Rhodium Group

Taking Stock 2020

The COVID-19 Edition

JULY 9, 2020

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About this Report

For the past six years, Rhodium Group has provided an independent annual assessment of US greenhouse gas (GHG) emissions and progress towards achieving the country's climate goals in our Taking Stock report series. Each year we explore changes in federal and state policy, shifting energy market and technology advancements, as well as expectations for growth of the American economy—all of which are central drivers of the outlook for US GHG emissions over the coming decade.

This year's edition is different. We focus on the largest source of uncertainty in the current outlook for US GHG emissions: COVID-19's impact on the US economy. In this report, we provide a range of potential outcomes for post-COVID GHG emissions through 2030 based on the potential depth and duration of the pandemic and its economic toll. These scenarios provide a starting point for policymakers as they consider policies to both stem economic losses and invest in efforts to decarbonize and improve the resilience of our economy going forward, work our team at Rhodium will be conducting over the coming months.

This report offers an overview of our national results for 2020. For more granular detail on our results, Rhodium's Climate Service provides direct access to all emissions data from Taking Stock, as well as 50-state emissions and energy data (broken down by sector and by gas). Climate Service subscriptions include interactive data visualizations of a wider range of energy market and policy scenarios, as well as research coverage of key developments in US energy and climate policy.

About Rhodium Group

Rhodium Group is an independent research provider combining economic data and policy insight to analyze global trends. Rhodium Group's Energy & Climate practice analyzes the effects of policy and market developments on energy systems and greenhouse gas emissions, and provides actionable information about the risks of climate change by sector and region around the world. This interdisciplinary group of policy experts, economic analysts, energy modelers, data engineers, and climate scientists supports decision-makers in the public, financial services, corporate, philanthropic and non-profit sectors. More information is available at www.rhg.com.

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Executive Summary

For the past six years, Rhodium Group has provided an independent annual assessment of US greenhouse gas (GHG) emissions and progress towards achieving the country's climate goals. Each year, we explore changes in federal and state policy, shifting energy market and technology advancements, and expectations for growth of the US economy—all of which are central drivers of the outlook for US GHG emissions over the coming decade. However, this year's edition is different. Here we focus solely on the largest source of uncertainty in the current outlook for US emissions: COVID-19's impact on the economy.

It has been over 100 years since the US has confronted a pandemic of this magnitude, so there are few historical precedents for understanding what to expect over the coming years. There are four main components of uncertainty: 1) the epidemiological outcomes of COVID-19 and its spread; 2) how states, companies, and communities respond to the epidemiological risks through lockdowns or restrictions on activity; 3) the resulting impact to the US economy; and 4) the response of federal and state governments to shore up the economy through stimulus and recovery measures.

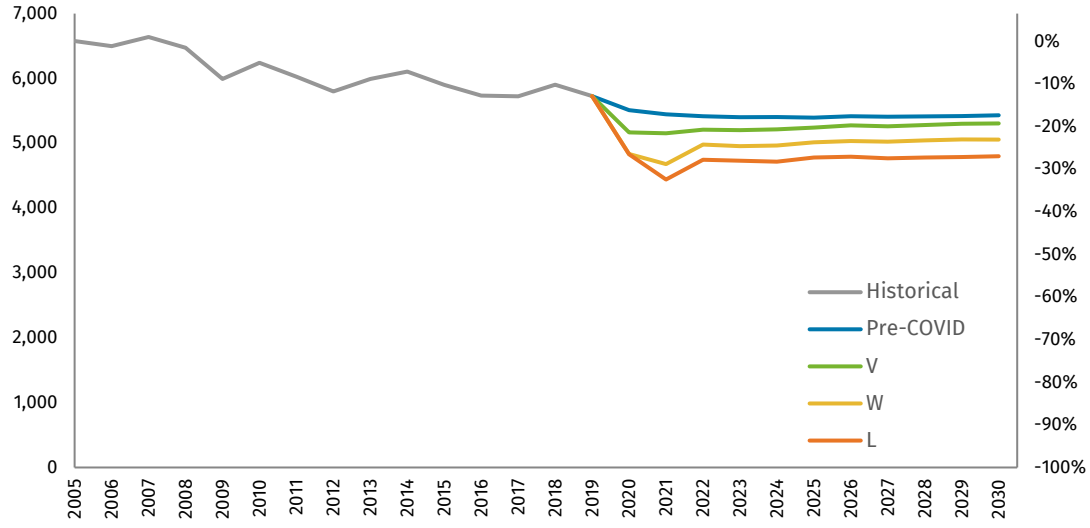
In this report, we provide a range of potential scenarios for the first three sources of uncertainty. We plan to explore the fourth source of uncertainty in subsequent research. These scenarios provide a starting point for policymakers as they consider policies to both stem economic losses and invest in efforts to decarbonize and improve the resilience of our economy.

The spread of COVID-19 has already substantially reduced GHG emissions over the past few months. We estimate that between March 15 and June 15, emissions declined by 18% compared to last year's levels. Less clear is how the crisis will shape emissions in the years ahead. We find the potential for a persistent effect on GHG emission trends—with reductions of 6-12% this year relative to pre-COVID projections, and 2-12% by 2030, depending on the depth and duration of the crisis and the pace of recovery (a V, W, or L-shaped recovery) (Figure 1).

FIGURE 1

US greenhouse gas emissions under current federal and state policy

Net million metric tons CO_2e (left), % change from 2005 (right)



Source: Rhodium Climate Service

COVID-19's most dramatic effect to date has been in the transportation sector. Between March 15 and June 15, transportation emissions declined by 28% compared to last year's levels, as air travel and personal vehicle usage have plummeted. In our post-COVID economic recovery scenarios, we expect the crisis to continue to disrupt transportation more than any other energy sector. The range of emission reductions could be between 1 to 14% below the pre-COVID baseline by 2030, depending on the pace of economic recovery and the extent of lasting behavioral changes.

In the electric power sector, overall demand has weakened in response to COVID-19. This, combined with low natural gas prices, has accelerated coal's long decline. At the peak of the lockdown, coal generation was down more than 30% year-on-year, with wind and solar generation surpassing coal for the first time in US history. Already in trouble before the pandemic, coal gets hit even harder in our post-COVID scenarios. However, while power sector emissions continue to trend downward, they flatten out by the mid-2020s due to the expansion of cheap natural gas.

Cheap natural gas, along with growing domestic oil production in recent years, has also bolstered industrial demand, driving up emissions. While the pandemic has dampened the steady rise in industrial emissions somewhat, in our post-COVID scenarios we find that industry remains on track to become the largest emitting sector in the next six years.

Overall, despite the sharp near-term drop in emissions, it falls far short of the scale of reductions needed to put the US on track for deep decarbonization and net zero emissions by mid-century. These emission reductions are achieved almost exclusively due to decreased economic activity and not from any structural changes that would deliver lasting reductions in the carbon intensity of our economy. Near-term emission reductions driven by COVID-19 also come at an enormous economic cost—$3,200-5,400 per ton of CO_2 reduced, on average this year.

Timely and well-targeted clean energy and climate investments made as part of sustained stimulus and recovery efforts can help shorten the duration of the crisis, accelerate the recovery, and deliver emission reductions based on sustained transformational changes needed to reach long-term decarbonization.

CHAPTER 1

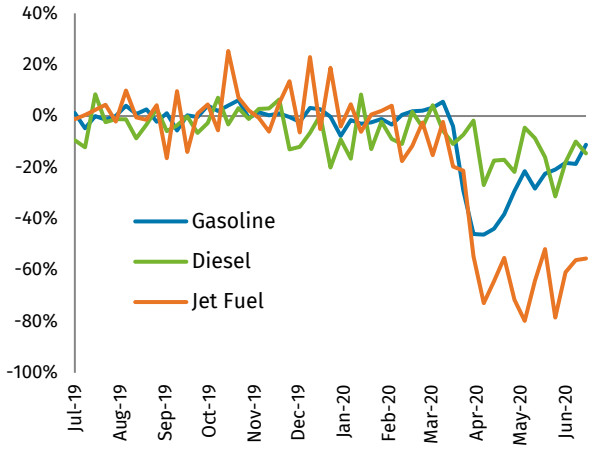
COVID-19's Energy and Emissions Impact to Date

It has now been three months since the first shelter-in-place orders were put into effect in the US. The unemployment rate remains at 13%—the highest since the Great Depression. States have begun reopening in the hopes of alleviating this economic pain, even though robust testing and tracing programs are still not in place. Below we assess the impact to date on three key sectors of the US economy—transportation, electricity, and industry—and assess the implications for US GHG emissions in 2020.

Transportation

COVID-19's most dramatic effect on energy markets has been in the transportation sector (which accounts for 33% of net GHG emissions in the US), with air travel grinding to a halt and personal vehicle usage falling dramatically as shelter-in-place orders were put in place across the country. By mid-April, US petroleum demand had fallen by more than 30%. Over the past two months, as some states have begun reopening, gasoline and diesel demand has started to recover (Figure 2). Jet fuel demand, however, remains less than half its level during the same period in 2019.

FIGURE 2
Change in weekly US petroleum demand
Weekly deliveries vs 4-week average the year prior

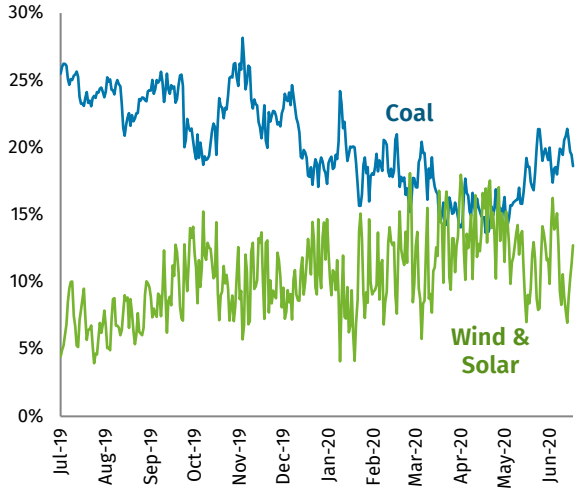


Source: EIA and Rhodium Group estimates

Electricity

Electricity demand (which accounts for 28% of net US GHG emissions) has weakened due to COVID-19. This, combined with low natural gas prices, has accelerated coal's decline. At the peak of the lockdown, coal generation was down more than 30% year-on-year, with wind and solar generation surpassing coal for the first time in US history (Figure 3). Over the past month, coal's market share has recovered somewhat, but is still considerably below 2019 levels.

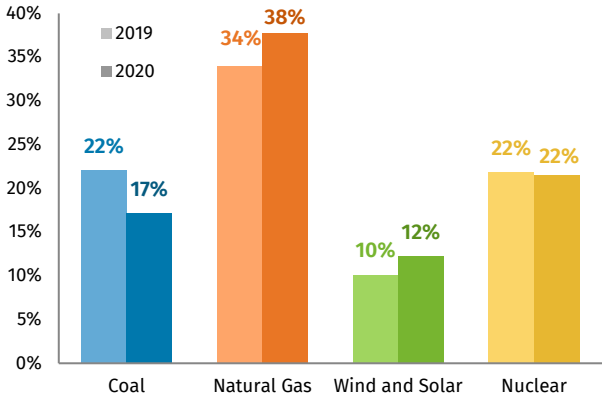
FIGURE 3
Daily average US electricity generation by source
Percent of total



Source: EIA and Rhodium Group estimates

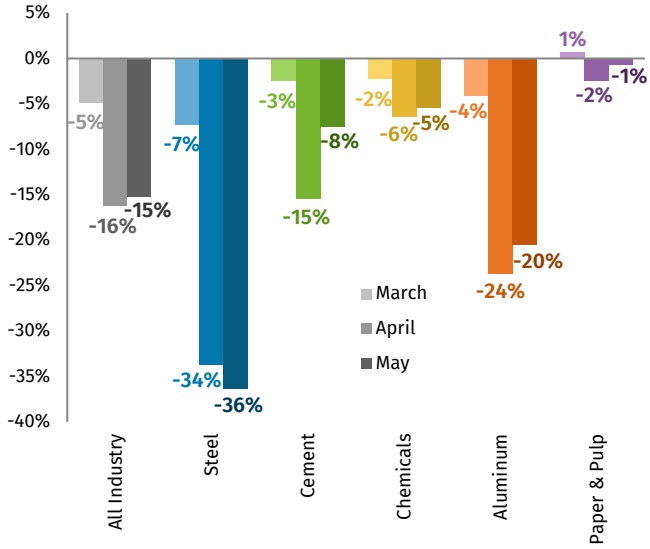
On average between March 15 and June 28, coal's market share was 17%, down from 22% during the same period in 2019. Wind and solar's market share grew from 10% to 12% (Figure 3). Natural gas prices have remained well below $2 per MMBTU at Henry Hub since the pandemic began, which has helped push gas generation's market share to 38%, compared with 34% during the same period the year prior (Figure 4).

FIGURE 4
Share of total power generation
March 15 – June 28



Source: EIA and Rhodium Group estimates

FIGURE 5
Year-on-year change in US industrial production
Percent



Source: FRED and Rhodium Group estimates

Industry

The impact of COVID-19 on US industrial activity (which accounts for 27% of net US GHG emissions) has been mixed. In March, overall US industrial activity was down 5% year-on-year. In April, the decline grew to 16%—just short of the 18% year-on-year decline experienced during the worst of the Great Recession. Production recovered slightly in May to -15% year-on-year.

Output of some energy-intensive goods has fallen even faster than overall industrial production (Figure 5). Steel production, for example, was down 7% year-on-year in March, 34% in April, and 36% in May. Cement production has not fallen as fast as steel and recovered more quickly in May. Aluminum production was down 24% in April and 20% in May. Chemicals has experienced a relatively modest decline, and paper and pulp production has been largely unaffected.

Aggregate emissions impact

Taking the COVID-driven changes in energy markets, industrial production, and transportation behavior, as well as building use and agricultural production, we estimate that US GHG emissions were 18% lower, on average, between March 15 and June 15 compared to the same period in 2019. Transportation has had the largest decline at 28%, followed by electric power and industrial production.

It is too early to know exactly where full-year emissions in 2020 will land. States have begun to reopen and emissions are starting to recover. If there is no second wave of COVID-19 and this reopening continues unimpeded, the full-year emissions decline could be less than half of current levels. If, on the other hand, there is another large outbreak and another wave of lockdowns, full-year emissions will remain closer to what we have seen over the past few months. In either case, the US will certainly see the largest annual drop in GHG emissions in recorded history in 2020.

CHAPTER 2

Outlook for Recovery

Events over the past few months will already have a significant impact on full-year 2020 GHG emissions. What happens over the next few months, and how policymakers respond, will determine US GHG emissions for years to come.

The difficulty of catch-up growth

There is a popular perception that economic shocks are temporary disruptions, and that subsequent catch-up growth returns economic output not just to pre-crisis levels but to pre-crisis baselines (i.e. where the economy would have been had the crisis never occurred). Unfortunately, there is little historical evidence of this materializing after large economic crises. Cerra and Saxena (2008) analyze a wide range of historical economic shocks across both developed and developing countries, ranging from currency crises to civil wars, and find no evidence of catch-up growth. These large shocks have meaningful and lasting impacts on economic performance.

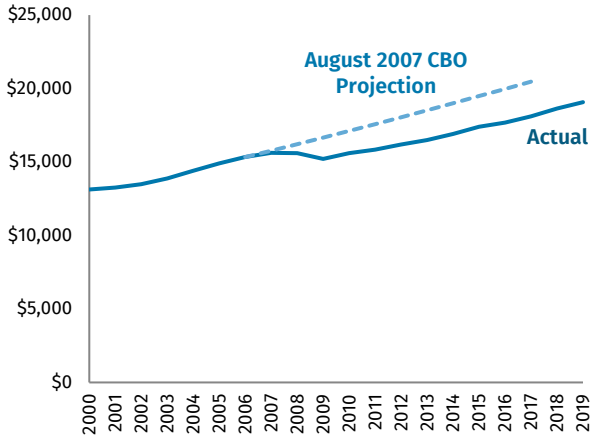
Reinhart and Rogoff (2014) find that among the 100 banking crises that have occurred since the mid-1800s, the median amount of time it took countries to return to pre-crisis levels (let alone catch up to where they otherwise would have been) was 6.5 years. Nakamura et al (2013) find something similar when looking at all large economic crises historically—6 to 7 years on average to return to pre-crisis levels, with a confidence interval spanning 3 to 14 years. They also find a persistent 14% reduction in output levels relative to the pre-crisis counterfactual after the "recovery" at the median across historical crises. After big shocks, it appears economic activity rarely fully catches up.

Perhaps the most recent example of this is the Great Recession. In its last economic forecast before the recession began, the Congressional Budget Office (CBO) projected that the US economy would grow at 2.7% on average in the decade to come, consistent with growth rates experienced during the previous few years and consensus among economists of "potential" US economic growth at that time. After the Great Recession, it took the US economy several years to return to pre-crisis levels, and output never caught up to the pre-crisis counterfactual. Between 2009 and 2017, the economy grew at 2.2% instead of 2.7%, which meant that in 2017 output was 12% below where CBO thought it would be in their pre-crisis projection (Figure 6).

FIGURE 6

Recessions can have lasting economic damage

Pre-recession CBO GDP projections vs. actual (Billion USD)



Source: CBO, BEA, and Rhodium Group

Three possible scenarios for the crisis and recovery

Given the range of outcomes experienced by both the US and other economies following past economic shocks, and remaining uncertainty around how large the COVID-19 shock will ultimately be, we adopt a scenario approach to future economic growth in updating our US GHG emissions projections.

In its April World Economic Outlook, the IMF estimated that the COVID-19 pandemic would reduce US economic output by 5.9% in 2020 (or 8% below their previous projections)—more than twice as deep as the

worst year of the Great Recession and easily the largest economic crisis since the Great Depression. In its core scenario, the IMF assumes the virus is under control by the second half of the year and that there is a rapid recovery, with the US economy growing by 4.7% in 2021. This is the basis for our **V-shaped recovery scenario**. At the time of publication, Goldman Sachs was forecasting a 4.2% decline in 2020 followed by a 5.8% rebound in 2021. CBO currently projects a steeper 6.0% decline in US GDP in 2020, but still a relatively robust 5.8% increase in 2021.

However, many forecasters now believe a rapid recovery is less likely. In its June outlook, the IMF reduced its 2020 US growth forecast to -8% and its 2021 forecast to 4.1%. The OECD currently projects a 7.3% decline in US GDP in 2020 and a 4.1% increase in 2021, even if the reopening policies around the country remain on track.

Given the rapid growth in COVID-19 infection rates in recent weeks, and the fact that some states have already begun slowing or reversing their reopening plans, there could well be a second economic shock later this year. To capture this, we include a **W-shaped recovery** scenario where economic growth falls by 7.6% in 2020 and rises by only 1.3% in 2021 (Table 1). This is fairly close to the OECD's "Double-hit scenario" in which the economy contracts by 8.5% in 2020 and grows by 1.9% in 2021. In our scenario, the US economy grows at 4.1% in 2022, slightly slower thereafter than in our V-shaped recovery scenario, leaving average 2022-2030 growth rates at roughly the same 1.9%.

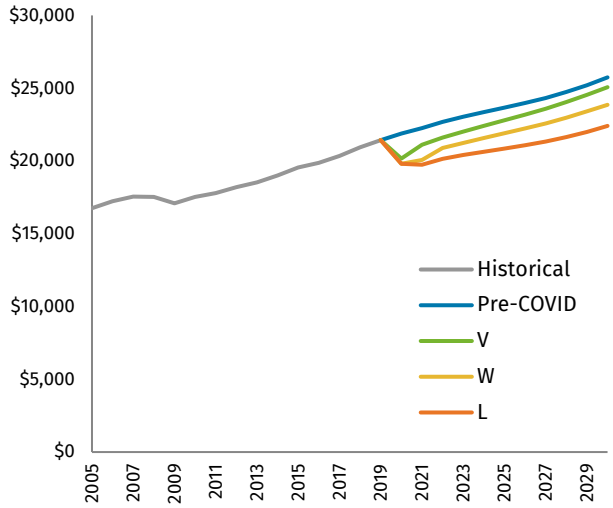
TABLE 1
Annual US GDP growth
Year-on-year change in GDP (%)

	2020	2021	2022-2030 avg.
Pre-COVID	2.1%	1.8%	1.6%
V	-5.9%	4.7%	1.9%
W	-7.6%	1.3%	1.9%
L	-7.6%	-0.3%	1.4%

Finally, we include an **L-shaped recovery** scenario, where a second lockdown (and subsequent lockdowns until an effective vaccine and treatment are widely available) does enough economic damage that the eventual recovery is as anemic as those following some of the larger economic crises in the past. In our L-shaped scenario, output 10 years after the COVID-19 crisis is still 7% below pre-crisis projections, which is still a smaller effect than the Great Recession as well as the median effect of the historical economic crises analyzed by Nakamura et al.

It is important to note that there are reasons why a V-shaped recovery could turn into a W or L other than policy-driven lockdowns. The public could prove far less willing to return to work in the weeks and months ahead than many policymakers hope, out of fear of infection. From an economic standpoint, this would have largely the same effect. Relief funding to businesses and individuals could run out (COVID-specific unemployment insurance is currently scheduled to run out July 31), which would add a demand shock to the current supply shock and exacerbate the economic crisis. Aggressive liquidity measures by the Fed have thus far prevented a financial crisis. If the Fed pulls back, or if their tools cease being effective in backstopping corporate and mortgage debt, a V could very quickly turn into an L as well. Figure 7 shows the outlook for the US economy under our pre-COVID baseline and three post-COVID scenarios.

FIGURE 7
US economic recovery scenarios
GDP, Billion 2019 USD



Source: EIA and Rhodium Group estimates

CHAPTER 3

Outlook for Emissions

In previous editions of Taking Stock, we explored US emissions accounting for uncertainties around carbon removal from forests and soils, energy markets, and federal policy, in addition to economic growth. This year is different. The uncertainties surrounding COVID-19 and its economic impact will have a far more influential impact on US GHG emissions than the cost of solar or the rate of soil carbon sequestration. We hold all assumptions around carbon removal, renewable technology costs, and policy constant across our scenarios. We do, however, capture COVID-19's effect on oil and natural gas production and prices.

Uncertainty around federal policy has evaporated since our last edition of Taking Stock, as the Trump administration finalized multiple actions to dismantle Obama-era climate policies. The most notable regulatory rollback came in April when fuel economy rules were finalized at a much lower level of stringency than under Obama rules. The rule will lead to hundreds of millions of tons of additional emissions in the atmosphere over the next decade and higher costs for consumers.

Despite the lack of forward momentum at the federal level, the last year brought a wide range of new mid- and long-term climate goals from states, companies, and others looking to fill the gap. However, much of the work to implement these ambitions remains to be done. In order to assess progress, we incorporate only those state-level policies that have been adopted and contain clear, implementable milestones. Over the past year, for example, Maine and New York adopted more stringent Renewable Portfolio Standards, Virginia decided to join the Regional Greenhouse Gas Initiative, and Colorado adopted California's vehicle emission standards. It remains to be seen what impact the pandemic will have on new subnational climate action going forward.

Aggregate emissions implications

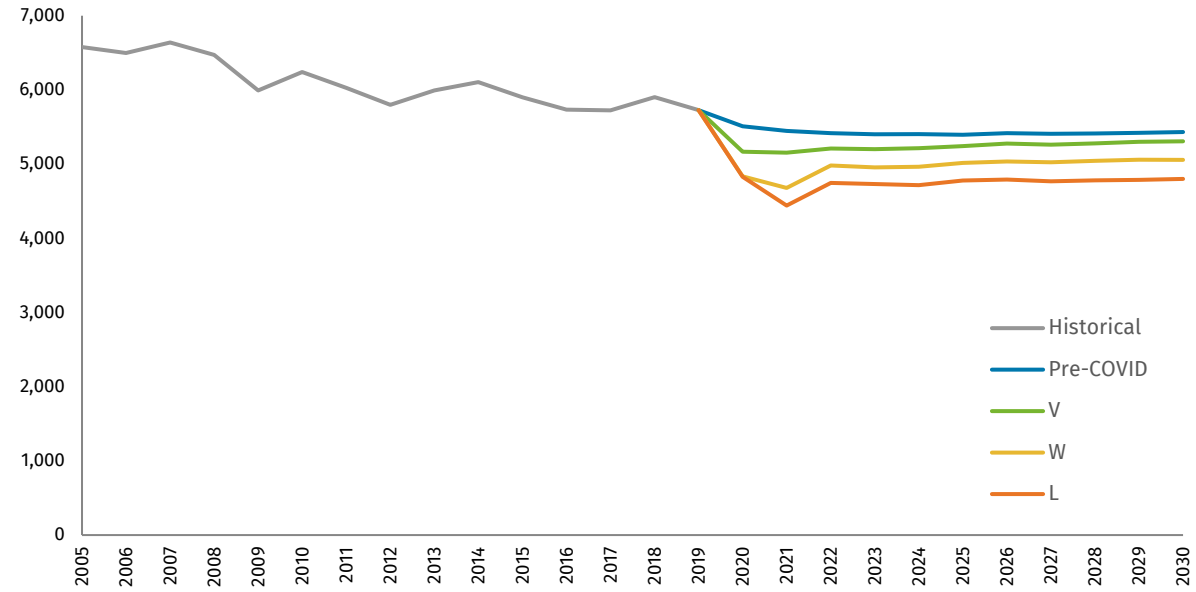
Under our **pre-COVID economic baseline** and with our central natural gas price and renewable technology cost assumptions, net US GHG emissions fall 4% year-on-year in 2020 (or 16% below 2005 levels), due primarily to a rapid decline in coal-fired power generation. This alone represents the largest year-on-year drop in emissions since the Great Recession. The US would have come within range of its Copenhagen Accord target to reduce emissions "in the range of 17%" below 2005 levels by 2020. But looking out to 2025, the pre-COVID emissions trajectory under current policy would put the US far from meeting its Paris Agreement target of a 26-28% reduction below 2005 levels.

If US economic activity "only" drops by 5.9% (our **V scenario**), net GHG emissions fall by 10% in 2020 compared to 2019 (reaching 21% below 2005 levels). This would represent a considerably larger drop than the 7% experienced in 2009 during the depths of the Great Recession. In this scenario, the economy grows by 4.7% in 2021 and then slightly faster than pre-COVID projected GDP growth rates through 2030. Emissions recover somewhat but remain 2-4% below the pre-COVID baseline every year from 2022 through 2030.

In our **W scenario**, the economy contracts by 7.6% in 2020 and then grows by 1.3% in 2021 and 4.1% in 2022. After that, growth returns roughly to pre-COVID projected rates. We find that emissions fall by 16% year-on-year in 2020 (27% below 2005 levels). Because those reductions result only from an economic lag, rather than fundamental changes to the GHG intensity of the US economy, emissions pick back up again, hitting 24% below 2005 levels in 2025 and 23% below in 2030, absent additional policy.

Our **L scenario** looks like W in 2020, but the recovery doesn't begin until 2022. Emissions remain at around 27% below 2005 levels through 2030. Although this dire

FIGURE 8
US greenhouse gas emissions under current federal and state policy
Net million metric tons CO_2e



Source: Rhodium Climate Service

TABLE 2
US GHG emissions
% change in annual net GHG emissions, from 2005 and from pre-COVID baseline

	Change from 2005			Change from pre-COVID baseline		
	2020	2025	2030	2020	2025	2030
V	-21%	-20%	-19%	-6%	-3%	-2%
W	-27%	-24%	-23%	-12%	-7%	-7%
L	-27%	-27%	-27%	-12%	-11%	-12%

scenario may bring emissions down to levels consistent with the US target under the Paris Agreement, it comes at enormous economic cost and hardship. It also falls far short of a straight-line pathway to net zero emissions by mid-century. We estimate that emissions need to be in the range of 40-50% below 2005 in 2030 to stay on such a path.

Electricity

Electric power emissions drop in the near-term due to a wave of coal retirements and a surge of renewables. Cheap natural gas continues to expand, outcompeting zero-emitting power sources and halting further emission reductions from the mid-2020s onward.

In our pre-COVID scenario, the long decline of coal in America continues. The combined impact of cheap natural gas, tepid electric demand growth, and a surge of new renewables drives coal generation down 25% year-on-year in 2020. The result is a 7% year-on-year drop in electric power sector emissions. This represents the largest annual percentage decline of coal generation in history and the lowest power sector emissions since 1983. Beyond 2020, emissions continue to decline but at a slower rate, then flatten out from 2024 onward, due to the expansion of cheap natural gas.

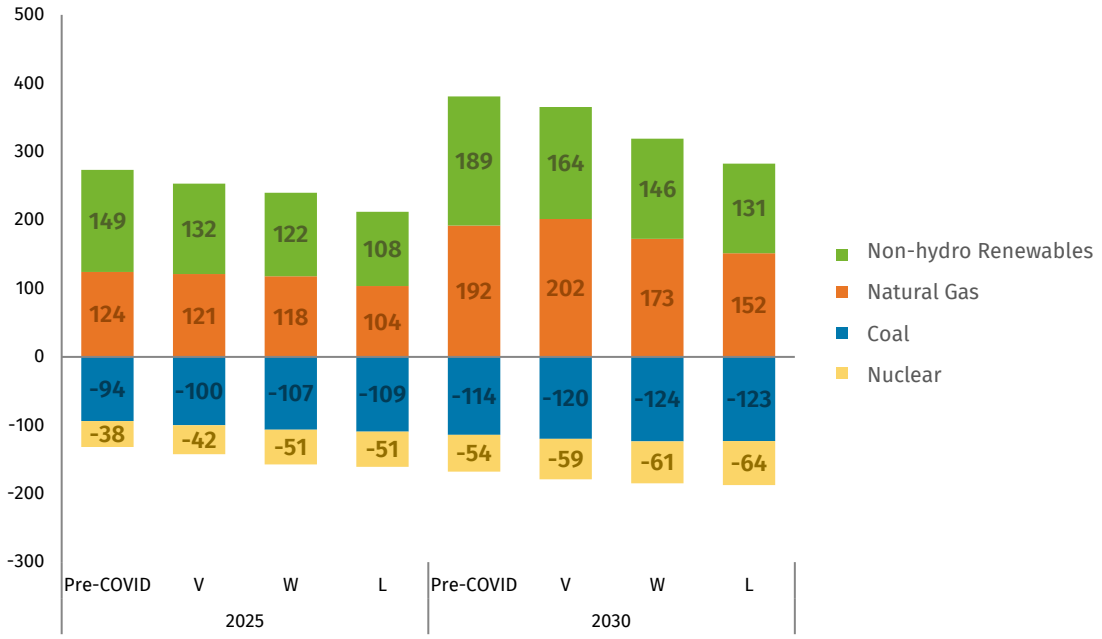
Already in trouble before the pandemic, coal gets hit even harder in our post-COVID scenarios. This is because lockdowns and reduced economic activity push

electric demand down. This puts pressure on generators with high operating costs such as coal and nuclear plants. In 2020, coal generation drops 28-31% year-on-year and electric sector emissions fall by 12-15% in our post-COVID scenarios. This marks the lowest electric power sector emissions in the US going back to at least 1973. Despite pandemic conditions, solar and wind continue to grow steadily, spurred by continued cost declines, federal tax credits, and state policies, but at a lower deployment rate than in our pre-COVID baseline. Nearly a gigawatt (GW) of utility-scale wind and solar were added in April 2020 in the deepest part of the lockdown, and an additional 30 GW are under construction and due to come online before 2022. Some of these forthcoming projects may see delays in commissioning due to the pandemic but are unlikely to halt altogether. As a result, in all post-COVID scenarios, wind capacity increases by 45% by 2025 compared to 2019 levels and utility-scale solar capacity increases three or four-fold in the same timeframe.

Despite early disruptions to electric demand, the pandemic does not significantly change current electric power market fundamentals. With wholesale natural gas prices at Henry Hub of $2.5/MMBTU or lower through 2030 across our scenarios, existing and new natural gas plants outcompete existing coal and nuclear. By 2030, coal capacity declines by over 50% relative to 2019 across our post-COVID scenarios, with 97 to 101 GW remaining online. Nuclear capacity declines by 60-66% over the same period. While renewables continue to drop in cost, slack electric demand and a phase-out of incentives slow their growth substantially after 2025.

Post-2025, zero-emitting generation hovers around a third of total power generation, while natural gas generation increases from about a third of the US total to over half by the end of the decade. The net result is that across our post-COVID scenarios, emissions continue to trend downward but they flatten out by the mid-2020s, just as in our pre-COVID baseline but at lower levels. Although power sector emissions remain below 2019 levels through 2030, they begin to tick up from the mid- to late-2020s in every post-COVID scenario.

FIGURE 9
Change in utility-scale electric power capacity from 2019 levels
Gigawatts



Source: Rhodium Climate Service

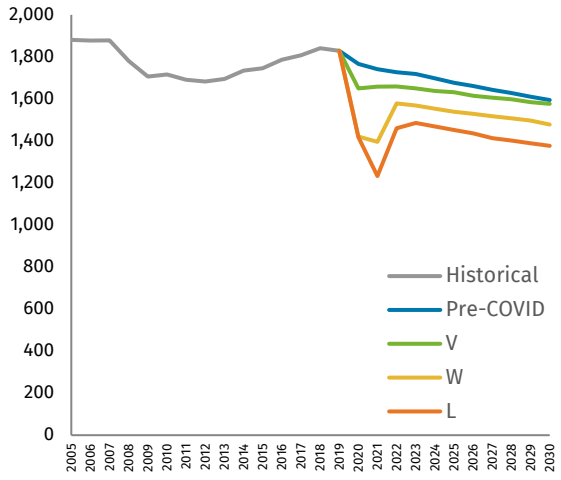
Transportation

Lockdowns deal a major blow to transportation demand, resulting in a steep near-term drop in sector emissions. The long-term impact depends on the pace of economic recovery and lasting behavioral change.

After growing steadily since 2012, transportation emissions have begun to turn a corner, falling slightly in 2019. In our pre-COVID baseline, transport emissions from fossil fuel combustion fall by 3% in 2020 (reaching 6% below 2005 levels), driven largely by fuel economy improvements in passenger vehicles and a slowing of vehicle miles traveled (VMT) growth. From there, emissions gradually decline to 11% below 2005 levels by 2025 and 15% by 2030. The pace of emissions reductions is slowed in part by weaker fuel economy standards adopted by the Trump administration for passenger vehicle model years 2021-2026.

In our post-COVID scenarios, we expect the crisis to continue to disrupt transportation more than any other energy sector. The extent of the disruption depends on whether there are additional restrictions, the rate of economic recovery, and the pace and extent to which Americans feel comfortable resuming their pre-COVID commutes, non-essential trips, and air travel.

FIGURE 10
Energy-related transportation sector emissions
Million metric tons CO_2e



Source: Rhodium Climate Service

In the V-shaped recovery scenario, personal and commercial travel demand continues to pick up through the summer. Transportation emissions dip by 10% in 2020 before declining more gradually, reaching 3% below pre-COVID by 2025 and 1% below by 2030.

In the W scenario, a second wave reverses the recent rebound in travel demand, bringing 2020 emissions down 22% year-on-year. Emissions remain between 7 and 9% below the pre-COVID baseline from 2022 through 2030, reflecting lasting economic damage and a prolonged drop in commuter and leisure travel.

In the L scenario, travel demand does not begin to recover until 2022, after which weaker economic growth and a more pronounced shift in travel patterns keep emissions between 13 and 14% below pre-COVID levels through 2030.

Industry

The pandemic dampens the steady rise in industrial emissions, but industry remains on track to become the largest emitting sector in the next six years.

Cheap natural gas and growing domestic oil production in recent years has bolstered industrial activity, driving up emissions. In our pre-COVID baseline, industrial emissions, including methane leakage from upstream oil and gas production and pipelines, increase 3% in 2020 and continue to rise through 2030.

In the V scenario, industrial emissions fall by 5% year-on-year in 2020. As economic growth resumes, emissions rebound to pre-lockdown levels by 2021. Emissions continue to rise but remain 2-3% below pre-COVID baselines through 2030. In the W scenario, a second wave of lockdowns pushes emissions down by 8% year-on-year in 2020, and a sluggish recovery keeps industrial emissions at 6% below pre-COVID baseline through 2030. In the L scenario, it is 2029 before industrial emissions return to pre-pandemic levels.

The oil and gas sector, accounting for more than a fifth of industrial emissions in 2019, has taken a big hit in the early stages of the COVID pandemic. If the recent boom in oil and gas production were to continue without the

demand shock of the pandemic, the sector would have seen a 6% increase in emissions between 2019 and 2020. Instead, the economic downturn coupled with a collapse in oil prices has led to dramatic cuts in domestic oil and natural gas production. As a result, emissions fall by 0.5-2% in 2020 across our post-COVID scenarios. They rebound in 2021 but remain 1-5% below our pre-COVID baseline through 2030.

Regardless of the path to recovery, industrial emissions ultimately resume their upward trajectory, putting industry on track to become the largest source of US emissions by no later than 2026.

Buildings

Building emissions remain the least impacted by COVID-19, as declines in commercial building energy use are offset by higher residential energy demand.

Even in the absence of the crisis, emissions in buildings were expected to fall 6% in 2020 due to a relatively warm winter. The pandemic is expected to drive building emissions down this year by an additional 1-2%. This is the net effect of an anticipated rise in residential energy demand as Americans spend more time at home, and a decline in commercial building energy consumption due to shuttered businesses.

Building emissions recover in 2021 but remain at 1-2% below pre-COVID baseline levels through 2030 in the V scenario. In the W and L scenarios, emissions remain at roughly 3-6% below pre-COVID baselines through 2030, respectively, reflecting lower building occupancy and the slow pace of new office and home construction.

After early setbacks from COVID-19, building emissions in all scenarios gradually climb as cheap natural gas and slow stock turnover hinder efficiency improvements and delay fuel switching from fossil to electricity.

CHAPTER 4

Opportunities for a Green Recovery

The enormous toll of recession-driven emission reductions

The emission reductions associated with our scenarios, while sizeable, are certainly no cause for cheer. The economic damage and human suffering of COVID-19 has already been substantial and will likely continue for some time. Even if a V-shaped recovery occurs, this will have been the largest economic crisis since the Great Depression and the deadliest pandemic since the 1918 flu. If there is a second outbreak later this year, or, absent that, if business and household finances unravel faster than currently expected, the economic consequences of the crisis could persist for years.

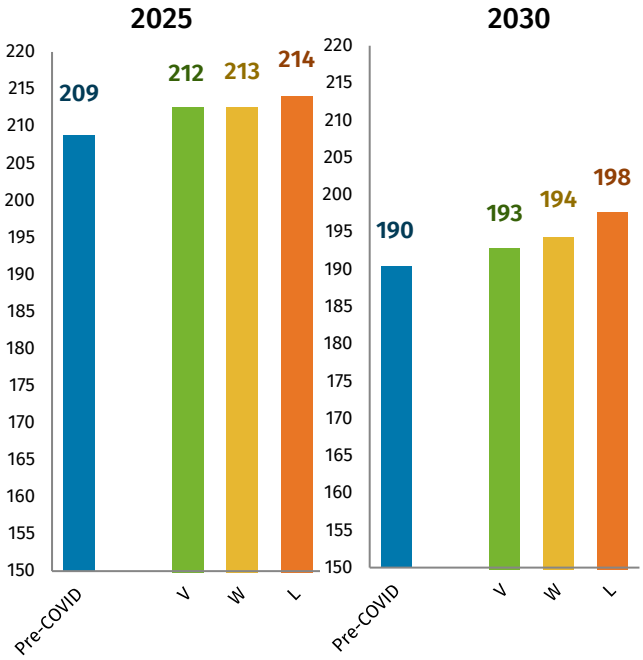
Climate policy and technology is often assessed for cost-effectiveness on the basis of dollars per ton of CO_2 emissions avoided. For example, Gillingham and Stock (2018) use this metric to evaluate the cost-effectiveness of a wide range of emission-reduction policies and technologies in the US. They find that onshore wind reduces CO_2 emissions at $24 per ton and utility-scale solar at $27 per ton. The Obama administration's Clean Power Plan would have reduced emissions at $11 a ton according to Gillingham and Stock, and relatively expensive renewable fuel subsidies cost $100 a ton.

Compared to this, the emission reductions achieved this year as a result of COVID-19 are incredibly costly. We estimate the US will spend between $3,200 and $5,400 of lost economic output per ton of emissions avoided, depending on the shape of the recovery scenario.

Without new policy, no progress toward transformational change

The carbon intensity of the US economy has been on a steady downward decline for decades as increases in output have outpaced emissions. Secular shifts towards services and away from manufacturing have also played a role. COVID-19 will leave a legacy of a more carbon intensive economy compared to our pre-COVID baseline without additional policy action. In 2025, the US economy will emit 4-5 tons more CO_2 per million dollars of GDP compared to pre-COVID levels (Figure 11). The spread grows over time to as much as 8 tons more in 2030. This further illustrates the lack of structural change in the US energy system towards decarbonization from COVID-19 and is one more example of why the emission reductions we see in our scenarios are nothing to cheer about.

FIGURE 11
Carbon intensity of the US economy
Metric tons CO_2 / $ million GDP



The good news is the future is not set in stone. The US can decarbonize by developing and deploying low-carbon technologies and investing in clean energy infrastructure for a small fraction of the cost of what we are experiencing right now due to COVID-19. Indeed, made in the wake of the current crisis, those

investments (if well-designed) will have negative abatement costs as they will help accelerate the recovery and reduce the risk of our L-shaped economic scenario coming to pass.

As the federal government and states contemplate any further responses to the pandemic and the recession, we will be tracking developments and analyzing leading proposals. Through 2020 and into next year, we will assess green recovery policy ideas for their potential to put people back to work and spur economic growth while also quantifying their potential to cut emissions and drive clean technology deployment.

Explore the data

Rhodium's annual Taking Stock report provides objective, up-to-date analysis of GHG emissions under potential economic, technology, and policy action at the US federal and state levels in a framework consistent with accounting methodologies of the US government and United Nations Framework Convention on Climate Change. This report offers an overview of our national results for 2020. For more granular detail on our results, Rhodium's Climate Service provides direct access to all emissions data from Taking Stock as well as 50-state emissions and energy data (broken down by sector and by gas). Climate Service subscriptions include interactive data visualizations of a wider range of energy market and policy scenarios, as well as research coverage of key developments in US energy and climate policy.

TABLE 3
US GHG emissions under COVID-19 uncertainty
Million metric tons of CO_2e, ranges provide estimates that span our V, W, and L recovery scenarios

Gas	2005	2018	2020			2025			2030		
Carbon Dioxide	6,132	5,425	4,471	to	4,799	4,463	to	4,843	4,431	to	4,835
Methane	680	634	600	to	606	583	to	622	574	to	620
Nitrous Oxide	432	434	426	to	427	380	to	409	373	to	411
HFCs	129	172	167	to	169	179	to	193	189	to	208
Other F-Gases	19	11	9	to	10	8	to	9	7	to	8
Gross GHG emissions	7,391	6,676	5,672	to	6,011	5,613	to	6,075	5,575	to	6,083
Carbon Removal*	-815	-774	-840			-830			-780		
Net GHG emissions	6,577	5,903	4,832	to	5,171	4,783	to	5,245	4,795	to	5,303
% change from 2005	*0%*	*-10%*	*-27%*	*to*	*-21%*	*-27%*	*to*	*-20%*	*-27%*	*to*	*-19%*

Source: Rhodium Climate Service. Columns represent the minimum and maximum annual net US emissions given potential economic, energy market, policy and carbon removal outcomes.
*Includes Land Use Land Use Change and Forestry (LULUCF) and carbon capture and sequestration.

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