RHODIUM GROUP

ENERGY & NATURAL RESOURCES

Taking Stock 2017: Adjusting Expectations for US GHG Emissions

Since 2014, Rhodium Group has provide an independent annual assessment of US greenhouse gas (GHG) emissions and progress towards achieving the country's international climate commitments. In this, our 2017 "Taking Stock" report, we update our forecast to include policy changes under the Trump Administration, new EPA GHG inventory estimates, and energy market and technology developments over the past year. We find that under current policy, the US is still set to come within striking distance of its Copenhagen target of a 17% reduction below 2005 levels by 2020. But absent new policy (whether at the federal or state and local level), the US is on course for a 15-19% reduction in GHG emissions by 2025 – considerably short of its 26-28% commitment under the Paris Agreement. There is still time to correct course, whether at the subnational level over the next couple years or through new federal policy a little further down the road. But with President Trump's election, it will certainly be a tougher lift.

May 24, 2017

Kate Larsen
kmlarsen@rhg.com

John Larsen
jwlarsen@rhg.com

Whitney Herndon
wjherndon@rhg.com

Shashank Mohan
smohan@rhg.com

Trevor Houser
tghouser@rhg.com

INTRODUCTION

What a difference a year makes. In our last installment of Taking Stock, we summarized a raft of new policies adopted or proposed by the Obama administration as part of the Climate Action Plan. Since then, President Trump has made good on his campaign promise to undo his predecessor's climate agenda, signing an Executive Order (EO) March 28 that directed agencies to rescind any pending rules and regulations related to the Climate Action Plan and instructed EPA to review and potentially withdraw Obama's signature rule, the Clean Power Plan.

Now the Trump Administration is considering whether to fulfill a second campaign promise to "cancel" the Paris Agreement. After much internal back and forth, the administration has indicated it will make a decision on the fate of US participation after President Trump's trip to the Group of 7 (G7) meetings later this week. Contributing to the unease among some administration officials is the likely inability of the US to meet its Paris commitment while fulfilling Trump's campaign commitment to tear up the Climate Action Plan. International negotiating partners are also trying to gauge the impact of Trump's policy agenda on America's emissions trajectory, and state, city and corporate actors are exploring opportunities to mitigate the damage.

Of course policy alone doesn't determine a country's GHG emissions, a combination of policy, economic, technological and market factors do. Recent developments in clean energy technology, energy efficiency, and oil and gas production as well as economic growth dynamics are also shaping America's emissions future.

In this edition of Taking Stock, we present US GHG emissions projections that account for these recent economic, market and technology developments as well as changes in federal and state policy since the end of 2015. This is a forecast based on policies on the books today, not an assessment of US emission reduction *potential*. As we note above, a lot can happen in a year, let alone a decade. Changes if state and local policy either independent of the new administration or in direct response to it, will shape future US

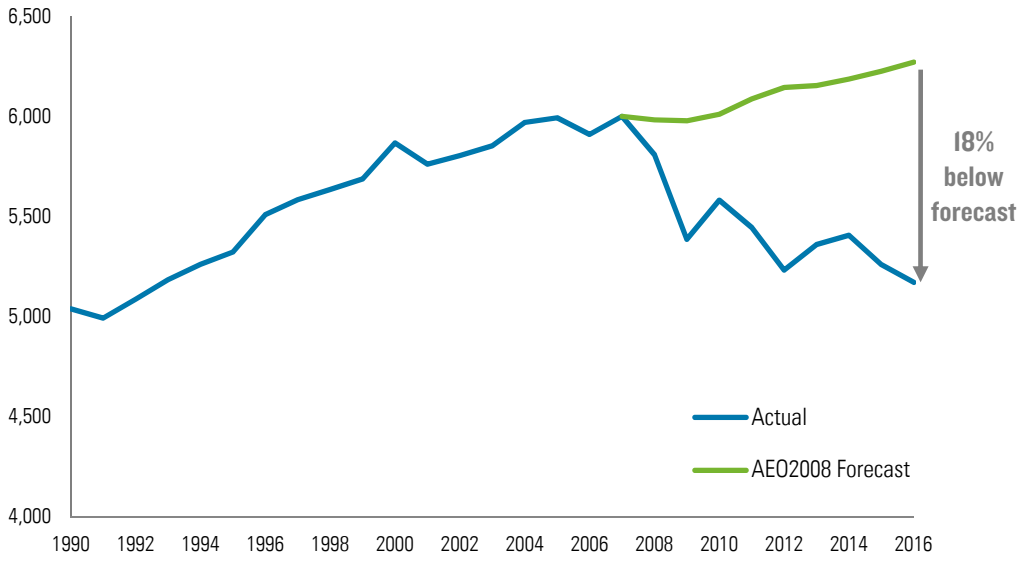
Important disclosures can be found in the Appendix

emissions, as will the outcome of the 2020 Presidential election. But the forecasts presented here provide a useful signpost for where the US is headed as of today, and how much work remains to be done.

PROGRESS TO DATE

The year before President Obama took office, the Energy Information Administration (EIA) projected in its Annual Energy Outlook (AEO) that carbon dioxide (CO_2) emissions from US energy consumption would continue to grow at their historical average of nearly 1% per year for the foreseeable future. US CO_2 emissions have instead declined significantly in absolute terms due to policy actions taken by the Obama Administration, slower than expected economic growth, and technological developments like the shale gas boom and dramatic reductions in wind and solar costs. By the end of 2016, US CO_2 emissions from energy consumption (which account for roughly 80% of total US GHG emissions) were 13.7% below 2005 levels and 17.6% lower than projected by the EIA in 2008 (Figure 1).

Figure 1: 2016 emissions 18% lower than projected in 2008



Source: EIA, Rhodium Group analysis.

The 1.1 billion metric ton (MMt) drop in emissions between the AEO2008 forecast and what actually occurred in 2016 was due to a combination of slower than expected economic growth, and a reduction in the carbon intensity of energy supply. In the 2008 AEO, EIA projected 2.7% average annual growth in Gross Domestic Product (GDP) between 2008 and 2016. Instead, thanks to the financial crisis, Great Recession, and relatively sluggish recovery, the economy grew at an average annual rate of 1.5%. That meant overall economic output was 11.1% lower in 2016 than expected.

There were significant energy efficiency improvements over this period of time, both in buildings and vehicles. But overall, the energy-intensity of the US economy was right about where the EIA projected in 2016. The carbon-intensity of energy supply—the amount of CO_2 emitted per unit of energy consumed—fell 9.6% between 2008 and 2016, which explains the rest of the emissions decline in Figure 1. This is the result of an unprecedented increase in the availability and use of natural gas from shale resources coupled with expanded renewable power generation thanks to the federal Production

Tax Credit (PTC) and Investment Tax Credit (ITC), state Renewable Portfolio Standards (RPS), other federal and state policies, and a decline in renewable technology costs.

Other GHG emissions have not declined as quickly as energy-related CO_2. As a result, the EPA estimates that total US GHG emissions were 11.5% below 2005 levels in 2015 (the last year for which all gas inventory data is available), compared to 12.2% for energy-related CO_2.[1] Given the 1.7% year-on-year decline in energy-related CO_2 in 2016, economy-wide GHG emissions were likely 12%-13% below 2005 levels.

The Obama administration adopted or proposed a range of policies that would have continued to reduce US GHG emissions, from the Clean Power Plan to methane regulations for oil and gas production, to fuel economy standards for passenger vehicles. During the 2016 Presidential campaign, Hillary Clinton pledged to build on this agenda and accelerate clean energy deployment and US GHG emissions. Donald Trump promised to do the opposite, a promise he attempted to make good on with his March 28th EO.

EMISSIONS OUTLOOK UNDER CURRENT POLICY

When the EO was released, we did a quick analysis of the impact on US emissions if all Obama-era policies identified are successfully eliminated. As we noted then, however, it is unclear whether the requested agency reviews will result in complete elimination of the policies in the EO's crosshairs, in particular as any attempts will be subject to court challenge. For this assessment, we assume all recently finalized policies not explicitly rolled back by the EO remain intact, including the 2017-2025 corporate average fuel economy (CAFÉ) standards, oil and gas methane standards for new sources and existing sources on public lands, and phasedown of hydrofluorocarbons (HFCs) under the Kigali amendment to the Montreal Protocol. With EPA's Clean Power Plan (CPP) effectively on indefinite hold, we exclude it altogether. We also do not include potential Trump administration policies that were discussed on the campaign but have yet to be put into effect, including potential expansion of offshore oil and gas production.

Our forecast incorporates current state and city policies as of April 2017, including RPSs, energy efficiency resource standards (EERS), zero-emission vehicle (ZEV) requirements, extension of California's AB32 emission reduction program out to 2030 and the Northeast Regional Greenhouse Gas Initiative cap-and-trade program. We do not include state or city emission reduction targets that have yet to be supported with binding policy, such as the long-term emission reduction pledges made by US signatories to the Under2 MOU.

We model the impact of current policy on US GHG emissions using RHG-NEMS, a modified version of the National Energy Modeling System used by EIA to produce its Annual Energy Outlooks that we have augmented to project all GHG emissions, not just energy-related CO_2.[2] For our Taking Stock Baseline Scenario, we use the

[1] All historical data through 2015 come from EPA's 2017 GHG inventory. Throughout this report we use 100-year Global Warming Potential (GWP) values from the IPCC's 4th Assessment Report (AR4) to compare CO_2 and non-CO_2 gases on an equivalent basis. This is consistent with EPA's GHG Inventory and UNFCCC reporting guidelines.

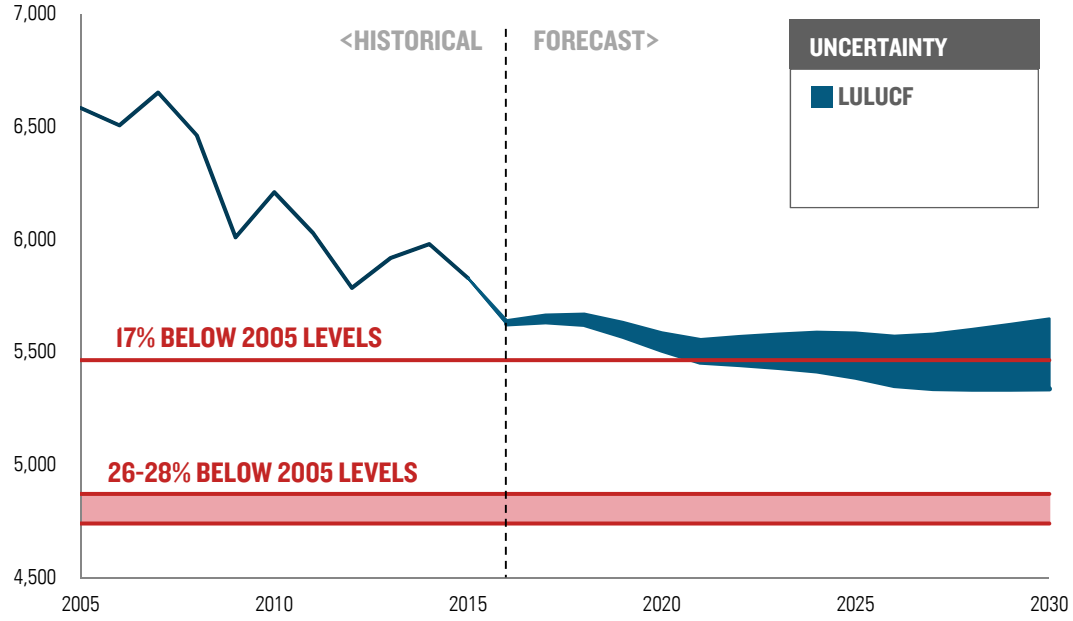
[2] For CO_2 emissions from sources other than fossil fuel combustion as well as all other GHG emissions contained in the baseline we primarily rely on EPA best practice methods. Methane emission reductions from petroleum and natural gas systems from existing federal and state policy are derived from analysis conducted by the Clean Air Task Force. LULUCF sequestration projections are derived from the latest US Biennial Report and calibrated to EPA's latest inventory.

macroeconomic and oil and gas price assumptions from the EIA's AEO2017 reference case with updates to account for recently announced coal and nuclear power plant retirements. For renewable energy technology costs, we use NREL's Annual Technology Baseline mid cost case.

In this scenario, US GHG emissions continue to decline to 15-16% below 2005 levels by 2020, within striking distance of the US Copenhagen target of 17% (Figure 2). The range is due to uncertainty surrounding the ability of US forests and other lands to sequester carbon (referred to as "LULUCF"). Emissions then begin to flatten out, putting the US at 15-18% below 2005 levels in 2025 and 14-19% by 2030. That's a fair way off from the 26-28% Paris commitment for 2025 and even further from the kind of 2030 reduction required to be on track to meeting long term US emission reduction objectives.

Figure 2: Net US GHG emissions under current policy

MMt CO_2e



Source: EPA, Rhodium Group analysis.

Carbon dioxide

Despite recent progress in decreasing the carbon intensity of the US economy, CO_2 continue to make up the lion's share (82%) of gross US GHG emissions in 2015 (Table 1). By 2025 in our Baseline scenario, CO_2 emissions from fossil fuel combustion decline from 2015 levels in all major sectors except for industrial sources. In the electric power sector, tepid growth in electric demand, increasingly cheap renewables, and a continued shift from coal to natural gas drive emissions down 8% from today's levels to 1,757 million metric tons in 2025 - the lowest since 1988. Federal tax credits for renewables as well as state energy efficiency and renewable energy policies also play a role. All told, decarbonization of the US power sector will continue despite the rollback of key Obama era policies, though we estimate that the CPP could have delivered up to an additional 100 million metric ton reduction in 2025 (or just under 6% of total electric power sector emissions in that year).

Table I: US GHG emissions by gas and sector under current policy

MMt CO_2e

Gas	Sector	2005	2015	2020	2025	2030
Carbon Dioxide	Electric power	2,401	1,901	1,789	1,757	1,774
	Transportation	1,887	1,736	1,750	1,655	1,557
	Industrial	828	805	846	889	892
	Buildings	581	566	542	538	535
	Other	435	403	434	444	444
	Total	6,132	5,411	5,361	5,285	5,202
Methane	Fossil fuel production	270	263	235	235	233
	Agriculture	242	244	256	264	267
	Waste	152	133	122	118	115
	Other	17	16	15	15	15
	Total	681	656	628	632	630
Nitrous Oxide	Agriculture	276	269	276	281	283
	Other	85	66	64	63	63
	Total	362	335	342	345	346
F-Gases	ODS substitutes	100	168	126	81	42
	Other	39	16	12	9	8
	Total	139	185	138	90	50
Total	Gross GHG emissions	7,313	6,587	6,469	6,351	6,229
	LULUCF sequestration	-731	-759	-883 to -961	-766 to -963	-581 to -892
	Net GHG emissions	6,582	5,828	5,508 to 5,587	5,388 to 5,585	5,337 to 5,648
	Change from 2005	*0%*	*-11%*	*-15% to -16%*	*-15% to -18%*	*-14% to -19%*

Source: EPA, Rhodium Group analysis. Note: CO_2 emissions for all sectors except "other" reflect emissions from fossil fuel combustion only. All non-combustion and territorial CO_2 emissions are contained in "other".

Outside the power sector, emissions decline modestly in our Baseline scenario, largely as a result of momentum from policies finalized in recent years and ongoing fuel switching trends. Despite an increase in demand, transportation emissions decline due in large part to federal light-duty and heavy-duty vehicle standards that become increasingly stringent through 2025 and 2027 respectively. Emissions from commercial and residential buildings decline slightly due in part to a continued shift away from petroleum towards natural gas as well as increased building and appliance efficiency. In the industrial sector emissions from fossil fuel combustion increase around 10% (reaching 889 MMt) in 2025, reflecting the sector's greater use of relatively cheap natural gas for chemical production and, Liquefied Natural Gas (LNG) exports. The majority of CO_2 emissions from other activities come from industrial feedstock use and non-energy use of fuels and explains why emissions from this category also increase by 10% from 2015 levels.

There is a risk that future changes in federal policy will erode some of these expected emission reductions. EPA and DOT, for example, are currently reviewing light-duty fuel economy standards for model years 2022 through 2025. If the review process yields less stringent standards, transportation emissions will be slightly higher in 2025, with an even greater difference by 2030. If the federal administration opens more public land for fossil fuel production, that could put downward pressure on energy prices and upward pressure on demand and CO_2 emissions.

Methane

After CO_2, methane is the second largest source of US GHG emissions, at around 10% in 2015. Resulting primarily from leaks in natural gas systems, livestock, and waste decomposition in landfills, methane is an extremely potent GHG, over 25 times as climate-forcing as CO_2. EPA reports a 4% decline in methane emissions since 2005, due primarily to a reduction in emissions from landfills, offsetting somewhat a rise in emissions from manure management. Leaks from natural gas systems, the second largest source of US methane emissions, increased slightly (1.6%) between 2005 and 2015 according to EPA estimates, primarily from an increase in field production, which grew nearly 50% between over that period.

Under current federal and state policy, methane emissions decline an additional 4% by 2020 in our Baseline scenario and then remain relatively flat through 2030 (Table 1). The bulk of the reductions come from oil and gas activities, despite an increase in natural gas production. This is the result of the several rules finalized in 2016, including New Source Performance Standards for methane emissions from new and modified oil and gas production sources, revised control techniques guidelines (CTG) for states in nonattainment areas, and BLM rules limiting venting and flaring on public lands. If EPA and BLM were to overturn these rules, methane emissions would be around 40 MMt CO_2e higher in 2025. State policies are also increasingly important for reigning in methane emissions from oil and gas activities.[3]

HFCs and other fluorinated gases

Fluorinated gases—including HFCs, Perfluorocarbon (PFC), and Sulfur Hexafluoride (SF6) - are thousands of times more climate-forcing than CO_2. HFCs, the most prevalent of the three and primarily used as a substitute for ozone-depleting substances in applications such as air conditioning and refrigeration, grew 44% over the last ten years. Unchecked growth in HFCs would lead to an additional 20% increase from today's levels by 2025 (nearly 75% above 2005 levels). In 2015 and 2016 EPA took steps to limit HFC emissions, finalizing regulations under the Significant New Alternatives Policy (SNAP) that prohibited the use of high-GWP HFCs and expanded the list of safer alternatives. EPA's ability to fully phasedown HFCs was limited, however, until a major development on the international front last year. In late 2016, years of diplomatic efforts by the Obama Administration finally won passage of the Kigali Amendment to the Montreal Protocol, which requires a global phasedown of the production and consumption of HFCs. Under the Amendment, the US is required to reduce baseline HFC consumption 10% by 2019, 40% by 2024 and 70% by 2029. Without any clear signals from the Trump Administration that they plan to walk away from its Montreal Protocol commitments, our current policy projections assume the US meets its Kigali targets, delivering reductions of over 50 MMt CO_2e in 2020 and more than 120 MMt CO_2e in 2025.

Nitrous oxide

Nitrous oxide (N_2O), a powerful gas nearly 300 times more potent than CO_2, contributed 5% of total US GHG emissions in 2015. Almost three-quarters of total N_2O emissions come from agricultural soil management, with the remainder primarily from fuel combustion in vehicles and other stationary sources. We expect N_2O emissions to increase slightly (about 3%) between 2015 and 2025 largely due to increased agricultural production. N_2O

[3] Projections account for methane regulations in Colorado and Wyoming. We do not incorporate California's pending regulations.

emissions from stationary combustion are expected to stay relatively flat, while mobile combustion emissions will decline slightly (~5%).

Forests and land use

The ability of American forests and other lands to sequester carbon continues to be a wild card for overall US net GHG emissions. In 2015, just over 11% of total US GHG emissions were offset as forests and other lands absorbed carbon from the atmosphere. Since 1990, the carbon sink has fluctuated between about 685 and 830 MMt CO_2, with the most recent estimate for 2015 at about 760 MMt CO_2. Recent studies suggest that as a result of changing land-use patterns and the effects of climate change itself, over the long-term US forests may absorb carbon at a slower rate. There is significant uncertainty, however, about if and when such slowing may occur. Due to significant uncertainty associated with market dynamics and other drivers of land-use change and forest use, as well as the effects of future climate change on our lands and forests, we present a range of potential land use, land use change and forests (LULUCF) emissions and removals through 2030. In the low sequestration scenario, forest area and forest carbon grow through 2020, after which they decline. In the high sequestration scenario, forest area and carbon continue to grow until 2020, flatten out through 2025, and then decline through 2030. The result is an uncertainty band of 78 MMt CO_2 in 2020, growing to 197 MMt CO_2 by 2025.

UNCERTAINTIES ABOUND

As the last year has made abundantly clear, the future is difficult to predict. And politics and policy are not the only unknowns as we look ahead. There is also considerable uncertainty surrounding the economic, technological and market forces that play a critical role in shaping US emissions outcomes. In our Baseline scenario, we account for uncertainty in the degree to which forests and other lands will sequester carbon and offset total US GHG emissions. In this section we account for two additional areas of uncertainty in our projections: energy markets and economic growth. Holding our policy assumptions constant, we examine how these variables could shape US emissions in the years ahead.

Energy markets

The price of both fossil and zero-emitting energy resources play an important role in determining overall US GHG emissions. If low and zero-carbon energy options are cheaper than expected, emissions will be lower all-else-equal. Since the shale revolution began a decade ago, US oil and gas production has continued to surprise. Each year, US supply seems to be larger and cheaper than the most optimistic estimates from just a few years before. The same holds true for wind and solar energy where thanks to dramatic cost and performance gains, these technologies have accounted for over half of new electric power capacity additions in recent years.

To capture this energy market uncertainty, we model a range of oil and gas resource assumptions and a range of renewable energy costs. For oil and gas, we explore resource base assumptions that translate into natural gas prices (at Henry Hub) ranging from $3.40 to $4.50 per MMBTU in 2025 and $3.75 to $4.85 in 2030. For renewables, we explore a range of cost estimates from NREL's Annual Technology Baseline Low cost scenario to EIA's AEO2017 reference case assumptions.

Widening the range of energy cost assumptions slightly expands potential US GHG emissions futures – by 65 MMT CO_2e in 2020 and 105 MMt CO_2e in 2025. That translates into a 15-17% reduction in US GHG emissions from 2005 levels in 2020, bringing the

Copenhagen target within range (Figure 3) as well as a reduction of 15-19% by 2025 and 14-20% by 2030 (Table 2).

Economic growth

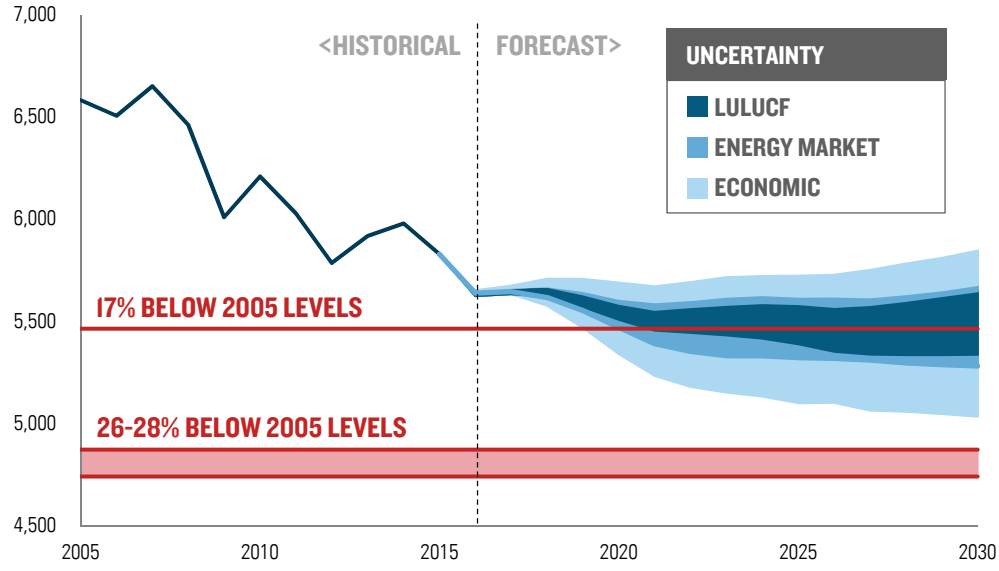
Our Baseline scenario takes macroeconomic assumptions from EIA's 2017 Annual Energy Outlook reference case. This includes a 2.4% average annual GDP growth projection between 2016 and 2025. That's considerably higher than what the US has experienced over the past eight years, and higher than the 1.9% average annual growth rate the Congressional Budget Office is currently projecting between now and 2025. As over the past eight years, lower than expected economic growth going forward will reduce GHG emissions through lower energy demand and slower growth in non-CO_2 emission sources.

To quantify the potential impact, we modelled a scenario in which US GDP grows at 1.7% per year, on average, between 2016 and 2025 – just below the current CBO projections. Combined with low natural gas prices and renewable energy costs and optimistic assumptions for LULUCF, this could lead to emissions falling 19% below 2005 levels by 2020, 23% by 2025 and 24% by 2030 (Figure 3 and Table 2).

Economic growth could also be faster than currently projected by the EIA. President Trump's budget released this week assumes the economy will grow at 3% a year, not 1.9%. When we model the impact of growth at roughly that level, we find that US GHG emissions could be as high as 14% below 2005 levels in 2020, 13% in 2025 and 11% in 2030.

Figure 3: US net GHG emissions under current policy with energy and economic uncertainty

MMt CO_2e



Source: EPA, Rhodium Group analysis.

Table 2: US net GHG emissions under current policy with energy and economic uncertainty
MMt CO_2e

	Net GHG Emissions								
	2020			2025			2030		
LULUCF	5,508	to	5,587	5,388	to	5,585	5,337	to	5,648
LULUCF & Energy Market	5,469	to	5,611	5,321	to	5,621	5,281	to	5,679
LULUCF & Energy & Economic	5,340	to	5,688	5,100	to	5,722	5,033	to	5,845
	Change from 2005								
	2020			2025			2030		
LULUCF	*-15%*	to	*-16%*	*-15%*	to	*-18%*	*-14%*	to	*-19%*
LULUCF & Energy Market	*-15%*	to	*-17%*	*-15%*	to	*-19%*	*-14%*	to	*-20%*
LULUCF & Energy & Economic	*-14%*	to	*-19%*	*-13%*	to	*-23%*	*-11%*	to	*-24%*

Source: Rhodium Group analysis.

OPPORTUNITIES FOR ACHIEVING ADDITIONAL REDUCTIONS

Our analysis shows that US emissions are likely to decline at least modestly from current levels over the next decade. However, even under the most optimistic federal policy and energy market scenarios, and relatively pessimistic economic growth scenarios, the US is not currently on track to meet its 2025 Paris emission reduction goal. While it's clear that the current US administration and Congress are unlikely to make climate change mitigation a priority, there are a few areas where addition federal action could contribute to continued progress. Bolstered by additional state and local action, as well as a growing number of corporate clean energy commitments, there is room to accelerate progress and help close the emissions gap.

Maintaining policies not yet rescinded by the Trump administration will go a long way to ensuring US emissions continue to decline. Expected reductions from the phasedown of HFCs under the Kigali Amendment and rules limiting methane emissions from new oil and gas sources are particularly important in the short and medium term. Any backtracking on federal CAFE standards and/or refusal to grant California's vehicle emissions waiver would have little to no effect in the 2020 timeframe, but would impact fuel demand and GHG emissions from 2025 onward. Other, less visible federal actions may also play a role. If the Federal Energy Regulatory Commission (FERC) follows through on proposed rules to open up wholesale markets to greater competition from distributed energy resources (DERs), greater deployment of zero-emitting DERs could push power sector emissions below what's in our projection range. Any actions by the Department of Interior to open up new public lands to natural gas production may lead to more coal displacement in the power sector and lower CO_2 emissions, though methane emissions may increase as a result. Permitting reform for electric transmission lines as part of a federal infrastructure bill could help accelerate development of high quality renewable resources in geographically remote locations.

Outside of the federal government, states can play an important role in pushing climate progress forward. They could increase the ambition of current renewable energy and energy efficiency policies, pursue new carbon pricing policies or join existing state level cap-and-trade programs. State policy is particularly important in reducing emissions outside the electric power sector, whether through adoption and enforcement of advanced building energy codes or policies to accelerate the deployment of electric vehicles. Cities and companies can also put a meaningful dent in US emissions. A growing number of both have come forward with ambitious renewable energy targets and emission reduction goals. The trick is adopting implementing policy that delivers emissions reductions additional to what state and federal policies will already achieve.

Finally, the US's ability to meet its 2025 Paris commitment will depend in large part on the outcome of the 2020 Presidential election. A change in the White House could bring about the same level of federal policy whiplash the country has just experienced, but in the opposite direction, and with enough time to make a meaningful dent in US emissions by the time the Paris commitment comes due.

DISCLOSURE APPENDIX