this momentum in turn sets the stage for more rapid decarbonization between 2025-30

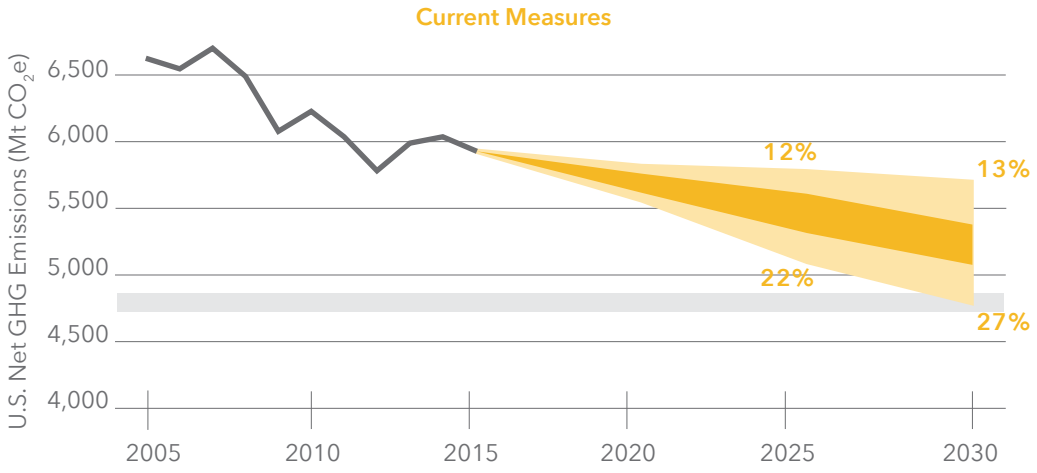
Figure 4-2: Progress Toward Near- and Long-term Climate Goals Varies Across the Three Scenarios (Mt CO_2e)

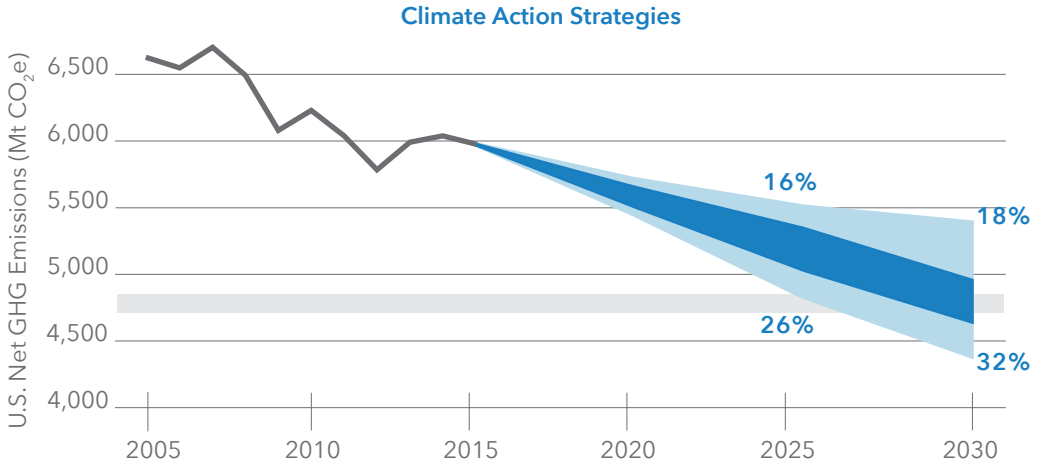


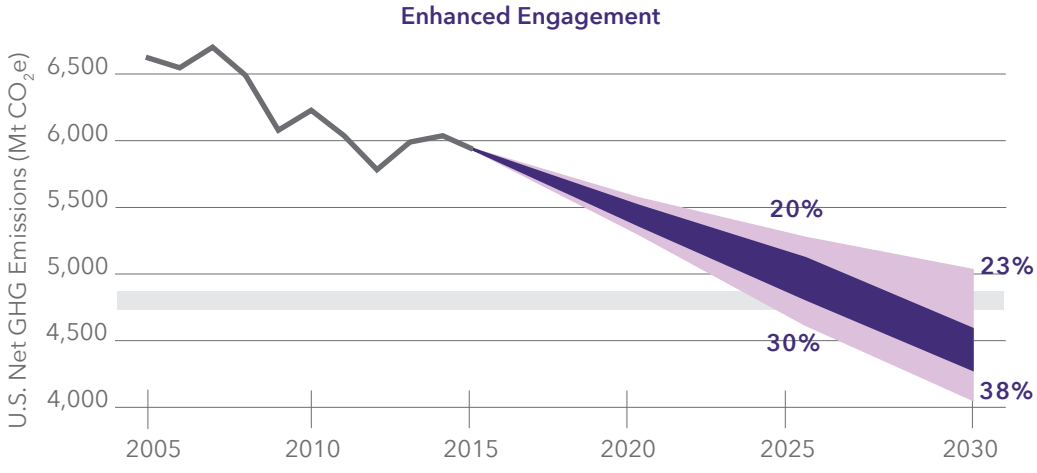
Source: America's Pledge modeling results

Comprehensive Cross-Sector Approach

This analysis demonstrates the potential for reductions across all sectors of the economy (see Figure 4-3). Although some sectors realize only modest emissions reductions by 2025 under the *Enhanced Engagement* scenarios, action across all areas is an important component of a comprehensive emissions reduction strategy. While some actions have relatively modest gains in early years, they help lay the groundwork for deep decarbonization by building cumulatively. For example, due to the slow turnover time of vehicles and the interaction between state policies and federal vehicle standards, investments in electric vehicle infrastructure may be slow to generate immediate emissions reduction benefits. However, investment today will help ensure that these vehicles proliferate in the decades to come. Building codes and land sector activities, which are available and rapidly scalable now, also deliver increasing impacts over time. Therefore, readers should not interpret the quantitative results presented here in isolation but should also take into consideration the complementary suite of enabling policies and programs that will help achieve deep decarbonization.


Current Measures
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
12%
13%
22%
27%


Climate Action Strategies
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
16%
18%
26%
32%


Enhanced Engagement
U.S. Net GHG Emissions (Mt CO_2e)
6,500
6,000
5,500
5,000
4,500
4,000
2005
2010
2015
2020
2025
2030
20%
23%
30%
38%

Modeling the Scenarios: Approach, Assumptions, and Uncertainty

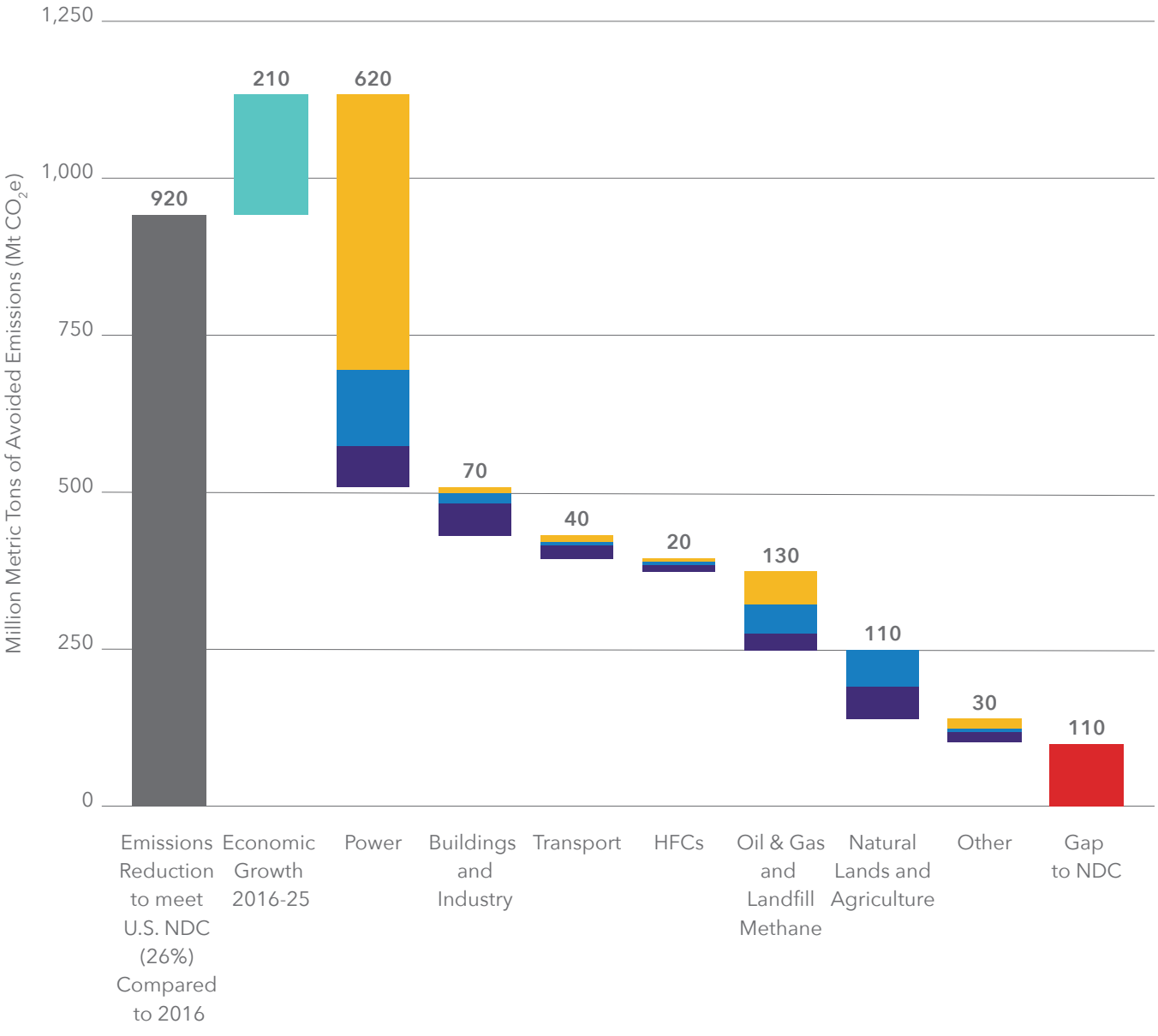
Modeling State, City, Business, and Other Real Economy Climate Action

Quantifying the overall implications of state, city, and business action presents a methodological challenge. Actions take place across different scales, from cities with narrow or broad impacts across their metropolitan area footprints to states with regional power imports and exports to businesses that themselves may operate across multiple U.S. jurisdictions and with globally integrated supply chains. Many of the measures estimated in our analysis interact with one another, in some cases complementing each other, and in other cases overlapping or even counteracting each other. Impacts of one action may completely subsume the impacts of another action.

To address these challenges, this report uses a novel approach for understanding the implications of city, state, and business actions (as outlined on Page 44 and detailed in the *Technical Appendix*). It combines bottom-up, granular accounting of the multiplicity of real economy actions across the United States (using the Aggregation Tool for modeling Historic and Enhanced Non-federal Actions [ATHENA] model) with top-down analysis (using the Global Change Assessment Model for the United States of America [GCAM-USA] model) to understand the cross-linkages across the U.S. and global economy and energy systems, enabling an estimate of the overall implications for all six GHGs. The report controls for double-counting and cross-sectoral interactions by employing the ATHENA and GCAM-USA tools designed—in part—to address explicitly address those challenges. Integrating aggregated, bottom-up inputs from ATHENA into the comprehensive, energy-economic integrated assessment modeling framework of GCAM also allows for an analysis of how complementary actions, such as increasing the use of electric vehicles and simultaneously promoting the use of low-carbon electricity, intersect and interact in the real world.

As with any other modeling analysis, the results of this exercise should be interpreted carefully. Importantly, 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. The key is to select a modeling approach that best addresses the need, and to discuss the assumptions and uncertainties clearly. This is the approach we take in this *Fulfilling America's Pledge* report.

Figure 4-3: Achieving Full Potential Entails Actions Across All Major Economic Sectors and GHG Gases (Mt CO_2e in 2025)



Source: America's Pledge modeling results

Scenario Assumptions and Uncertainty

To aid readers in interpreting the modeling outcomes described in this chapter, Figure 4-3 provides a detailed breakdown of assumed emissions reduction potential by sector and by scenario. Table 4-1 complements Figure 4-3 by providing an overview of the key assumptions used to define each of the scenarios in this chapter. More information is provided in the *Technical Appendix*.

Table 4-1: Key Climate Action Levers and Associated Potential

Sector	2005 Emissions ($MtCO_2e$)[1]	Change in Sector Emissions in 2016 relative 2005 ($MtCO_2e$)[2]	Percent Change in Sectoral Emissions 2016 Compared to 2005[3]	Scenario	Change in Sector Emissions in 2025 by Scenario($Mt CO_2e$)[4]	Total Feasible In-Sector Emissions Reductions 2005-25 as % of 2005[5]
 Power	2,439	-593	-24%	Current	-440	-50%
				Strategies	-120	
				Enhanced	-60	
				Total	-620	
 Buildings	1,696	-160	-9%	Current	-10	-14%
				Strategies	-10	
				Enhanced	-50	
				Total	-70	
 Transportation	1,904	-99	-5%	Current	-10	-7%
				Strategies	-10	
				Enhanced	-20	
				Total	-40	
 HFCs	103	+56	+54%	Current	-5	+35%
				Strategies	-5	
				Enhanced	-10	
				Total	-20	

Oil & Gas and Landfill Methane[7]	469	-20	-4%	Current	-50	-32%
				Strategies	-50	
				Enhanced	-30	
				Total	-130	
Natural & Working Lands and Agricultural Emissions[8]	-211	+57	+26%	Current	0	-25%
				Strategies	-60	
				Enhanced	-50	
				Total	-110	
Total Net GHG Emissions	6,589	-795	-12%	Current	-530	-24%
				Strategies	-250	
				Enhanced	-240	
				Economic Growth[9]	+210	
				Total	-810	

Notes:

1. Sector emissions based on 2016 U.S. EPA GHG inventory estimates. Some small sectors are omitted and therefore sum does not add to total net GHG emissions. As some sectors are estimated and calculated, values may differ slightly from EPA GHG inventory.
2. Change in sector emissions between 2005 and 2016 calculated based on 2016 U.S. EPA GHG inventory estimates.
3. Percent sectoral emissions reductions between 2005 and 2016 as % of 2005 sectoral emissions (based on 2016 U.S. EPA GHG inventory)
4. Total sector emissions reductions across three scenarios modeled by America's Pledge relative to a 2025 reference scenario.
5. Total feasible in-sector emissions reductions quantified as the total emissions reductions between 2005 and 2016 (based on U.S. EPA GHG inventory) and modeled emissions reduction between 2017 and 2025 (based on America's Pledge analysis), compared to the 2005 baseline.
6. Direct emissions from residential, commercial and industrial sectors. Does not include indirect emissions associated with electricity consumption which is included in power sector. Does not include industrial-related methane and HFCs included in other sectors.
7. GCAM assumes significant growth in methane emissions between 2005 and 2025. While total emissions grow, actions taken by real economy actors has the potential to cut emissions by over 30% against below 2005 levels. Agricultural methane included in Natural and Working Lands
8. Net change in emissions inclusive of land-sector sink and agricultural emissions. Both land-sector sink diminished in magnitude and agricultural emissions increased between 2005 and 2016, resulting in net increase in emissions of 26%.
9. Total GHG emission increases by 210 Mt CO2e in the GCAM reference scenario from 2016 to 2025. Emission reductions are measured relative to this scenario.

Table 4-2: Achieving Full Potential Entails Actions Across All Major Economic Sectors and GHG Gases (Mt CO_2e in 2025)

Sector	Scenario	Scenario Assumptions
 **Power**	Current	Federal wind and solar incentives through 2020/2022; state RPS targets; 104 cities with RE goals; all announced coal and uneconomic coal units retire (69 GW by 2025).
	Strategies	Extend state RPS targets through 2025/2030, while states with voluntary targets achieve and modestly expand targets; Additional cities in open markets achieve 50% RE targets by 2030; Additional uneconomic coal plants close, including plants in traditionally regulated markets (94 GW by 2025)
	Enhanced	States with an RPS set ambitious new targets; States without an RPS adopt a conservative mandate; A greater number of uneconomic plants close (128 GW by 2025)
 **Buildings**	Current	All 26 states and 56 cities with stated efficiency targets meet the target
	Strategies	40 additional cities with a population over 100,000 and that 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 model year 2025; CA and 9 other states implement 2025 ZEVR targets; 34 cities with EV procurement goals achieve target; States and cities (CA, VT, and WA and 32 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	California achieves its goals under its March 2018 target, SNAP program, and Refrigerant Management Program; 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
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 California, Colorado, New Mexico, Ohio, Pennsylvania, Utah, and Wyoming; 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, inline with achievable source-specific best practices.
Natural Lands and Agriculture	Current	Land sector sink remains constant through 2030
	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 even further, such than nationally, total sequestration reaches 100 Mt CO_2 by 2025. Roughly tripling the number of farmers and ranchers who have installed methane digesters could realize an additional reduction of 10 Mt CO_2e by 2025.
Carbon Pricing / GHG Targets	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 and projected reductions
	Enhanced	Additional states achieve reductions in line with RGGI for power sector and Paris Agreement for transportation sector

** Economy-wide actions cut across all major sectors of the economy and therefore are not modeled or quantified separately from sector-specific policies, commitments, and other actions.*

This report uses a novel approach for understanding the implications of city, state, and business actions, combining a bottom-up, granular accounting of real economy actions with a top-down analysis to understand the cross-linkages across the U.S. and global economy and energy systems.

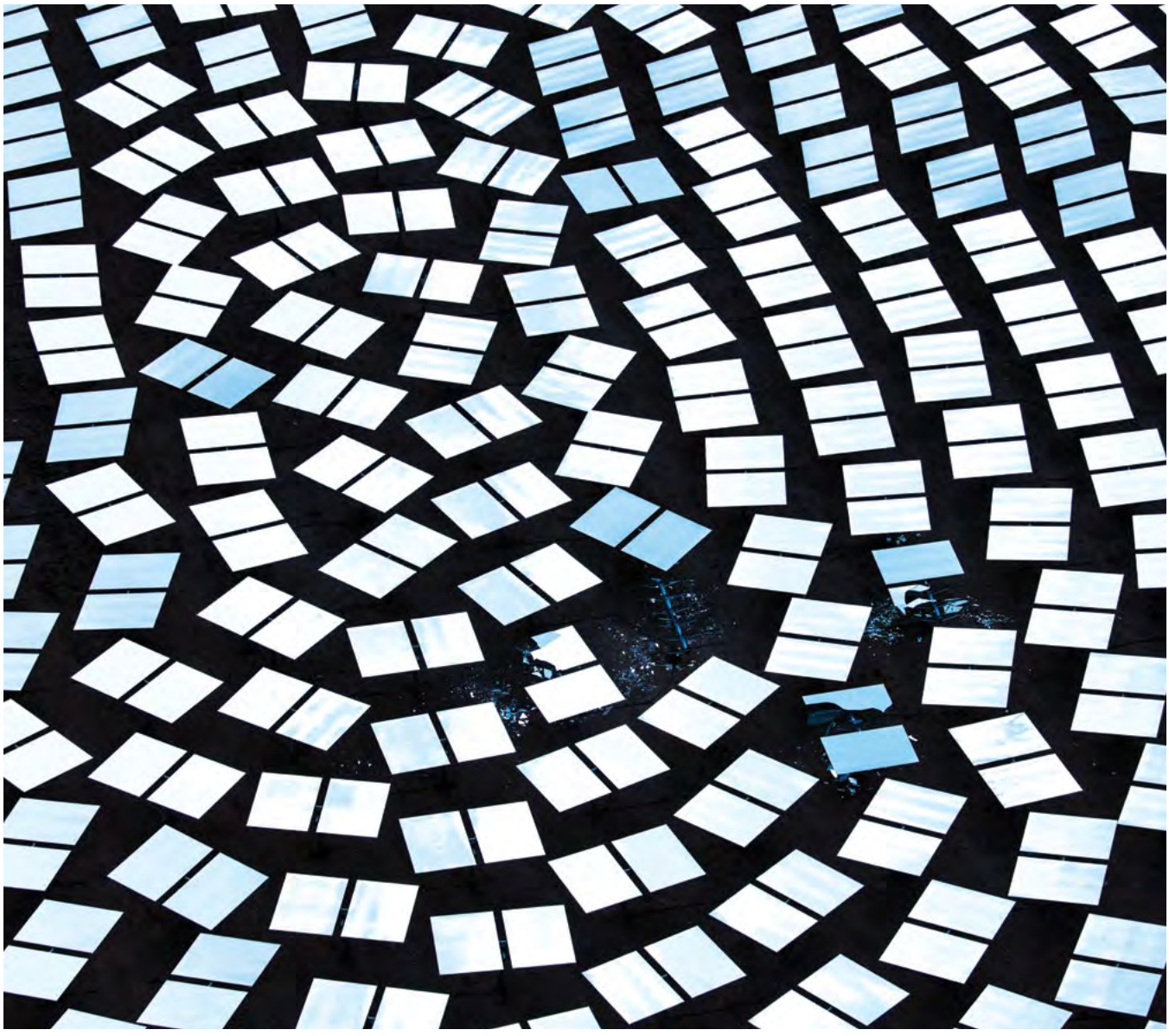


Photo by Dennis Schroeder / NREL

Economic and Energy System Assumptions and Uncertainty

The modeled outcomes in this analysis are strongly influenced by forces and factors that are independent of the real economy actions described in the scenarios. These include broad demographic and economic trends, technology trends, and the prices of key energy commodities. The assumptions used to define the central estimates for the scenarios in this study are provided in Table 4-2.

Although these assumptions were chosen to be plausible central estimates given what we know today, actual outcomes will likely vary. For example, in the future, GDP might grow at a higher or lower rate, or fossil fuel prices might trend higher or lower. In order to allow others to understand the implications of different plausible future pathways, different assumptions for such variables were tested using what is called a sensitivity analysis, which is also summarized in Table 4-2. This sensitivity analysis explores a range of uncertainties in the inputs for these primary technology, demographic, and macroeconomic assumptions. Four sources of uncertainty were taken as the focus of this exercise: economic growth, fossil energy prices, clean energy technology costs, and the nature of the U.S. land use sink.

Table 4-3: Economic and Model Assumptions and Sensitivities

Scenario	Current Measures Scenario	Sensitivity	AEO 2018 Comparison[21]	BNEF NEO 2018 Comparison
Economic Growth	Overall GDP[1] growth at 1.9%/yr	1.4%/yr (low growth) 2.4%/yr (high growth)	2.1% (reference) 1.4%/yr (low economic) 2.4%/yr (high economic)[12]	2.0% (median) 1.7% (low) 2.3% (high)
Population Growth	Overall population[2] growth at 0.8%/yr	No sensitivity	0.7%/yr (reference) 0.6%/yr (low economic)[13] 0.8%/yr (high economic)[13]	0.7% (Med) 0.6% (Low) 0.7% (High)
Fuel Prices	Oil prices[3] grow at 2.5%/yr	1.6%/yr (high resources) 3.3%/yr (low resources)	4.7%/yr (reference) 3.3%/yr (high resources) 5.4%/yr (low resources)[14]	Expect Brent crude oil price to decline out to 2030
	Gas prices[4] grow at 0.8%/yr	-4.3%/yr (high resources) 4.4%/yr (low resources)	4.2%/yr (reference) 0.9%/yr (high resources) 9.1%/yr (low resources)[15]	Gas prices grow at 2.8%/yr in the reference
Land Use	Terrestrial carbon sink assumed to be largely unchanged relative to today[5]	Uncertainty[6] set at +150 $MtCO_2e$ and -150 $MtCO_2e$	-	-
Electric Vehicles	Electric LDVs are price competitive with internal combustion engines by 2030[7]	Modeled as explicit policy measures	Sales of electric vehicles grow 11 times by 2030, with decreasing prices[16]	-
Solar Power	Solar PV costs[8] drop to $737/kW by 2025	Modeled as explicit policy measures	Average capacity-weighted LCOE is $59.1 /MWh by 2022[17]	Solar PV costs drop to $737/kW by 2025
Wind Power	Wind Turbine (class 5)[9] costs drop to $1357/kW by 2025	Modeled as explicit policy measures	Average capacity-weighted LCOE is $48 /MWh by 2022[18]	Wind Turbine (class 5) costs drop to $1357/kW by 2025
Power Plant Retirements	Coal[10]: 3.4%/yr	Modeled as explicit policy measures	Coal[19]: 3.3%/yr	See power sector assumptions
	Nuclear[11]: 0.7%/yr	Modeled as explicit policy measures	Nuclear[20]: 0.9%/yr	See power sector assumptions

Data Sources for Table 4-2:

All data, unless otherwise noted, is from 2015 to 2025.

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

These uncertainties capture some, but not the full range, of the potential outcomes. One reason for this is the large possible range of all forces that could affect future emissions. For example, there could be different relationships between energy demand and economic growth, levels of end-use electrification, and nuclear power plant retirements, all of which could affect the results. Lower energy demand would generally lower emissions; less electrification would reduce emissions from electricity but would increase emissions from end-uses; faster nuclear retirements would increase emissions. Higher prices for oil would encourage the sale of electric vehicles but increased production of associated gas could also have repercussions for natural gas prices and hence the relative pricing and deployment of gas-fired power, coal, and renewables.

A second consideration when interpreting these scenarios is that they are dependent on two models—ATHENA and GCAM-USA—that are simplified representations of a complex reality. The simplifications inherent in modeling necessarily lead to differences between projections of the future and the future that actually comes to pass. Moreover, in aggregating city, state, and business actions to be incorporated into the models, a number of assumptions must be made, many of which can have important implications for the results. These caveats should be taken seriously in interpreting the precise numerical estimates and uncertainty ranges in this chapter. The best way to balance these considerations is to note that although a study such as this one cannot provide a precise view of the future, it can provide insight into the range of possibilities that might emerge from real economy actions and the potentially substantial value and impact of those actions.

A Note on Future National and International Ambition

This report focuses primarily on the impact of real economy actors on the near-term emissions trajectory of the United States over roughly the next decade. However, we know that in the medium to long term, in embracing the opportunities for a cleaner, economically vibrant, and climate-safe future, emissions reductions must continue to decline at a rapid rate by 2050 and beyond. As this report demonstrates, states, cities, businesses, and other actors are taking significant actions today that are building a cleaner and healthier economy and also driving down the overall emissions trajectory in the United States. But the speed and scale of the transition required to address climate change will require all levels of government, as well as broader civil society, to fully participate. The positive economic and health benefits from accelerating the clean energy transition will increasingly be attractive to an ever-broader set of American constituents and voters. Federal reengagement with climate change, driven by such political forces, would build on progress by states, cities, and businesses, enabling the United States to more effectively and quickly track toward a long-term, accelerated decarbonization trajectory.

Moreover, greater ambition in the future that goes beyond even the three core scenarios of this report is possible and ultimately necessary if countries are to meet the long-term targets of the Paris Agreement. Such shifts include the aforementioned changes in the national political landscape leading to renewed federal leadership, but also faster-than-expected technological advancement, or international impacts on U.S. technology advancement and decarbonization. Alternatively, continued investment in renewables and clean vehicles by international actors such as China could lead to lower-than-expected technology costs, making these resources more economically attractive to consumers. Other policies and programs enacted by international actors could benefit U.S. abatement, including helping U.S. real economy actors replicate initiatives domestically. In addition to creating new, real climate action as outlined in the three core scenarios of this report, states, cities, and businesses can help demonstrate proof of concept for policy interventions that could be replicated at a national level. And real economy actors can help build a broader umbrella of support for climate policies that will build momentum for federal intervention.

Finally, although the analysis developed and presented in this report focuses on the United States, the concepts and methods are applicable in other country contexts. Of course, such analysis is predicated on sufficiently detailed data and assessments of the commitments of such actors, as well as national inventories and other elements important to the global community as the pledge and review process of Paris is implemented more fully. As countries embrace the potential of their domestic actors to help raise ambition and implement real actions, the analytical approach developed here can be used to support the efforts of this increasingly diverse set of actors and may have relevance for countries considering how best to understand and account for national actions and potential impact driven by the real economy.


THIS IS A SILENT ENERGY SYSTEM
ALWAYS ASSUME LIVE VOLTAGE IS PRESENT
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Chapter 5

Conclusions and Implications

The vision of the Paris Agreement—as informed by the best science and analysis—calls for broad, rapid, and significant engagement across all parts of society to reap the benefits of an advanced, innovative, low-carbon, climate-resilient future, one fueled by clean jobs and economic growth.

And in the United States, states, cities, businesses, and other real economy actors have embraced this future—helping drive better outcomes for their own citizens and business operations. Although they are being driven in part by necessity, in light of the lack of national-level leadership on climate change, these real economy actors have embraced action for the benefit of their own economies while helping bend the emissions curve downward. This renewed climate leadership of states, cities, and businesses has already made an impact, and this impact will only grow as additional action is taken—in three ways:

Inspiring through Demonstration

First, the emphatic embrace of climate action opportunities from real economy actors continues to inform and inspire broader action across the United States economy. These initiatives reflect enthusiasm from constituents, businesses, and governments for the opportunities provided by climate and energy leadership, and their example provides additional evidence of the broad-based economic, health, and environmental benefits of taking action.

Deploying Real Solutions to Change the World Today

Second, the commitments and actions taken by states, cities, and businesses are already making a significant impact on the U.S. emissions trajectory, and expanding the set of actors and actions can drive emissions down even further. Although the long-run trajectory of decarbonization in the United States will require participation by all actors and all levels of government, the U.S. democracy has enabled and encouraged climate action to continue during this period of disengagement at the national level.

Building the Groundwork for Future Progress

Third, the implementation of commitments and ambition by real economy actors allows for more significant reductions over time. This report has demonstrated that essential deep decarbonization (80 percent or more by 2050) can be led by the bottom-up efforts of real economy actors—but only with deep collaboration and engagement. The groundswell of action will set the tone for the future of climate ambition and will make possible more ambitious future efforts. Indeed, because of the important work that can be carried out in the near term by states, cities, and businesses, a new administration that understands the significance of the Paris Agreement as a global climate governance mechanism would find supportive and ready partners on climate policy.

Photo by Abbie Trayler-Smith / Panos Pictures / Department for International Development

Our success will ultimately depend on the commitment of these leaders to implement their pledges and adopt more ambitious policies in the coming years. Importantly, while the current political situation in the United States is unique, the approach we are developing, based on bottom-up and diversified actions across the economy, can serve as a blueprint for implementing climate action in other places—for example, as countries identify opportunities to engage the real economy and deliver greater climate ambition. This is critical as the world seeks to dramatically bend the curve on the current trajectory of GHG emissions and close the emissions gap.

America's Pledge is just the beginning of a new phase of America's climate action, a moment that not only reflects the work and potential of real economy actors in the United States, but is also a way of inspiring and integrating climate action across all sectors of society as the world moves to a cleaner, healthier, more economically vibrant, and more climate-friendly future.

America's Pledge is just the beginning of a new phase of U.S. climate leadership

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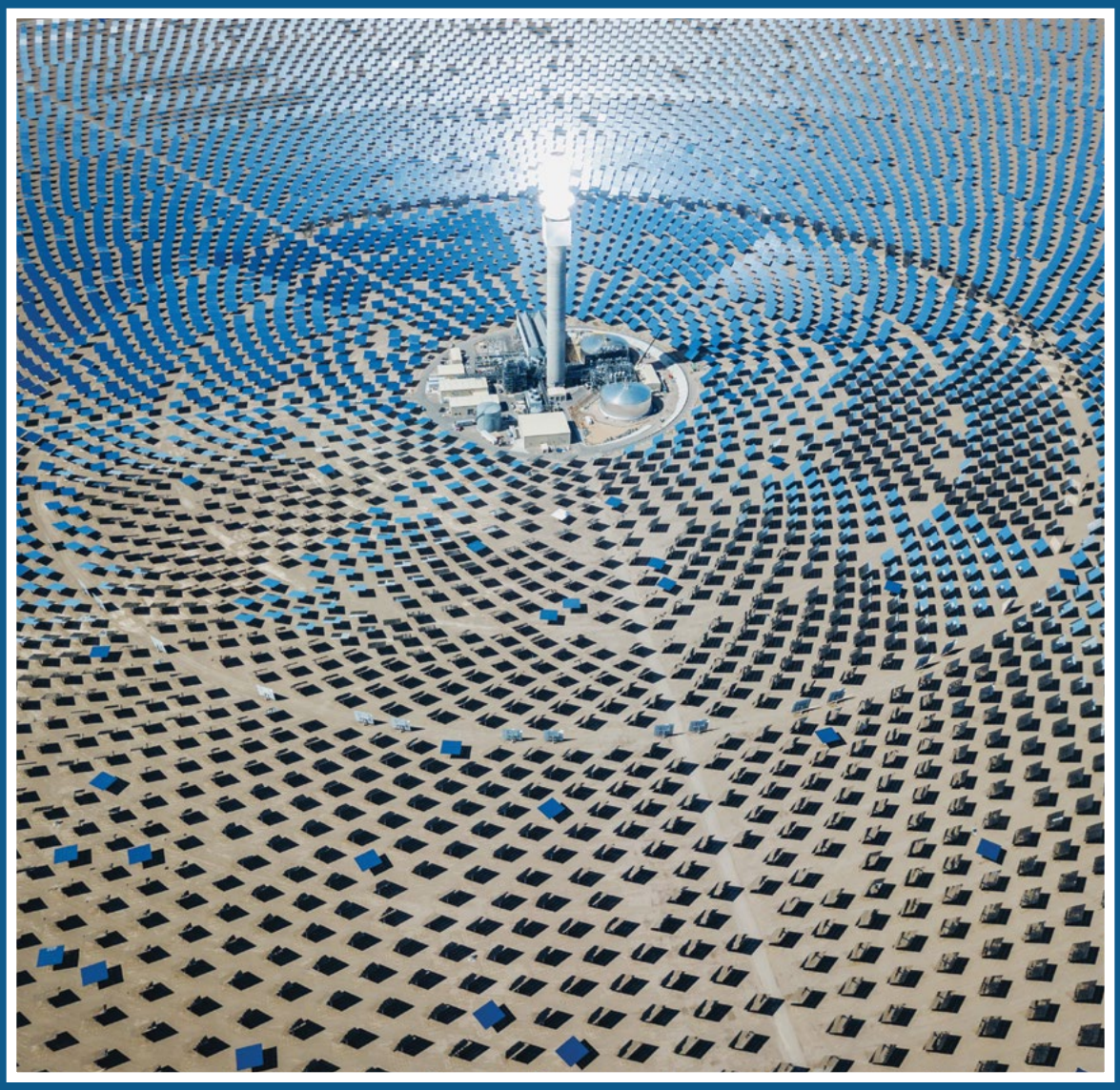


Technical Appendix

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*.

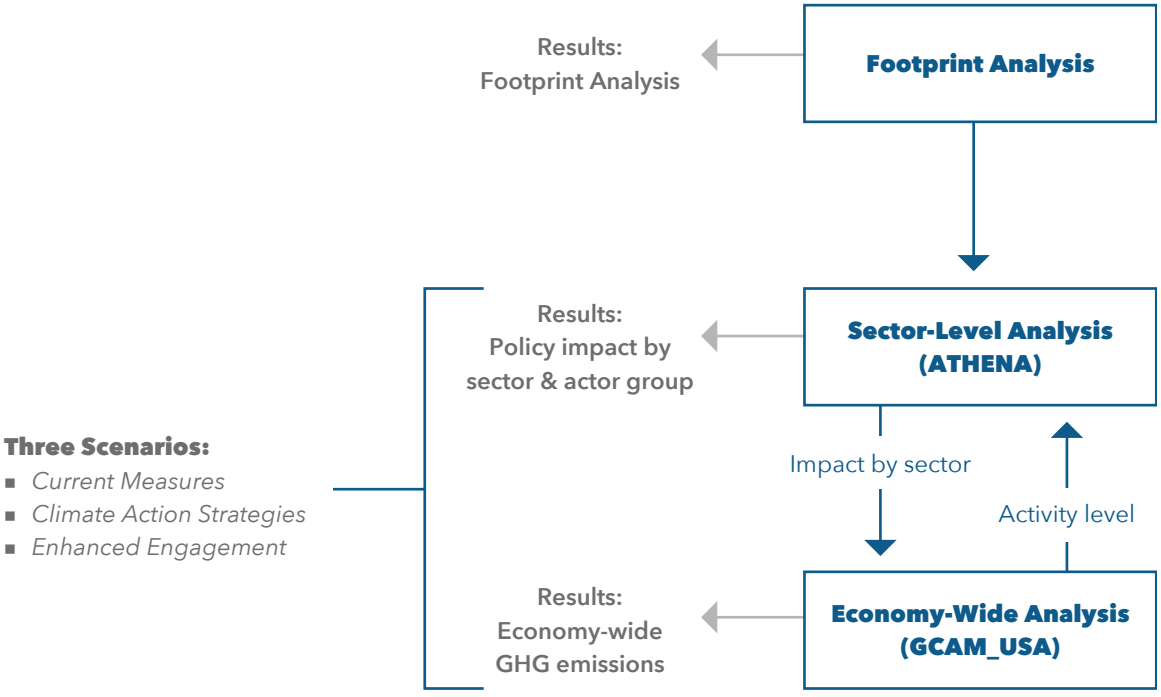
Second, we estimated the impacts of current commitments, along with the impacts of the *Climate Action Strategies* and *Enhanced Engagement* scenarios, and aggregated those impacts at the sector level. At this step in the analysis, we measured activity data appropriate to the sector, for example, TWh 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.

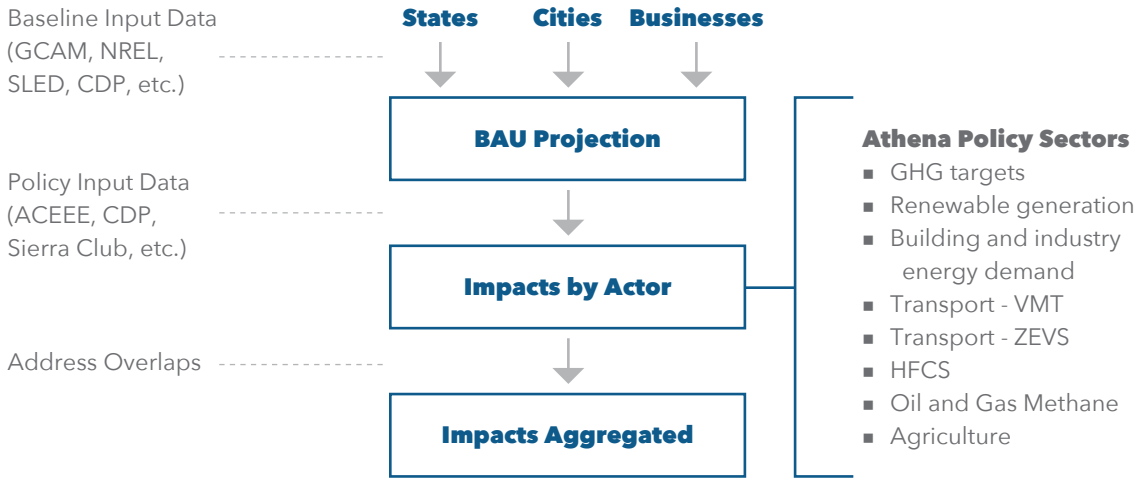
The outputs of the sectoral analysis and modeling are found in Chapters 2 and 3 of *Fulfilling America's Pledge*. The subsequent sections only describe methods and assumptions relied upon to establish the universe of actions and estimate sector-specific impacts by sector, prior to being modeled in GCAM, 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.

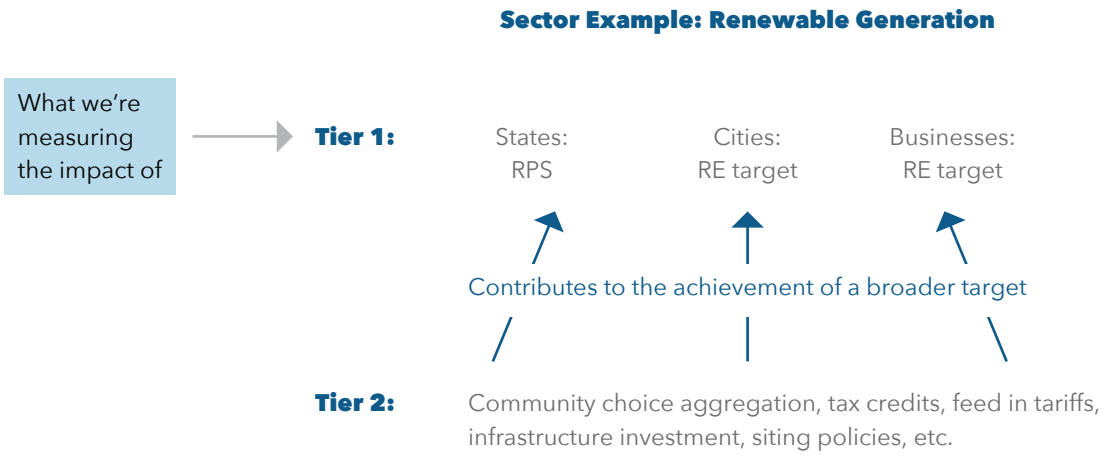
Figure 2. ATHENA Modeling Flow



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



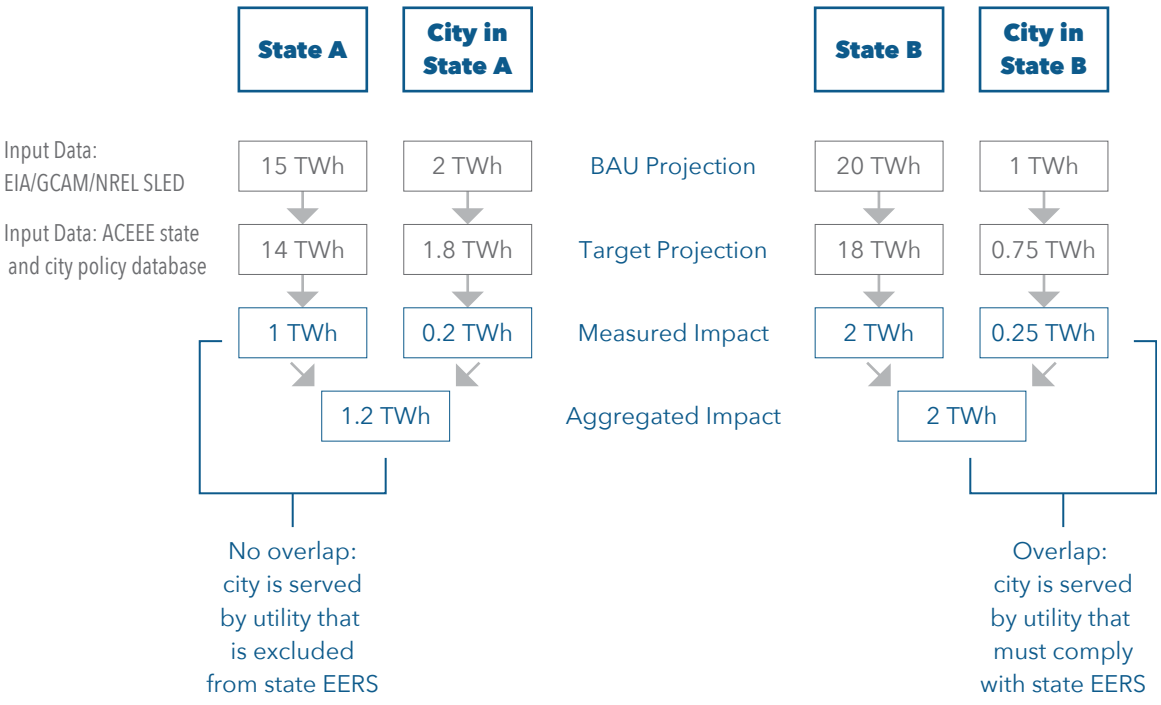
While Tier 1 actions may often subsume actions characterized as Tier 2, this is not always the case. For example, significant infrastructure investment or local siting policies may occur within regions or communities without top-down tier 1 targets, but which nonetheless will lead to increased renewable 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.

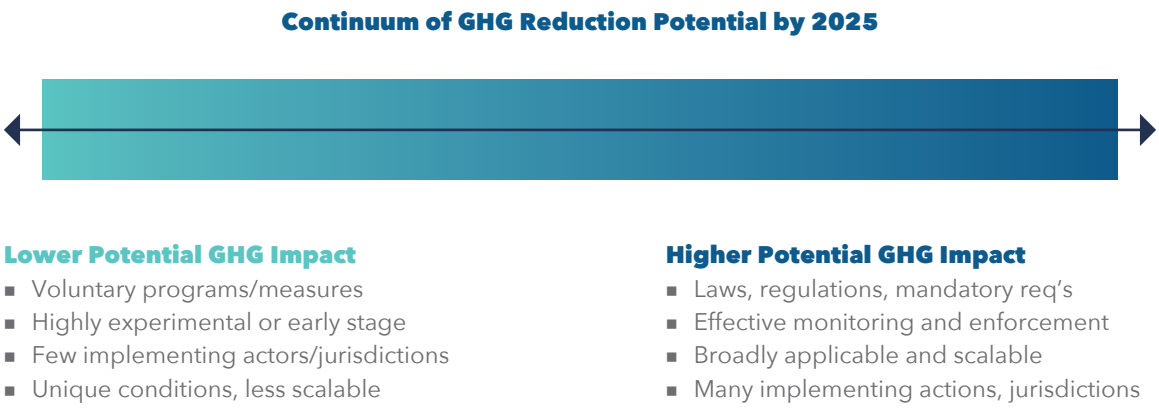
- **States with aspirational GHG targets** (e.g., by executive order (EO)):
  - Colorado: 26% below 2005 levels by 2025 (EO, statewide GHGs).
  - District of Columbia: 26-28% below 2005 levels by 2025; 50% below 2006 by 2032 (EO).
  - Illinois: 1990 levels by 2020 (EO).
  - Maine: 10% below 1990 levels 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.

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; 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; 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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Collaboration and deep engagement by cities, states, and businesses – within realistic legal and political constraints –can drive down overall U.S. greenhouse emissions to within range of America's pledge for 2025 under the Paris Agreement.