The impact of methane leakage on achieving Clean Power Plan emission goals

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SUMMARY: The EPA's Clean Power Plan aims to cut 32% of power sector greenhouse gas emissions by 2030, for the first time regulating climate pollutants from the sector responsible for the largest portion of these emissions. However, if upstream methane emissions are not taken into consideration, these efforts may fall far short of achieving real reductions of this magnitude across the lifecycle of electricity generation. The EPA has projected that CO_2-equivalent (CO_2e) emissions from electricity generation will fall to 32% below 2005 levels under the Plan, but attributes nearly half of those reductions to historic coal-to-gas switching between 2005-2013, and projects continued switching in the coming years. However, this calculation does not reflect the full climate impact of methane leakage across the natural gas system, which erodes the climate benefits of switching to gas.

Methane is a much more powerful greenhouse gas than CO_2, and numerous recent scientific studies have found leakage rates to be much higher than reflected in the EPA's Greenhouse Gas Inventory. Here, we consider the impact of methane leakage rates from 1-6% on achieving the Plan's targets, reflecting these recent scientific findings. While the 32% emission target is achieved under the low leakage rate of 1.5% found in the Inventory, the EPA's Clean Power Plan compliance scenarios only reduce emissions by about 28-29% at a 4% leakage rate when using the 100-year global warming potential for methane; using a 20-year timeframe and 4% leakage, the emission reductions under these compliance scenarios are only 22-23%. The upper limit of the leakage range evaluated, at 6%, brings these reductions below 20%. We next introduce two scenarios with higher renewable energy mixes: in the first we deploy the full renewable energy potential calculated by the EPA, and in the second we assume that the maximum historic annual growth rate of renewables is achieved every year beginning in 2020. We find that even with high methane leakage rates, the Plan's targets can be achieved or even surpassed by adopting such renewable-based energy mixes. This finding suggests that reducing the climate impact of electricity generation requires a greater focus on curbing upstream methane leakage rates or, even more reliably, that state implementation plans encourage the continued growth of renewables to match these historic national deployment rates.

1 Introduction

The power sector is the single largest contributor to U.S. greenhouse gas emissions [1], and therefore the reduction of these emissions is critical for mitigating the risks of climate change. The U.S. Environmental Protection Agency (EPA) released the Clean Power Plan in August, 2015, to set the first national carbon pollution standards for power plants and curb greenhouse gas emissions from electricity generation. Under the rule, states are required to develop implementation plans to meet state-specific emission targets, with an overarching goal of reducing greenhouse gas emissions from the power sector in 2030 by 32% from 2005 levels [2].

The EPA introduced three carbon-cutting "building blocks" to achieve these targets: 1) improved efficiency at coal plants; 2) switching generation from coal to natural gas combined cycle (NGCC) plants; and 3) displacing fossil generation with renewable resources like wind and solar generation. However, the calculation of these emission reductions does not reflect the most recent research on lifecycle greenhouse gas emissions, and therefore the upstream methane emissions from gas production may greatly reduce the real climate benefits of the EPA's projected Clean Power Plan compliance scenarios.

Recent studies (e.g., [3, 4, 5]) have suggested that fugitive methane emissions from natural gas systems may be much higher than reflected in the EPA's Greenhouse Gas Inventory [1], meaning that the actual climate benefit of switching coal to gas for electricity generation is likely much lower than estimated by the EPA.

> “... *upstream methane emissions from gas production may greatly reduce the real climate benefits of the EPA's projected Clean Power Plan compliance scenarios.*”

According to the EPA's greenhouse gas estimation methodology, nearly half of the Clean Power Plan's 32% emission reduction target had already been achieved by 2013 [6], due in part to coal-to-gas switching fueled by the U.S. shale gas boom. The Integrated Planning Model, used by the EPA to calculate electricity mixes and costs under different policy constraints, only reflects combustion-related CO_2e emissions. In an Appendix to the Regulatory Impact Analysis for the Clean Power Plan, the EPA assessed the impact of the Plan on upstream methane emissions, but used outdated values for methane's global warming potential and lower leakage estimates than found in the latest field measurements [6]. If current fugitive methane emissions from the oil and gas sector are as high as those found in these recent field measurements, then both historic and projected coal-to-gas switching for Plan compliance will mean the power sector will fall short of 2030 goals when accounting for lifecycle greenhouse gas emissions.

Under the Clean Power Plan, states have an opportunity to develop their own compliance plans to meet emission reduction goals. States can use different resource mixes than those projected by the EPA to meet or even surpass the Plan's targets, including higher levels of efficiency and renewables. Here, we compare the greenhouse gas emissions of the EPA's projected base case and EPA-modeled Clean Power Plan compliance cases to two higher renewable energy scenarios we designed based on the EPA's own calculations of potential renewable resources. We analyze a range of upstream methane leakage rates found in recent studies or reflecting Administration targets (1-6%), use the most recent consensus values for the global warming potentials of methane from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) [7], compare the 20-year and 100-year timeframes of these global warming potentials, and assess the ability for each resource scenario to achieve Clean Power Plan emission reduction targets when fully accounting for fugitive methane emissions with the most current science.

2 Methane leakage

The objective of this report is not to investigate greenhouse gas emissions themselves, but rather to analyze the impact of lifecycle greenhouse gas emissions on the effectiveness of the Clean Power Plan. We therefore draw from greenhouse gas emission estimates from the scientific literature to perform this analysis. Greenhouse gas emissions from electricity generation include both direct emissions from fuel combustion and indirect emissions, such as the leakage of methane from other parts of the natural gas system before the gas reaches a power plant. Methane emissions include gas vented or leaked during production, processing, transmission, distribution, storage and end-use across the natural gas system.

The rate of emission of such fugitive methane from natural gas systems, nationwide and across the entire lifecycle from drilling to power plant, is currently highly uncertain. The U.S. Greenhouse Gas Inventory developed by the EPA reported a nationwide, lifecycle emission rate of around 1.5% of total methane well withdrawals [1], calculated using a bottom-up approach by summing all of the industry-reported estimated emissions from each individual component and process across the natural gas system.[1] About two thirds of these reported emissions occur during production and transmissions/storage, while the remaining third occurs during processing and distribution.

However, an increasing number of recent peer-reviewed studies have found significantly higher natural gas system leakage rates, primarily using top-down approaches that measure atmospheric concentrations of methane *in situ*. The results from such field measurements present competing issues for their interpretation. These studies report emissions from only portions of the lifecycle, and suggest strongly that the EPA estimate is too low. However, these studies also measure emissions regionally, not nationally, so there remains uncertainty concerning how representative each study is on a national scale. For example, studies of individual gas fields have found a mean leakage rate of 4.1% over Colorado's Denver-Julesburg Basin [5], 8.9% over Utah's Uinta Basin [9], and 9.1% and 10.1% over the Eagle Ford and Bakken, respectively [10], with significant uncertainty associated with many of these measurements. A few papers [11, 12] have found lower regional emission rates, although, once again, these studies did not measure complete lifecycle emissions and are therefore not directly supportive of the current EPA estimate. Moreover, the accuracy of the methane sensors used in Allen *et al.* [11] has been called into question by Howard [13, 14].

With such a large range of uncertainty between the nationwide, lifecycle EPA bottom-up estimate and the regional, less-than-lifecycle actual top-down measurements, we must base our analysis on a range of potential emission rates. The low end of this range, 1%, falls below the scope of current Administration efforts to identify and remediate methane leaks from oil and gas production [15]. The high end, 6% of production, is a rough estimate of an upper limit for nationwide, lifecycle natural gas leakage if fugitive methane emissions are on the high end of estimates and all measured excess methane is attributable to the natural gas sector [16]. As we demonstrate in this report, emission rates much lower than this estimated upper limit are sufficient to erode the potential for the Clean Power Plan to meet its emission reduction goals.

3 Energy scenarios

The EPA developed state-specific emissions targets under the Clean Power Plan by first calculating potential deployment levels for each of its three suggested forms of emission reductions (coal plant efficiency, coal-to-NGCC switching, and renewables growth) across the three grid interconnects – Eastern, Western and Texas. The EPA then applied these regional targets to the resource mix in each state. Targets are given either as a reduction in the rate of emissions (lbs CO_2/MWh) or reduction in total mass of emissions (short tons CO_2). The EPA employed ICF's Integrated Planning Model (IPM) to assess the least-cost pathways and resource mixes to comply under the rate-based and mass-based plans, and compared the results to a base case built on the Annual Energy Outlook (AEO) from the U.S. Energy Information Administration (EIA). The EPA's rate-based and mass-based compliance scenarios assume an annual demand-side efficiency savings of 1% per year, ramping up from each state's current efficiency savings by 0.2% per year be-

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[1] This 1.5% value was revised upward in the April 2016 Greenhouse Gas Inventory, which was released after this analysis was performed [8].

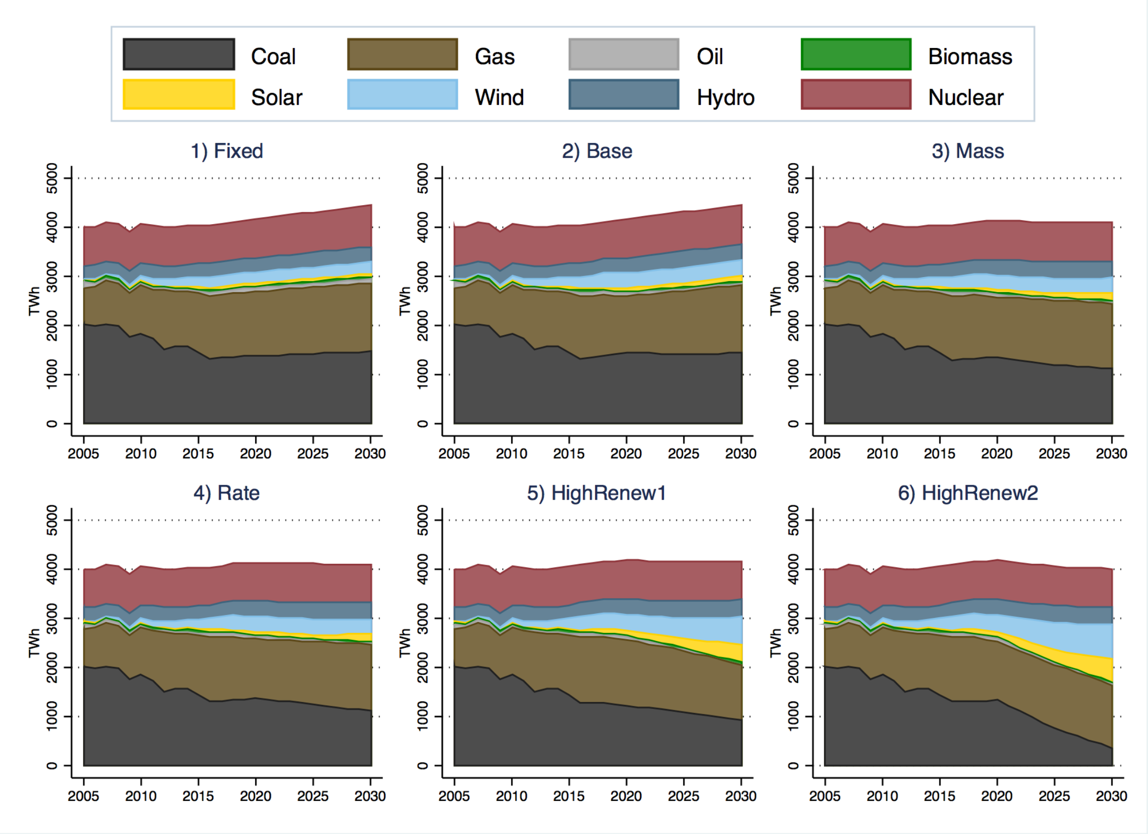

Figure 1: Electricity generation resource mixes from 2005-2030 for six scenarios: 1) fixed resource mix; 2) EPA base case; 3) EPA mass-based Clean Power Plan compliance case, 1% efficiency; 4) EPA rate-based Clean Power Plan compliance case, 1% efficiency; 5) high renewable scenario using full EPA renewable resource potential and 1.3% efficiency; and 6) high renewable scenario using maximum EPA renewable resource growth rate beginning in 2020, 3.1% rooftop solar by 2030, and 1.5% efficiency.

ginning in 2020 until the 1% target is met.

In Figure 1, we show the electricity generation resource mix from 2005-2030 for each of the scenarios we analyze. The first “fixed” scenario is based on a constant mix of today’s resources and projected demand growth from the “base” case. The next three scenarios were developed by the EPA and include the base case and two Clean Power Plan compliance scenarios (rate- and mass-based). Finally, we include two additional high-renewable, high-efficiency scenarios. In order to comply with the EPA’s emission reduction targets, it is not necessary to deploy the full potential capacity of renewable energy resources used to calculate the regional targets (Building Block 3). As a result, non-hydro renewables are under-utilized and provide only 12% of generation in the EPA’s rate- and mass-based compliance scenarios. We therefore deployed these higher potential levels of renewables in our final two scenarios to illustrate how wind, solar and other resources can help meet and exceed emission reduction goals.

The EPA scenarios also include lower levels of annual efficiency savings than are achievable and ramp up these savings slowly, so we include higher rates of efficiency to reflect full deployment of this resource potential. In the HighRenew1 scenario, we assume a demand-side efficiency savings of 1.3% per year, and in the HighRenew2 scenario a demand-side efficiency savings of 1.5% per year. Both efficiency rates are reached by ramping up from present-day savings by 0.5% per year beginning in 2020 (Figure 1). The EPA reports that in 2013, 15 states had an annual incremental efficiency savings of greater than 1%, with a high of 2% in Rhode

Island, so these rates fall in the range of historic demand-side efficiency savings [17]. We note that these levels of efficiency, while achievable, would require a concerted effort to accelerate efficiency in regions that have historically limited experience in this area; in the results section we will discuss the impact of achieving only the 1% annual savings used by the EPA.

In addition to efficiency, we include a higher level of renewable energy in these two HighRenew scenarios, with our first case based on the full deployment of renewable energy capacity included in the EPA building block calculations. The EPA itself ran a separate IPM model with full deployment of the potential renewable energy capacity used to calculate state targets, but included lower efficiency savings. In our HighRenew1 scenario, we deploy the full renewable energy resource potential and assume that it displaces a mix of coal and gas, ultimately reaching the same proportion of coal generation to gas generation as in the mass-based compliance case (although with a lower net level of fossil generation). Although the EPA calculated its regional targets by assuming renewables displaced coal and gas in proportion to existing generation mixes, we consider it unlikely that both fuels would be displaced at the same rate given current electricity generation trends and projections that the Clean Power Plan is expected to reduce coal generation; therefore we deem the EPA's compliance case to provide a reasonable ratio of coal to gas under Clean Power Plan regulations. The HighRenew1 scenario yields a final resource mix of 21.7% renewable energy (excluding hydropower) in 2030. We note that some regions, such as California, have already have surpassed this fraction of in-state renewable generation [18], and therefore these levels should be very achievable.

In HighRenew2, we instead use the potential renewable energy *growth rate* assumed by the EPA, but assume this growth begins in 2020 rather than waiting until 2024. To calculate the renewable energy resource potential, the EPA first calculated the historic average and maximum annual renewable energy additions from 2010-2014. They added this average renewables growth rate to base projections beginning in 2022, and this maximum growth rate beginning in 2024. For the HighRenew2 scenario, we assume this average renewable energy growth rate continues until 2020, and then growth increases to the maximum historic annual growth rate for the years 2020-2030. In short, we assume the historic maximum deployment rate would be achieved again in 2020, rather than delayed until 2024. This approach yields a final renewable energy fraction of 26.3% of utility-scale generation. Unlike the IPM model we also include the deployment of rooftop solar following Lawrence Berkeley National Laboratory reference estimates [19], reaching 3.1% of total demand in 2030. This deployment rate is still lower than projected for the U.S. Department of Energy's SunShot Initiative [20] and is likely to prove conservative. We assume that these resources primarily displace coal, which would require a targeted focus on reducing coal generation on the grid. Overall, these efficiency and renewable energy deployments fall within the scope of the EPA's estimates, but are simply deployed on an accelerated timeline, rather than waiting until 2024 to reach maximum deployment; these levels have been historically demonstrated and are at a similar rate to recent years.

4 Results

We analyzed the emission reductions from our six energy resource scenarios (fixed, base case, mass-based compliance, rate-based compliance, HighRenew1, HighRenew2) compared to 2005 emissions using a methane leakage range of 1-6% and comparing both 100-year 34x and 20-year 86x

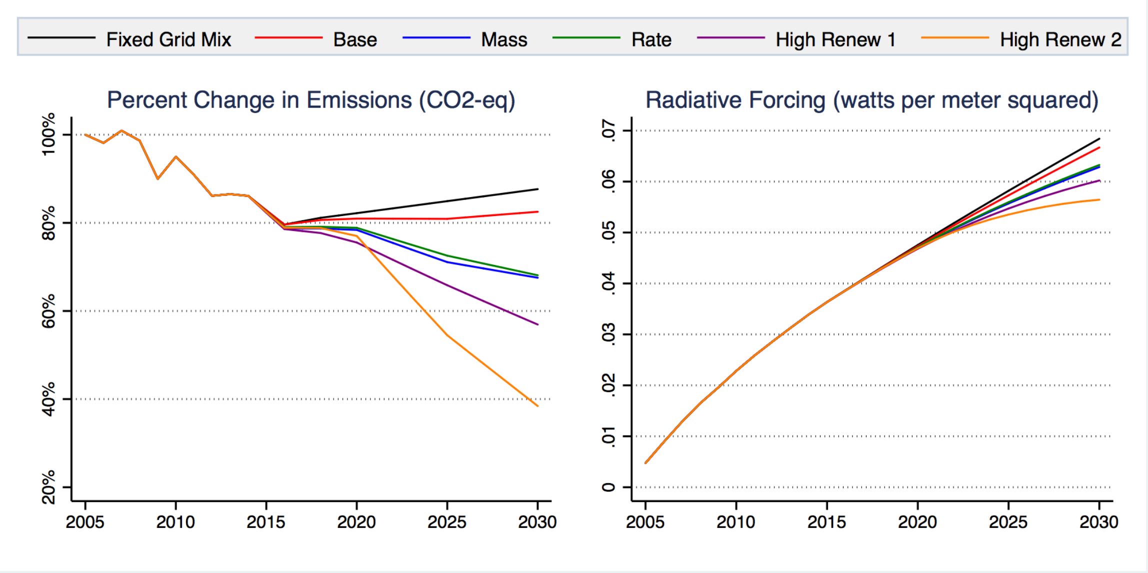

Figure 2: Percent change in power sector CO_2e greenhouse gas emissions from 2005 levels for all six scenarios using the EPA's 1.5% leakage estimate and a 100-year global warming potential for methane; and the radiative forcing for each of these scenarios.

global warming potentials for methane [7]. In Figure 2, we first present the CO_2e greenhouse gas emission reductions from the power sector for each of these scenarios using the EPA's 1.5% methane leakage estimate and typical 100-year timeframe for global warming potential, as well as the resultant radiative forcing from each of these scenarios. The radiative forcing numbers follow the approach outlined in Hausfather (2015) [21]. **The highest renewable energy scenario, under these assumptions, achieves 61% reductions while the base case scenario achieves 17% reductions from 2005 emission levels.**

In Figure 3, we show the impact of upstream methane leakage from oil and gas systems (1-6%) on greenhouse gas emission reductions, calculated using a 100-year methane global warming potential. The EPA estimate of 1.5% leakage is

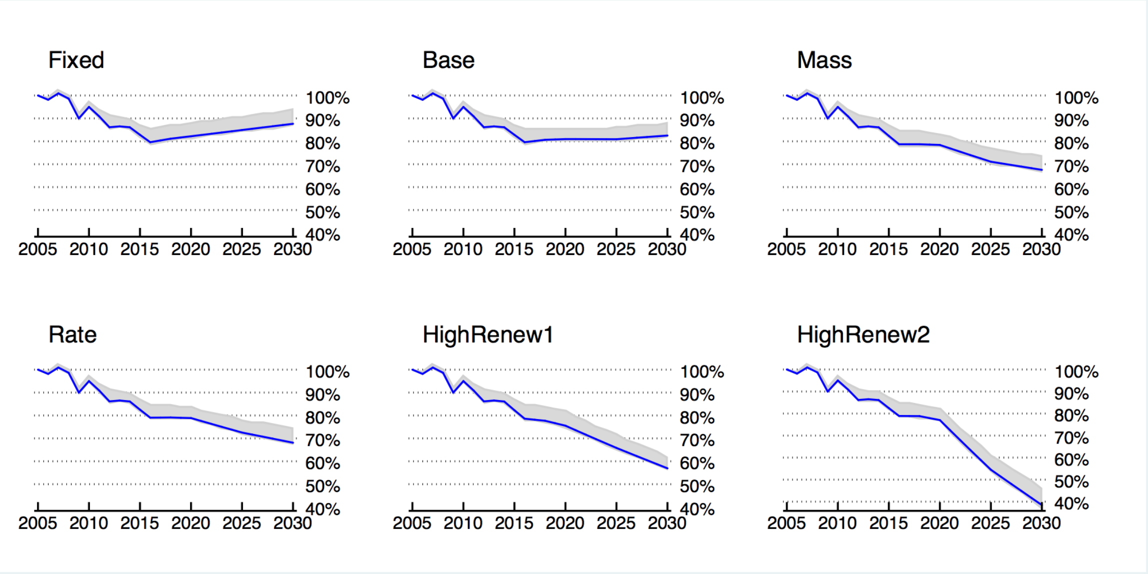

Figure 3: CO_2e emission reductions from the power sector from 2005 levels, showing 1-6% methane leakage range (blue line = 1.5%) and using a 100-year global warming potential for methane.

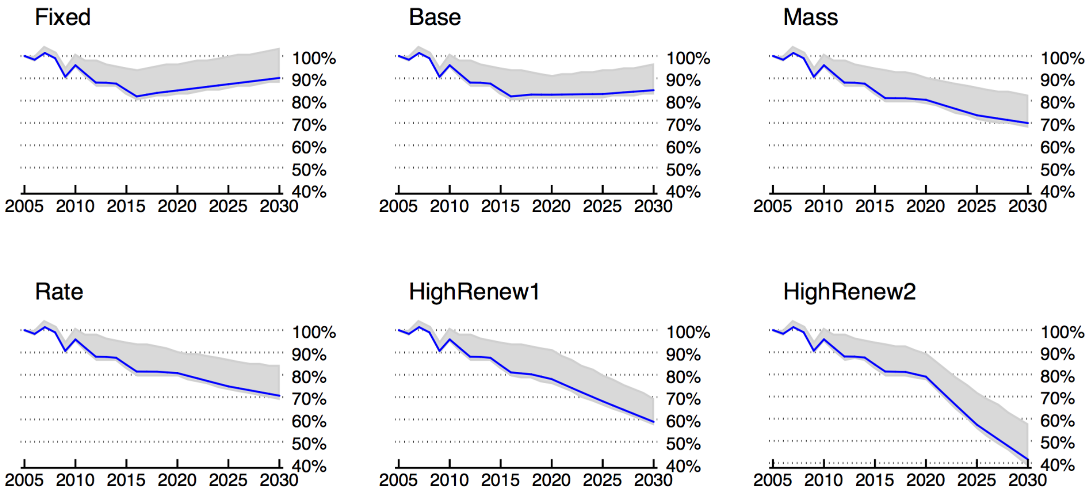

Figure 4: CO_2e emission reductions from the power sector from 2005 levels, showing 1-6% methane leakage range (blue line = 1.5%) and using a 20-year global warming potential for methane.

shown with a blue line. While the rate- and mass-based compliance cases achieve the 32% emission reduction target under low leakage, **at 4% leakage these scenarios reduce emissions by only 28.3% and 29.1%; with 6% leakage these cases only reduce emissions by 25.6% and 26.5% respectively.** Leakage rates would have to be below 1.4% for the rate case and 1.8% for the mass case for the 32% reduction target to be achieved. The high renewable energy cases both easily surpass emission reduction targets. We also note that the base case alone is expected to reduce CO_2e emissions by 17.5% by 2030 under a 1.5% leakage rate, so the compliance scenarios are not much more aggressive than base projections.

In Figure 4, we show the emission reductions for each scenario when taking into account a 20-year global warming potential for methane. Under these scenarios, the emission reduction potential of rate- and mass-based compliance scenarios is significantly eroded unless leakage is very low. **Using a 20-year global warming potential, the rate- and mass-based scenarios achieve only 21.7% and 22.8% CO_2e emission reductions from 2005 levels at 4% leakage, and only 16.6% and 17.9% at 6% leakage.** However, the first renewable energy scenario achieves 32% emission reductions under leakage rates below 5.4% using a 20-year timeframe. The second renewable scenario ensures targets are surpassed under all considered leakage rates. When using a 20-year global warming potential, leakage rates must be below 0.7% for the rate case and 0.9% for the mass case to achieve the 32% reduction target.

We also looked at the sensitivity of a number of the assumptions included in this analysis. If we assume renewables and efficiency primarily displace coal in HighRenew1, rather than a coal and gas mix, we find an additional 7% reduction in greenhouse gas emissions at low leakage rates using a 100-year global warming potential for methane, but less at high leakage rates and even less using a 20-year global warming potential. Targeted displacement of coal provides the greatest greenhouse gas emission reductions, but this effect is much less pronounced at higher leakage rates and over shorter timeframes. We next compare the HighRenew1 scenario (with coal displacement) to a scenario with 1% per year demand-side efficiency savings, rather than 1.3%, and find emission reductions are cut on the order of 3% percent, varying with the timeframe and leakage rate. Even in this lower efficiency rate scenario, however, the Clean Power Plan's emission reduction targets can be exceeded at high leakage rates under a 100-year timeframe and moderate leakage rates under a 20-year timeframe.

5 Discussion

Cutting greenhouse gas emissions from electricity generation is a critical component of reducing U.S. emissions of climate pollutants. However, the power sector is unlikely to achieve the target greenhouse gas emission reductions of 32% of 2005 levels by 2030 if states comply with the Clean Power Plan in alignment with EPA projections, which assume an increase in natural gas generation from current levels, if the upstream methane leakage rate is in the range found in many recent studies. This target shortfall is largely due to historic coal-to-gas switching between 2005 and 2013, which the EPA credits with achieving nearly half of the target emission reductions. If upstream methane emissions are higher than the 1.5% estimated in the EPA greenhouse gas inventory, then the power sector has much further to go to actually achieve these levels of emission reductions. Furthermore, if we consider the 20-year global warming potential of methane, then any increase in methane leakage even more dramatically erodes calculated emission reductions.

Regulatory efforts to curb methane leakage on the state and federal level can help minimize the risk of high leakage rates, but pursuing energy mixes based on renewables and efficiency can ensure that GHG reductions are achieved with more certainty, even if reducing leakage proves difficult. Furthermore, individual states cannot necessarily pursue efforts to reduce the bulk of upstream methane emissions, unless gas production is in-state, suggesting that in many cases the best approach for states to help reduce national upstream methane emissions may be to reduce their reliance on natural gas. States are not required to include upstream methane emissions when developing their Clean Power Plan implementation plans, but doing so would help ensure that their plans yield the greatest benefits to the climate.

States are given significant flexibility in how they can comply with the Clean Power Plan. Those states that hope to achieve the greatest climate benefit can use the opportunity to pursue an electricity resource mix that ensures real reductions in greenhouse gas emissions rather than a mix that is likely to fail to achieve these targets when lifecycle emissions are fully accounted for. We have shown two scenarios that incorporate moderate increases in efficiency and a higher reliance on renewable energy, both based on already achieved historic deployment rates in the U.S. These scenarios would allow the power sector to not only reach but actually surpass the 2030 emission targets, even when accounting for potentially high methane leakage rates. Rather than rely on continued coal-to-gas switching, states can develop plans in line with these scenarios and realize real reductions in greenhouse gas emissions from the power sector to help curb climate change.

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