ARTICLE

THE SECOND ELEMENT, FIRST PRIORITY

STEVEN FERREY[1]

[1] Steven Ferrey is Professor of Law at Suffolk University Law School, served as Visiting Professor of Law at Harvard Law School, and in 2015 he was designated as Distinguished Professor of Energy Law by Vermont Law School. Since 1993, Professor Ferrey has been a primary legal consultant to the World Bank and the U.N. Development Program on their renewable energy and carbon reduction policies in developing countries, where he has worked extensively in Asia, Africa, and Latin America. He holds a B.A. in Economics, a Juris Doctorate, a Master's Degree in Urban & Regional Planning, and between his graduate degrees was a Fulbright Fellow at the University of London. He is the author of seven books on energy and environmental law and policy, the most recent of which are: UNLOCKING THE GLOBAL WARMING TOOLBOX: KEY CHOICES FOR CARBON RESTRICTION AND SEQUESTRATION (PennWell Corp. 2010); THE LAW OF INDEPENDENT POWER, (Thomson/West 44th ed. 2017); ENVIRONMENTAL LAW: EXAMPLES & EXPLANATIONS (Aspen Publishers 7th ed. 2016). He is also the author of more than 100 articles on these topics published in law reviews. Professor Ferrey thanks his research assistant, Nebyu Retta, for his help with research.

I. THE SECOND ELEMENT

The Earth's atmosphere cannot survive inaccurate science. Leaders now admit that they committed a fundamental miscalculation in basic math, pushing world climate to "critical thresholds that will alter regional and global environmental balances . . . ." and "tipping points that are irreversible within the time span of our current civilization."[2] U.S. officials significantly misapplied the critical constant: Time. It is time that we no longer have.

Without a grip on time, national and world policy becomes poorly focused. Traditional climate policy focused on one warming chemical, carbon dioxide (CO_2), the most prevalent greenhouse gas.[3] Policy myopia will miss the (warming) forest for the (chemical) trees. Climate officials dramatically underestimated the second most important warming chemical's impact on climate, when actual real time is the metric. This error is not of only a few percent or a 'rounding error,' but rather distorts actual data and impact by several hundred percent—a miscalculation of Herculean proportions for a small Planet.

Neither U.S. carbon policy nor the United Nations Framework Convention on Climate Change (UNFCCC) correctly calibrated the constant factor of time. The most recent United Nations report from the Intergovernmental Panel on Climate Change (IPCC) concluded that in order to maintain world warming below an additional increase of 2°C, there must be a 40-70% reduction of

[2] *New Science and Developments in Our Changing Environment*, 2009 Y.B. U.N. Env't Programme 21, U.N. Doc. UNEP/GC.25/INF/2.

[3] Marianne Fay et al., *Decarbonizing Development: Three Steps to a Zero-Carbon Future,* at 25, WORLD BANK GROUP [WBG] (2015); *see* Sustainable Development Solutions Network [SDSN] & Institute for Sustainable Development and International Relations [IDDRI], *Pathways to Deep Decarbonization 2014 Report*, at VIII (Sept. 2014), http://unsdsn.org/wp-content/uploads/2014/09/DDPP_Digit.pdf [https://perma.cc/2PY2-DRHW] [hereinafter SDSN & IDDRI] (focusing on carbon dioxide "emissions from the burning of fossil fuels and industrial processes . . . .").

greenhouse gas emissions from their 2010 levels achieved by no later than 2050.[4] A U.S. report also concluded that to limit the increase in temperatures to 2°C above pre-industrial levels, greenhouse gas emissions must be reduced by 80% below recorded 1990 levels by 2050.[5]

This Article navigates the analysis through this additional dimension of real "time." In real time, it is not *annual* carbon emissions often reported by the media, but rather the accumulation of total warming gases over time in the atmosphere which threatens the climate.[6] The impact of short-lived chemicals, particularly methane, the second element altering climate, has been miscalculated as if time and intensity do not matter.

The short-lived global warming chemicals, including methane (CH_4), black carbon ('soot'), and fluorinated gases (F-gases, including hydrofluorocarbons), together in real time are responsible for about 40% of current net climate forcing and change.[7] This is 200%-300% more impact than the approximately 16% that officials have attributed to the chemicals in guiding law and policy.[8] Methane is responsible for most of this much larger 40% share.[9] Methane is the second element, the second most pernicious warming chemical after CO_2, as shown in Figure 1, even *before* calculating the factor of real time, which increases significantly its real impact.[10]

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[4] Intergovernmental Panel on Climate Change [IPCC], *Climate Change 2014 Synthesis Report Summary for Policymakers*, at 20 (2014), https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf [https://perma.cc/HCT3-GEX8]; *see also* Susan Solomon, et al., *Irreversible Climate Change Due to Carbon Dioxide Emissions*, 106 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 1704 (2008).

[5] James H. Williams et al., *Pathways to Deep Decarbonization in the United States: Technical Report*, at xii (Nov. 2015), http://deepdecarbonization.org/wp-content/uploads/2015/11/US_Deep_Decarbonization_Technical_Report.pdf [https://perma.cc/4FZB-PX4M].

[6] *See* Anna LoPresti et al., *Rate and Velocity of Climate Change Caused by Cumulative Carbon Emissions*, 10 ENVTL. RES. LETTERS 1, 6-9 (2015), http://iopscience.iop.org/article/10.1088/1748-9326/10/9/095001/pdf [https://perma.cc/8CJN-5G7G].

[7] CAL AIR RES. BD., PROPOSED SHORT-LIVED CLIMATE POLLUTANT REDUCTION STRATEGY 13 (2016), https://www.arb.ca.gov/cc/shortlived/meetings/04112016/proposedstrategy.pdf [https://perma.cc/P8VV-D2VA] [hereinafter CLIMATE POLLUTANT REDUCTION STRATEGY].

[8] *Global Greenhouse Gas Emission Data*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data [https://perma.cc/52MP-3M8K] (last updated Apr. 13, 2017).

[9] CLIMATE POLLUTANT REDUCTION STRATEGY, *supra* note 7, at 7.

[10] *See*, *Overview of Greenhouse Gases*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane [https://perma.cc/5CHU-ZK22] (last updated Apr. 14, 2017).

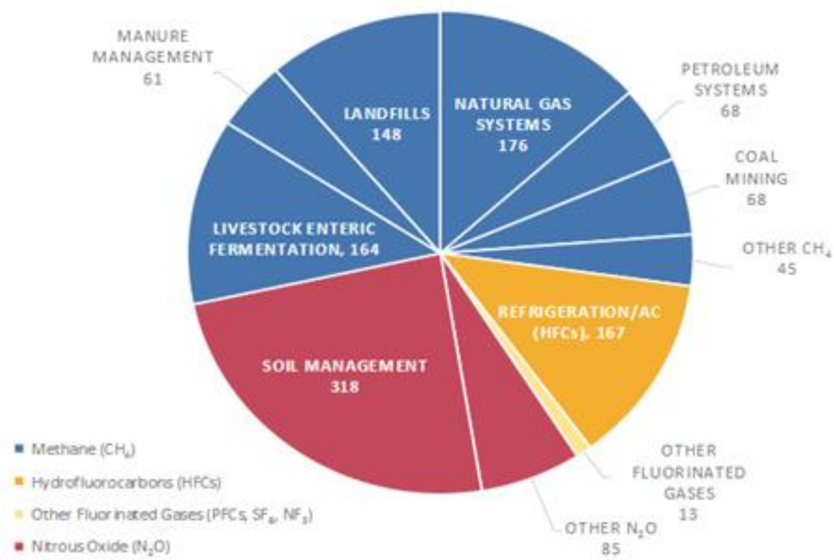

FIGURE 1: Sources of U.S. Non- CO_2 Greenhouse Emissions by Gas, 2014 (MMT CO_2E)[11]

The dominant role of methane, and sources of warming gases that are dissected in this Article, are shown in Figure 2.[12] This Article places international science and policy under a different lens in real time: we analyze methane both quantitatively and qualitatively. This Article develops and outlines necessary corrections in U.S. policy which has underestimated the real-time impact of methane on the Planet's environment.

Methane is a much more significant causative factor than officially calculated, pushing the Earth to its climate warming "tipping point."[13] Warming molecules released anywhere on the Planet, warm the entire world, not just the immediate space where they are released.[14] Methane, misunderstood, is not correctly

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[11] U.S. WHITE HOUSE, U.S. MID-CENTURY STRATEGY FOR DEEP DECARBONIZATION 89 (2016), https://obamawhitehouse.archives.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf [https://perma.cc/4PMV-TWMY] [hereinafter U.S. WHITE HOUSE, DEEP DECARBONIZATION].

[12] *Id.* at 88.

[13] *Id*. at 22.

[14] *See* Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070, 1081 (9th Cir. 2013) ("One ton of carbon dioxide emitted when fuel is produced in Iowa or Brazil harms Californians as much as one emitted when fuel is consumed in Sacramento."); Brief of Ken

estimated in its real-time impact and it is multiplying as a major warming problem.[15]

This Article identifies the magnitude of the critical significant math error and corrects the quantitative record. Next, it critically examines what policies have and have not been implemented, and details all legal policy options for methane emission control in each differentiated sector of the economy. The Article identifies improved 'win-win' policy options, which become imperative once we correctly view the warming emissions problem in the dimension of time. Intelligent policy must follow this metric.

Section II re-examines the science of methane in real time and in all its dimensions: both quantitatively in its growing global impact, and qualitatively in its actual impact in real time. Section II outlines corrections in how policy has underestimated the real-time impact of methane on the Planet's environment and derives corrections for each economic sector. Section III examines legal policy options to stop methane escaping from waste handling in landfills, human waste processing, agriculture, and from coal extraction. Section III analyzes fixes sector-by-sector in real time.

Section IV delves in to the energy core sectors, analyzing the means of methane release from our prodigious use of fossil fuels which powers the modern world economy. Section IV analyzes the impacts of recent and progressing substitution of natural gas for coal to produce electricity, and the substitution of renewable energy sources for electricity generation, assessing their benefits and challenges. Section IV itemizes the U.S. options on methane.

Section V re-sets methane policy and law. While increases of chemical releases, such as CO_2, are principally caused by the growing use of fossil fuels in *developing* countries,[16] recent increases in methane emissions are

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Caldeira, Ph.D., et al. as Amici Curiae Supporting Defendants-Appellants at 27, Rocky Mountain Farmers Union v. Corey, 730 F.3d 1070 (9th Cir. 2013) (Nos. 12-15131, 12-15135), 2012 WL 2376705 ("Greenhouse gas emissions contribute to the problem of global climate change wherever they are emitted."); *Environmental Impact by Energy Source*, ENERGY4ME, http://energy4me.org/all-about-energy/sustainability/environmental-impact-by-source/ [https://perma.cc/2WWK-3PLV].

15 *See infra* Section II.A.

16 *See* Joel Kirkland, *Global Emissions Predicted to Grow through 2035*, SCIENTIFIC AMERICAN (May 26, 2010), https://www.scientificamerican.com/article/global-emissions-predicted-to-grow/ [https://perma.cc/KQ6J-HE5D] (predicting that through 2035, Organisation for Economic Co-operation and Development (OECD) countries are expected to have a 14% increase in energy consumption, while non-OECD countries will have 84% increase in energy consumption); *Developing Countries Are Responsible for 63 Percent of Current Carbon Emissions*, CENTER FOR GLOBAL DEVELOPMENT, https://www.cgdev.org/media/developing-countries-are-responsible-63-percent-current-carbon-emissions [https://perma.cc/GMA6-8NQG] (stating that developing countries are responsible for 63% of carbon emission).

substantially a U.S. phenomenon.[17] In any society that produces waste and uses energy, to successfully address methane requires a much more nuanced and sculpted climate policy. This Article addresses this by differentiating chemicals, correctly calculating their real impact over time, and identifying distinct and differentiated policies for each sector. The initiatives of the Obama Administration are examined to provide context for future legal policy.

II. METHANE IN ITS COMPARATIVE SCIENTIFIC CONTEXT

A. The New Math of Climate Law

Mathematic miscalculations can warp legal policy. The Paris Agreement reached by the UNFCCC Conference of the Parties on Climate Change in December 2015, had almost every country in the world agree to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and to "pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[18] These legal commitments avoid a key reality: The world appears not mathematically able to maintain anything close to this international pledge of no more than a 1.5-2°C temperature increase; instead, world climate is already on a path to reach a temperature increase of at least 4°C.[19]

The three predominant greenhouse gases, CO_2, nitrous oxide, and methane, occur both naturally and as by-products of human activities.[20] The three more minor greenhouse gases, hydrofluorocarbons, sulfur hexafluoride and perfluorocarbons, all are synthetic chemicals manufactured and released only by humans.[21] Methane is, by a large margin, the second most damaging greenhouse gas, after CO_2. According to critical public Environmental Protection Agency (EPA) and UNFCCC policy calculations, methane has twenty to thirty times more greenhouse warming capacity (the ability to trap infrared heat) per molecule than does CO_2.[22] Even a recent EPA press release on the Obama

[17] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90 (stating that "new information from studies of the U.S. oil and gas industry have indicated that methane emissions are much higher than previously understood.").

[18] United Nations Framework Convention on Climate Change, Conference of the Parties, *Paris Agreement*, art. 2.1(a), U.N. Doc. FCCC/CP/2015/L.9/Rev.1 (Dec. 12, 2015), https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf [https://perma.cc/82KR-LQF9] [hereinafter *Paris Agreement*].

[19] SDSN & IDDRI, *supra* note 3, at 4.

[20] STEVEN FERREY, ENVIRONMENTAL LAW: EXAMPLES & EXPLANATIONS 249-50 (7th ed. 2016) [hereinafter FERREY, ENVIRONMENTAL LAW].

[21] *Id.*

[22] STEPHEN H. SCHNEIDER, GLOBAL WARMING: ARE WE ENTERING THE GREENHOUSE

Administration's tightening of methane rules proclaimed that "[m]ethane, the key constituent of natural gas, is a potent greenhouse gas with a global warming potential more than 25 times greater than that of carbon dioxide."[23]

The problem is that this is not accurate because the EPA did not perform its calculations in real time. In fact, a gram of methane absorbs seventy times more infrared radiation than a gram of CO_2.[24] Therefore, in real time methane is approximately eighty-six times more heat trapping than CO_2.[25] EPA and UNFCCC calculations have not factored in time, and have underestimated the role of methane by a factor of approximately 300%-500%—not 25, but 86-105 times more heat retention than molecules of CO_2. This original analysis not factoring in time translates to a major policy miscalculation that jeopardizes the climate future of the fast-warming planet.

This legal policy miscalculation on climate is not a simple problem with application of the 'new' math. It occurred because policymakers have not factored in the impact of time, which is a key additional dimension. Here's the error: The EPA's and UNFCCC's calculation of chemical impact calculates all impacts over 100 years regardless of actual impact; for methane, this arbitrarily and inaccurately dilutes its actual impact in real time, and results in assigning methane a heating value of only 28 to 36 times that of CO_2, rather than 70 times or more.[26]

In other words, calculations incorrectly assume that methane and every other chemical lasts for 100 years;[27] to artificially extend the lifetime of methane by several hundred percent to 100 years, they correspondingly reduce its actual qualitative and quantitative impacts by a similar amount. Therefore, the actual absorption of heat by methane molecules is artificially extended way beyond its real life to a much longer standardized 100 years and its real annual impact is artificially diminished. The reality is that methane does all of its damage in a more concentrated, intense period of slightly more than a decade, before

CENTURY? 101 (1989).

[23] Joe Romm, *How the EPA and New York Times Are Getting Methane All Wrong*, THINKPROGRESS (Aug. 20, 2015), https://thinkprogress.org/how-the-epa-and-new-york-times-are-getting-methane-all-wrong-eba3397ce9e5/ [https://perma.cc/C3YB-EVUD].

[24] HEM S. RAY, ELEMENTS OF CREATIVE MANAGEMENT 175 (2006).

[25] Romm, *supra* note 23. The IPCC Fifth Assessment Report now calculates that a molecule of methane with its calculated lifetime of 12.4 years, exhibits a global warming potential of eighty-six times that of CO_2 (with a value of one) when calculated over twenty years or thirty-four time that of CO_2 when calculated over 100 years. *Id.*

[26] Bill McKibben, *Global Warming's Terrifying New Chemistry*, THE NATION (Mar. 23, 2016), https://www.thenation.com/article/global-warming-terrifying-new-chemistry/ [https://perma.cc/2M9M-CPLF] [hereinafter McKibben, *New Chemistry*].

[27] *See Climate Change Indicators: Greenhouse Gases*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/climate-indicators/greenhouse-gases [https://perma.cc/S3F5-N6ZT] (last updated Feb. 22, 2017).

degrading.[28] These underestimated miscalculations of the actual real-time impact of methane on warming has been repeated verbatim in the national media, by the Washington Post, USA Today, and the Wall Street Journal.[29]

This incorrect math ignores the real dimension of time and grossly underestimates the actual heat-retaining impact of methane in real time on the environment. Using this artificial calculation, the IPCC estimates for a 100-year time period, a molecule of methane is 28-36 times more warming, nitrous oxide is 265-298 times more warming, and various hydrofluorocarbons a thousand to tens of thousands of times more warming, than a molecule of CO_2.[30] A one-hundred year averaged calculation underestimates the real impact of methane. Over its actual real-time ten to twenty-year life, the actual real impact of methane is five times greater than when artificially extended by mathematical calculation over a hypothetical one-hundred years.[31] Correctly adjusting for real time, a Harvard University researcher places the real climate damage of methane at between 86 and 105 times that of CO_2.[32]

In addition to warming, methane in the atmosphere also contributes to tropospheric ozone formation, increasing the quantity of that warming chemical by a significant multiplier,[33] and potentially depleting more stratospheric ozone.[34] Methane, when burned, produces only half as much carbon as burning an equivalent heating value of coal, although when it escapes unburned, it traps heat in the atmosphere 86 – 105 times more than CO_2.[35] These characteristics make methane an extremely potent greenhouse gas, giving it as much as one hundred and twenty times more power to cause global warming than CO_2.[36]

Making only this qualitative adjustment accurately reflecting the additional

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[28] *See* Euan G. Nisbet et al., *Methane on the Rise – Again*, 343 SCIENCE 493 (2014).

[29] Romm, *supra* note 23.

[30] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11.

[31] *See id.*

[32] McKibben, *New Chemistry*, *supra* note 26.

[33] Ivar S. A. Isaksen et al., *Atmospheric Ozone and Methane in a Changing Climate*, 5 ATMOSPHERE 518, 518-519, 521, 528 (2014) (explaining that methane increases tropospheric ozone, a warming chemical, through a current feedback loop multiplier of 1.3-1.5).

[34] *See* Inst. for Governance & Sustainable Dev., Primer on Short-Lived Climate Pollutants 14–15 (Nov. 2013) (unpublished manuscript), http://www.igsd.org/documents/PrimeronShort-LivedClimatePollutantsNovemberElectronicversion.pdf [https://perma.cc/L25B-2DFR] (noting that methane also contributes to global background levels of ozone in the lower atmosphere (troposphere)).

[35] McKibben, *New Chemistry*, *supra* note 26.

[36] U.S. ENVTL. PROT. AGENCY, METHANE EMISSIONS AND OPPORTUNITIES FOR CONTROL 20–21 (1990) [hereinafter U.S. EPA, METHANE EMISSIONS] (publishing the findings of two international workshops sponsored by the IPCC, which focused on current methane emissions and opportunities to control these emissions).

dimension of time alone will not rectify incorrect legal policy. It is not as simple as stating that methane has three to five times the qualitative and quantitative impact previously calculated, although it disappears in one-fifth to one-third of the time. Time and quantity dimensions interact. Contrast the traditional 2010 data quantification of methane's impact as only 16% of greenhouse gas impact in Figure 2, with the even larger methane true actual impact adjusted for real time, as explained below.

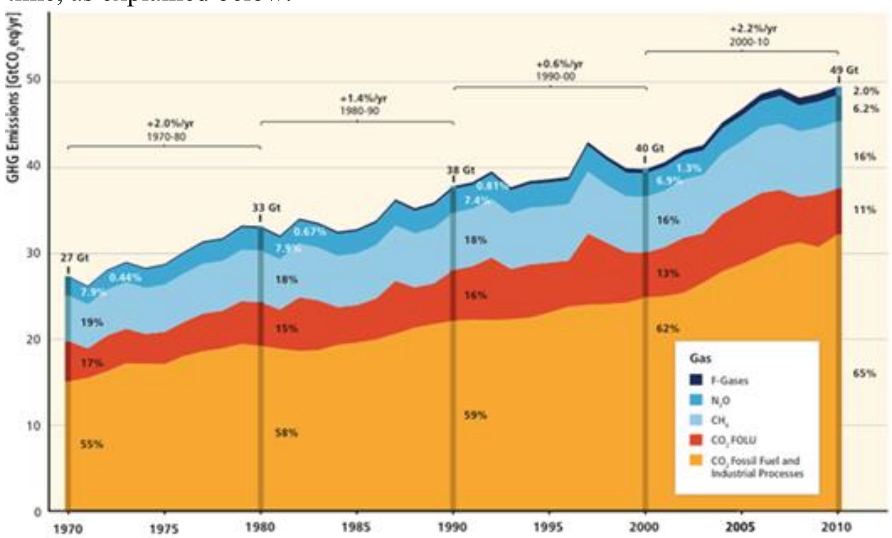

FIGURE 2: Total Annual Anthropogenic Greenhouse Gas Emissions by Groups of Gases 1970-2010[37]

Consequently, these assumptions have misrepresented the supposed success of U.S. climate policy. The EPA stated that methane was almost 10% of total greenhouse gas emissions in the United States in 2015, exceeding 26,000 kilotons of emissions.[38] Based on average emission rates, this probably understates total methane emissions.[39] Contrary to recent EPA reports of

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[37] IPCC, *supra* note 4, at 5.

[38] U.S. ENVTL. PROT. AGENCY, EPA 430-P-17-001, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2015 ES-5 to ES-7 (2017), https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf [https://perma.cc/2QK3-F9PQ] [hereinafter EPA, 1990-2015 INVENTORY OF EMISSIONS AND SINKS].

[39] *See* ROMANY WEBB, SAFETY FIRST, ENVIRONMENT LAST: IMPROVING REGULATION OF GAS PIPELINE LEAKS 18-19 (2015), http://kbhenergycenter.utexas.edu/files/2015/09/FINAL-White-Paper-Safety-First-Environment-Last-09-24-15.pdf [https://perma.cc/EZQ5-GTTK].

decreased greenhouse gas emissions during the past decade,[40] nationwide satellite data over more than a decade shows that U.S. methane emissions increased 30% over the past fifteen years, and total U.S. greenhouse gas emissions consequently increased, rather than decreased as officially reported by EPA.[41] New Harvard University research data suggests that the natural-gas infrastructure has been bleeding methane into the atmosphere in record quantities:

> The EPA insisted this wasn't happening, that methane was on the decline just like CO_2. But it turns out, as some scientists have been insisting for years, the EPA was wrong. Really wrong. . . . These leaks are big enough to wipe out a large share of the gains from the Obama administration's work on climate change . . . . In fact, it's even possible that America's contribution to global warming increased during the Obama years.[42]

Figure 3 shows the EPA official estimate of recent great success reducing the emission of global warming gases. During 2014, the EPA reported that U.S. methane emissions totaled 731 million metric tons of CO_2-equivalent.[43] Harvard research suggests that the EPA does not correctly estimate this success, and there may be an actual increase instead of reduction of warming chemical accumulation in the U.S.[44] The United States was responsible for approximately 11.2% of worldwide methane emissions in 1970, and 6.2% of worldwide methane emissions in 2012.[45] Petroleum and natural gas were responsible for 28% of U.S. methane emissions with the energy sector responsible for 41% of U.S. methane emissions.[46]

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[40] *E.g.*, U.S. ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2014 2-21 (2016), https://www.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-main-text.pdf [https://perma.cc/G5JR-4GW2] [hereinafter EPA, 1990-2014 INVENTORY OF EMISSIONS AND SINKS] (stating that U.S. landfill methane emissions have decreased 17.6% since 1990).

[41] McKibben, *New Chemistry*, *supra* note 26 ("Instead of peaking in 2007 and then trending downward, as the EPA has maintained, our combined emissions of methane and carbon dioxide have gone steadily and sharply up during the Obama years . . . . We closed coal plants and opened methane leaks, and the result is that things have gotten worse. . . . Under the worst-case scenario—one that assumes that methane is extremely potent and extremely fast-acting—the United States has actually slightly increased its greenhouse-gas emissions from 2005 to 2015.").

[42] *Id.*

[43] EPA, 1990-2014 INVENTORY OF EMISSIONS AND SINKS, *supra* note 40, at ES-6.

[44] McKibben, *New Chemistry*, *supra* note 26.

[45] *Methane Emissions*, WORLD BANK, https://data.worldbank.org/indicator/EN.ATM.METH.KT.CE?view=chart [https://perma.cc/S7E9-BFND].

[46] U.S. ENERGY INFO. ADMIN., DOE/EIA-0573(2009), EMISSIONS OF GREENHOUSE GASES

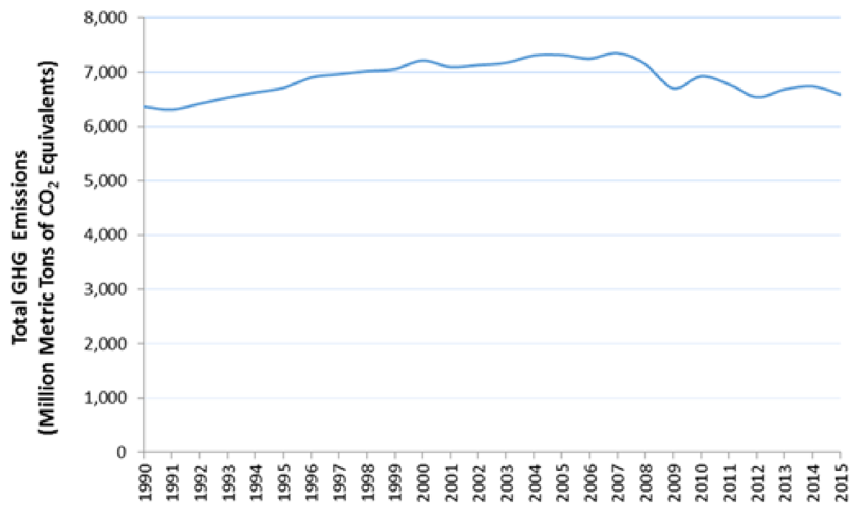


FIGURE 3: Total U.S. Greenhouse Gas Emissions, 1990-2015[47]

B. Reorienting Policy to Control Methane

Where does it come from? Where does it go? Methane is produced by bacteria that adapt to relatively oxygen-free environments including the intestinal tracts of animals, bogs, marshes, rice paddies, arctic permafrost, and garbage landfills.[48] It remains a potent climate pollutant, when assessed in real time that is approximately 86 times more powerful than CO_2 in trapping and retaining heat over a twenty-year timeframe with an even higher multiplied impact when normalized over a decade.[49] Such normalized impact is a more accurate metric, although it is only 34 times more powerful when math is used to spread it over an artificial 100 years.[50]

In actual time, data indicates that methane levels in the atmosphere increased

IN THE UNITED STATES 2009 35, 37 (2011), https://www.eia.gov/environment/emissions/ghg_report/pdf/0573%282009%29.pdf [https://perma.cc/4EPE-Z5LV] [hereinafter DOE/EIA-0573(2009)]; *see infra* Figure 5.

[47] *Sources of Greenhouse Gas Emissions*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions [https://perma.cc/E849-LZGM] (last updated Apr. 14, 2017).

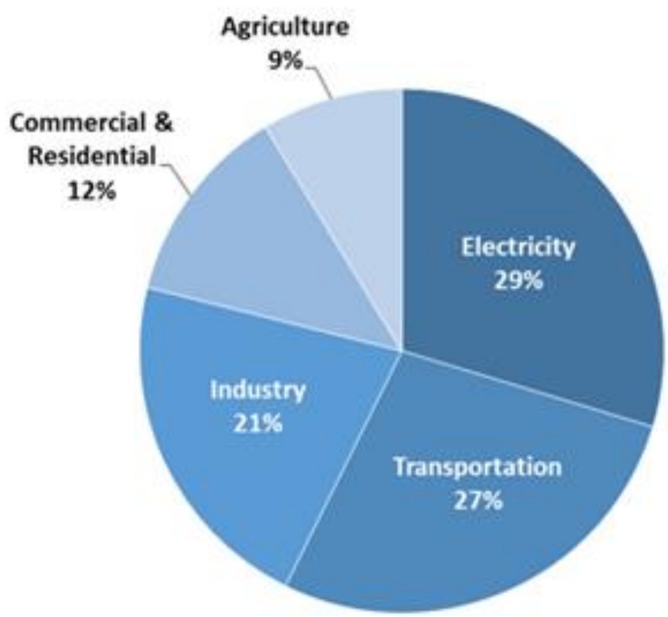
[48] SCHNEIDER, *supra* note 22.

[49] Jayni Hein, *Curbing Fugitive Methane Costs Little, Buys Time on Climate Change*, THE HILL (Dec. 29 2014, 06:00 AM), http://thehill.com/blogs/pundits-blog/energy-environment/228153-curbing-fugitive-methane-costs-little-buys-time-on [https://perma.cc/4929-U5H7].

[50] *Id.*

by almost 100% between 1800 and 1989.[51] Over a period of the prior three decades, there has been increasing atmospheric methane emissions punctuated with slower periods of growth in the middle of this period resulting in stabilization of accumulated methane in the atmosphere.[52] In terms of the historic role of methane in the last 265 years, one-fifth of the increase in radiative forcing by anthropogenic sources of greenhouse gases is attributable to methane.[53]

This is a larger increase of methane concentrations in the atmosphere than occurred for CO_2. Historically, this increase is mainly attributed to population growth and human-related activities, accounting for about 70% of total methane emissions.[54] Major anthropogenic sources of methane emissions, those created by human activity, include rice cultivation, increase in commercial livestock, biomass burning, coal mining, natural gas system leaks, waste management, and landfills.[55] The sectors of the economy responsible for methane emissions are shown in Figure 4.



[51] *See* SCHNEIDER, *supra* note 22, at 21.

[52] Nisbet et al., *supra* note 28, at 493.

[53] *Id.*

[54] U.S. EPA, METHANE EMISSIONS, *supra* note 36, at 7.

[55] *Id.*

FIGURE 4: Total U.S. Greenhouse Gas Emissions by Economic Sector in 2015[56]

Legal policy can do more to exert leverage to recapture more of this damaging release of methane. Although methane presents numerous problems when released directly into the Earth's atmosphere, it offers significant benefits when recaptured and utilized as an energy source. Methane is the main constituent of natural gas.[57] When compared with other fossil fuels, natural gas has significantly lower emissions of CO_2, sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and particulates.[58] When directly substituted for electricity generated by other fossil fuels, significant reductions of CO_2 are achieved by the use of natural gas.[59] Natural gas produced 27% of the electricity generated in the United States in 2014,[60] and this percentage has been rising until reaching 33.8% in 2016, making it the dominant U.S. source for power generation.[61]

Existing technologies and strategies could reduce substantially the quantity of short-lived climate chemical pollutant emissions and reduce the expected rate of global warming by half.[62] Using cost-effective and currently available technologies and strategies, worldwide anthropogenic sources of short-lived climate chemical pollutant emissions could be significantly controlled by 2030, resulting in global benefits.[63] To do so requires successfully implementing a multi-media, multi-sectoral strategy to recycle and utilize methane-containing organic waste for soil amendments/compost, electrical generation, transportation fuel and pipeline-injected renewable natural gas.[64] This would also require implementing a strategy to cut methane emissions from dairy operations in half, eliminate disposal of organic materials in landfills, and

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56 *Sources of Greenhouse Gas Emissions*, *supra* note 47.

57 *See* U.S. Steel Corp. v. Hoge, 468 A.2d 1380, 1382 (Pa. 1983) ("The gas which has commonly been referred to as 'natural gas' is generally found in strata deeper than coal veins, though it shares many of the characteristics of coalbed gas.").

58 *Environmental Impacts of Natural Gas*, UNION OF CONCERNED SCIENTISTS, http://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas [https://perma.cc/YP62-255A] (last visited Nov. 11, 2017).

59 U.S. EPA, METHANE EMISSIONS, *supra* note 36, at 37.

60 Hein, *supra* note 49.

61 *What is U.S. Generation by Energy Source?*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 [https://perma.cc/ZGS6-L735] (last updated Apr. 18, 2017).

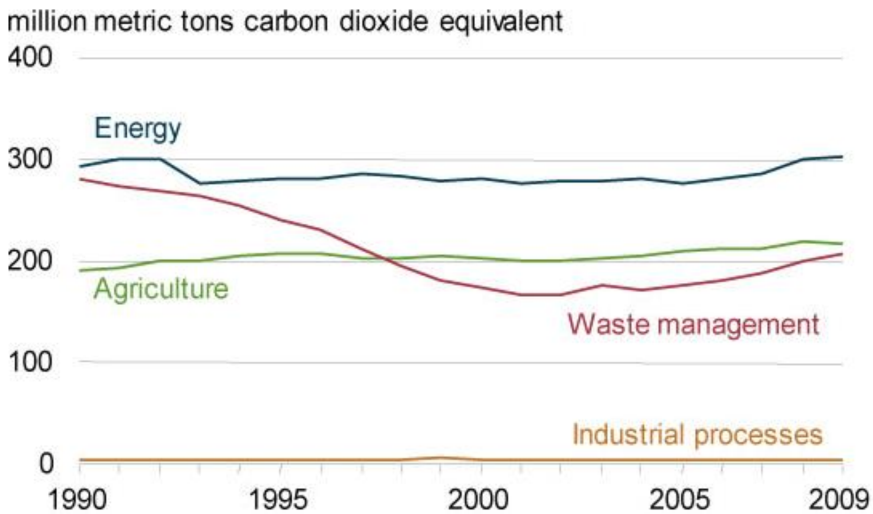
62 CLIMATE POLLUTANT REDUCTION STRATEGY, *supra* note 7, at 1 (nothing that this would also keep average warming below the threshold of 2º C at least through 2050, while cutting global SLCP emissions immediately would slow climate feedback mechanisms in the Arctic.).

63 *Id.* at 2.

64 *Id.* at 2-3.

significantly reduce fugitive methane emissions from oil and gas systems.[65]

Opportunities for control of anthropogenic methane emissions include the installation of methane recovery systems at landfills, improvements in leak



detection and containment at natural gas transportation systems, fire management programs for biomass burning, and recovery of coal-bed methane from coal mining operations.[66] It is estimated that if 8% of the methane release could be reduced, then atmospheric methane concentrations could be stabilized at current levels.[67] This is because methane lasts for approximately 12.4 years in the atmosphere before it is altered.[68]

FIGURE 5: U.S. Methane Emissions by Source, 1990-2009[69]

However, energy use patterns make this goal a challenge. Coal production worldwide is expected to remain constant with substitution of natural gas,[70] with a resulting decrease of methane emissions in the United States. Figure 5 illustrates the critical importance over the last two decades of managing methane

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[65] *Id.* at 4.

[66] *See infra* Parts III and IV.

[67] IPCC, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change*, at 10, https://www.ipcc.ch/pdf/climate-changes-1995/2nd-assessment-synthesis.pdf [https://perma.cc/JL52-J82M] (last visited Feb. 2, 2018).

[68] Romm, *supra* note 23.

[69] DOE/EIA-0573(2009), *supra* note 46, at 35.

[70] *See International Energy Outlook 2017*, U.S. ENERGY INFO. ADMIN. 64 (Sept. 14, 2017), https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf [https://perma.cc/F4C7-L3QQ].

emissions in the energy, agriculture, and waste management sectors; industrial sector methane emissions are much less significant. Section III below addresses in sectoral detail waste management and agricultural contributions to methane emissions, and legal policy solutions in these sectors of the economy.

III. WASTE METHANE RECAPTURE AND REUSE

A. Landfill Methane Generation

1. Landfill Methane

Methane escaping from both waste mismanagement activities and naturally from waste landfills is a worldwide problem. Landfills are the third largest source of U.S. methane emissions.[71] The per capita generation of municipal waste (MSW) is a function of both population and affluence.[72] The largest amount of MSW is generated by Organisation for Economic Co-operation and Development (OECD) countries, the most developed countries,[73] and lesser amounts by less developed countries.[74] This is an ongoing and increasing problem that must be effectively mitigated by law. Otherwise, the amount of MSW generated worldwide and the amount of potential methane emitted are expected to almost double to 2.2 billion tons annually by 2025.[75]

Approximately 29% of U.S. anthropogenic methane emissions—8.1 million metric tons—were released at the beginning of the 21st century from waste

[71] *Basic Information about Landfill Gas*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/lmop/basic-information-about-landfill-gas [https://perma.cc/E8KT-XH3U] (last updated Aug. 9, 2017).

[72] *See* Daniel Hoornweg & Perinaz Bhada-Tata, WHAT A WASTE: A GLOBAL REVIEW OF SOLID WASTE MANAGEMENT 8-12, WBG (2012), http://documents.worldbank.org/curated/en/302341468126264791/pdf/68135-REVISED-What-a-Waste-2012-Final-updated.pdf [https://perma.cc/QGF3-WUPD].

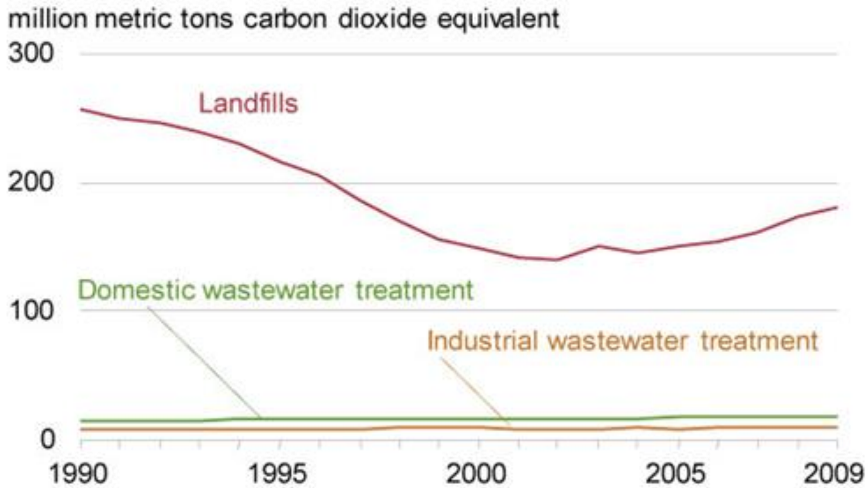
[73] *Id.* at 8-10. OECD countries include Andorra, Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States. *Id.* at xii.

[74] *Id.* at 8-10.

[75] *Id*. at 8.

management,[76] more recently estimated at 20%.[77] Landfills represented the source of 98% of this 8.1 million metric tons of methane emissions, by far the single largest source.[78] Approximately 4.9 million metric tons of the approximately 8.0 million tons of landfill methane annually were captured as landfill gas (LFG), and 2.5 million metric tons of this captured amount was used for productive energy use at the beginning of the 21st century, while the remaining 2.4 million metric tons of the recovered LFG were flared with no productive energy use of captured methane.[79]

Trash in landfills creates 17% of all anthropogenic methane production,[80] less



[76] *See* U.S. ENVTL. PROT. AGENCY, EPA 430-R-05-003, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2003 25, 261 (2005), https://www.epa.gov/sites/production/files/2015-12/documents/05cr.pdf [https://perma.cc/2ASF-MC8D] [hereinafter EPA, 1990-2003 EMISSIONS AND SINKS] (explaining that landfills constitute the single largest source of methane emissions within the United States and are responsible for almost one-third of human-related methane emissions, while human-related activities such as natural gas and petroleum systems, livestock, wastewater treatment and landfills account for 60% of all emissions); U.S. ENERGY INFO. ADMIN., DOE/EIA-0573(2001), EMISSIONS OF GREENHOUSE GASES IN THE UNITED STATES 2001 40 (2002), http://www.4cleanair.org/057301.pdf [https://perma.cc/SMN5-B37V] [hereinafter DOE/EIA-0573(2001)] (noting that this value has been decreasing since 1990 because of a robust effort to capture methane for productive purposes or destruction).

[77] *See* EPA, 1990-2015 INVENTORY OF EMISSIONS AND SINKS, *supra* note 38.

[78] EPA, 1990-2003 EMISSIONS AND SINKS, *supra* note 76, at 40. The remaining 2% of these emissions from waste management are associated with domestic wastewater treatment programs. *Id.*

[79] DOE/EIA-0573(2001), *supra* note 76.

[80] Dave Fehling, *Garbage Gas: Is Methane Going to Waste in Texas?*, STATEIMPACT

in amount than only livestock operations and natural gas production, as shown in Figure 5, and more than wastewater management, as shown in Figure 6. Trash creates climate change emissions because its organic materials decompose to methane under anaerobic conditions.[81] Landfills containing trash accounted for 6.3 million metric tons of methane emitted in 2002.[82] According to EPA data, methane constitutes the second most prevalent greenhouse gas, after CO_2.[83]

FIGURE 6: U.S. Methane Emissions from Waste Management by Source, 1990-2009[84]

The chemical destiny of the bulk of MSW is degradation to methane molecules.[85] Because landfilled waste is composed of a high percentage of organic materials—including paper, food scraps, and yard waste (see Figure 7)—over time, bacterial decomposition of organic material, volatilization of certain wastes, and chemical reactions within the landfill create copious quantities of gas.[86] More than half of the total amount of trash is organic matter that will degrade to release methane under anaerobic conditions.[87] Landfill gas is comprised primarily of 45-60% of each of methane and CO_2, while containing smaller amounts of non-methane organic compounds ("NMOCs") and some other trace organic elements.[88] For comparison, pipeline natural gas contains

(Dec. 4, 2012, 6:45 AM), http://stateimpact.npr.org/texas/2012/12/04/garbage-gas-is-methane-going-to-waste-in-texas/ [https://perma.cc/96X4-BQYS].

81 Agency For Toxic Substances And Disease Registry, U.S. Dep't of Health and Hum. Servs., Landfill Gas Primer: An Overview For Environmental Health Professionals 3-4 (2001), https://www.atsdr.cdc.gov/hac/landfill/pdfs/landfill_2001_ch2mod.pdf [https://perma.cc/72XJ-SJZX] (noting that organic materials include paper, food scraps, and yard waste).

82 U.S. Energy Info. Admin., DOE/EIA-0573(2002), Emissions of Greenhouse Gases in the United States 2002 37 (2003) [hereinafter DOE/EIA-0573(2002)].

83 *Overview of Greenhouse Gases*, *supra* note 10.

84 DOE/EIA-0573(2009), *supra* note 46, at 39.

85 *Overview of Greenhouse Gases*, *supra* note 10.

86 Agency For Toxic Substances And Disease Registry, *supra* note 81, at 3.

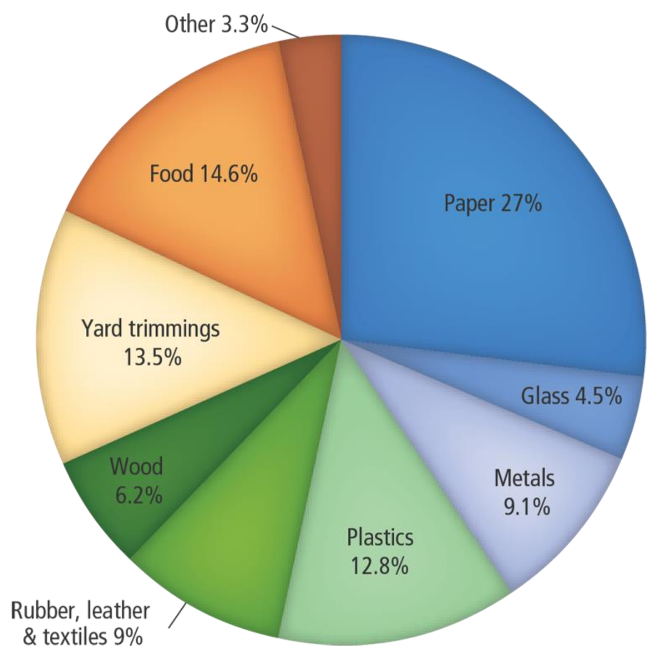
87 *See* EPA, 1990-2015 Inventory of Emissions and Sinks, *supra* note 38, at 7-18 (noting that in 2014, 20.2% of all waste sent to MSW landfills is food, 13.4% is paper and paper board, 7.6% is wood and 7.4% is yard trimmings).

88 Agency For Toxic Substances And Disease Registry, *supra* note 81, at 3.

about 99% methane.[89]

FIGURE 7: Total MSW Generation (by Material), 2013[90]

There are methane release mitigation solutions with current technology. On the output side of the process, additional fugitive emissions from landfills could be reduced by installing and maintaining bio-based systems.[91] The organic material entering landfills which decomposes to methane gas could be reduced through food waste reduction.[92] On the input side of the process, approximately 133 billion pounds of food end up in landfills in the U.S., making it the single



[89] *See* Jonathan Martel et al., *Obama Administration Sharpens Focus on Reducing Methane Emissions*, 15 DAILY ENV'T REP. (BNA) No. 16, Jan. 26, 2016, at B-3 (noting the breakdown of methane emissions in the natural gas industry, and stating "approximately 31 percent of methane emissions result from production, 15 percent from processing, 34 percent from transmission and storage and 20 percent from distribution").

[90] Municipal Solid Waste, U.S. ENVTL. PROT. AGENCY, https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/ [https://perma.cc/D3RC-2V4L] (last updated Mar. 29, 2016).

[91] Martel et al., *supra* note 89.

[92] *Id.* at B-2.

greatest contributor to municipal landfills.[93] In 2015, the U.S. Department of Agriculture (USDA) and EPA, along with many private sector and food bank partners, announced a national target to reduce food waste 50% by 2030.[94] Four states, including Massachusetts, Vermont, Rhode Island and Connecticut, have implemented regulations to reduce food waste from commercial sources.[95]

Vermont's food waste law is the most comprehensive because it covers anyone who generates any waste from food, including residents, as well as commercial restaurants and food processors.[96] Specifically, food scrap (organic, compostable kitchen waste) diversion began in a phased approach on July 1, 2014, targeting food scrap generators of greater than two tons per week and located within twenty miles of certified (composting, anaerobic digestion) facilities.[97] Furthermore, by 2020, all food scraps, including those from households, must be diverted from landfills with no exemption for distance from a certified facility.[98] This is in contrast to the other three New England states that ban only certain commercial, industrial and institutional entities from landfilling food waste, and whose statutes apply mainly to organic waste-producing institutions generating more than 104 tons per year.[99]

California also has begun efforts to "develop a regulation by 2018 to effectively eliminate organic [waste] disposal in landfills by 2025."[100] The California Department of Resources Recycling and Recovery ("CalRecycle") reports that Californians throw away six million tons of food waste each year, representing about 18% of all the material that goes to landfills.[101] CalRecycle will implement ways to foster food-waste prevention and food rescue (donation of cosmetically distressed food to free meal programs), to help meet a goal of

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93 Press Release, U.S. Dep't of Agric., USDA and EPA Join with Private Sector, Charitable Organizations to Set Nation's First Food Waste Reduction Goals (Sept. 16, 2015), http://www.usda.gov/wps/portal/usda/usdahome?contentid=2015/09/0257.xml [https://perma.cc/PU92-H636] [hereinafter USDA Press Release].

94 *Id.*

95 Emily Broad Leib et al., *Fresh Look at Organics Bans and Waste Recycling Laws*, BIOCYCLE, Nov. 2016, at 16-17.

96 *Id.*

97 VT. DEP'T OF ENVTL. CONSERVATION, UNIVERSAL RECYCLING LAW TIMELINE, http://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/Universal-Recycling/Timeline-factsheet_CURRENT.pdf [https://perma.cc/GVU3-FP47] (last visited Nov. 18, 2017).

98 *Id.*

99 *See* Emily Broad Leib et al., *supra* note 95, at 17.

100 CLIMATE POLLUTANT REDUCTION STRATEGY, *supra* note 7, at 8.

101 *Food Scraps Management*, CALRECYCLE, http://www.calrecycle.ca.gov/organics/food/ [https://perma.cc/W5HF-XEWY] (last updated Sept. 8, 2016).

75% food rescue by 2020.[102] The California Air Resources Board (ARB) and CalRecycle will work with the State and regional water boards to assess the feasibility and benefits of actions to require capturing and effectively utilizing methane generated from wastewater treatment, and opportunities for co-digestion of food waste at existing or new anaerobic digesters at wastewater treatment plants.[103]

2. Law Regulating Methane Management at Landfills.

Landfills accounted for 6.3 million metric tons of methane emitted in 2003,[104] and 4.6 kilotons of such emissions in 2015.[105] This methane can be captured and employed productively as a methane gas energy source, collected and flared for no productive purpose, or left alone to migrate into the environment as a potent greenhouse gas.[106] Of 989 open and closed registered U.S. landfills, 574 would be large enough to generate enough emissions to be required to collect and control their methane in 2025.[107] When utilized productively, landfill gas is considered a carbon-neutral fuel, since its combustion releases carbon that was recently sequestered by organic source materials before being placed in a landfill that, when degrading anaerobically, these organic wastes generate and release their methane content.[108]

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[102] *See California's 75 Percent Initiative: Defining the Future*, CALRECYCLE, http://www.calrecycle.ca.gov/75Percent/ [https://perma.cc/S7FE-328F] (last updated Aug. 17, 2017).

[103] *See generally* CAL. DEP'T OF RES. RECYCLING AND RECOVERY, AB 341 REPORT TO THE LEGISLATURE (2015), http://www.calrecycle.ca.gov/Publications/Documents/1538/20151538.pdf [https://perma.cc/P2DG-6MXG]. In an effort to collaboratively combat food waste, CalRecycle will build on its partnerships with local governments, industry, nonprofits, local air districts and water boards to support regional planning efforts and identify ways to safely and effectively develop necessary organics recycling capacity. Recovering and utilizing food that would otherwise be landfilled can help to reduce methane emissions and increase access to healthy foods for millions of Californians who suffer from food insecurity. *Id.*

[104] DOE/EIA-0573(2002), *supra* note 82.

[105] *See* EPA, 1990-2015 INVENTORY OF EMISSIONS AND SINKS, *supra* note 38, at ES-6.

[106] U.S. ENVTL. PROT. AGENCY, EPA 430-B-96-0004, TURNING A LIABILITY INTO AN ASSET: A LANDFILL GAS-TO-ENERGY PROJECT DEVELOPMENT HANDBOOK 1-2 (1996), https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=600008CZ.txt [https://perma.cc/Y49F-ETTS].

[107] *See* Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills, 80 Fed. Reg. 52,100, 52,118 (Aug. 27, 2015) (to be codified at 40 C.F.R. pt. 60) ("The Emission Guidelines in the baseline are estimated to require control at 574 of the 989 affected landfills in 2025 and achieve reductions of 57,300 Mg/yr NMOC and 9.0 million Mg/yr methane (226 million mt/yr CO_2e).").

[108] Jennifer Weeks, *Landfills Expand Energy Output*, BIOCYCLE, Aug. 2005, at 51.

About 12% of MSW in the United States was incinerated in 2012,[109] and some of which incineration is used in a turbine to produce electricity.[110] Waste-to-energy power generation can be achieved at $0.0457/Kwh,[111] which is less expensive than many forms of power supply and one of the least expensive renewable power generation options. As of mid-2017, 634 MSW landfills in the U.S. have LFG-to-energy projects.[112] The most significant deployment of waste-to-energy combustion facilities to handle MSW is in the New England region, where 35% of the waste stream is handled in this manner.[113] The EPA estimates that each megawatt of electricity generated from LFG has the same impact of planting 12,000 acres of forest, removing 8,800 cars per year from driving an average number of miles, or eliminating the need for 93,000 barrels of oil.[114]

The EPA maintains a database of more than 2,400 landfills that are potential LFG-to-energy locations in the U.S., where methane is now being captured and used.[115] The EPA Landfill Methane Outreach Program (LMOP) tracks

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[109] U.S. ENVTL. PROT. AGENCY, MUNICIPAL SOLID WASTE GENERATION, RECYCLING, AND DISPOSAL IN THE UNITED STATES: FACTS AND FIGURES FOR 2012 2 (2014), https://archive.epa.gov/epawaste/nonhaz/municipal/web/pdf/2012_msw_fs.pdf [https://perma.cc/MQ67-6NTK].

[110] *Energy Recovery from the Combustion of Municipal Solid Waste (MSW)*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw [https://perma.cc/F22V-99HD] (last updated Apr. 14, 2017) (stating that U.S. incineration in the early 1990s was more than 15% of MSW).

[111] U.S. ENVTL. PROT. AGENCY, REGULATORY IMPACT ANALYSIS FOR THE PROPOSED REVISIONS TO THE EMISSION GUIDELINES FOR EXISTING SOURCES AND SUPPLEMENTAL PROPOSED NEW SOURCE PERFORMANCE STANDARDS IN THE MUNICIPAL SOLID WASTE LANDFILLS SECTOR 3-6 (2015), https://www3.epa.gov/ttnecas1/docs/ria/landfills_ria_proposed-nsps_2015-08.pdf [https://perma.cc/E7AC-W8SX].

[112] *Project and Landfill Data by State*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/lmop/project-and-landfill-data-state [https://perma.cc/3744-W9GH] (last updated Nov. 30, 2017).

[113] Phil Simmons et al., *The State of Garbage in America*, BIOCYCLE, Jan. 2004, at 27. The least use of this technology is in the Rocky Mountain and Midwest regions, and conversely, the areas where the largest percentage of waste is landfill is the Rocky Mountain region, where 90% of MSW waste stream is landfilled, the Midwest, where 75% of the waste stream is landfilled, the Great Lakes region of the Midwest where 68% of the waste is landfilled, and the South where 69% of the waste is landfilled. *Id.* at 33-34.

[114] Steven Ferrey, *Converting Brownfield Environmental Negatives into Energy Positives*, 34 B.C. ENVTL. AFF. L. REV. 417, 430 (2007) (footnote omitted) [hereinafter Ferrey, *Brownfield Environmental Negatives*].

[115] *Landfill Gas Energy Project Data and Landfill Technical Data*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/lmop/landfill-gas-energy-project-data-and-landfill-technical-data [https://perma.cc/EB5T-XYB6] (last updated July 5, 2017) (providing maps of locations

operating LFG projects in the U.S. and identifies more than 400 additional landfills as good candidates because of their size and methane generation characteristics.[116] It is estimated that "each year . . . 421 to 613 billion cubic feet of methane from landfills alone is wasted . . . ."[117] That amount of methane could produce up to 4000 megawatts of electricity, which would be enough to power three million homes.[118]

Even when not turned into usable energy, two existing and long-standing statutes administered by EPA require the management of methane at very large landfills. They are the federal air and land environmental statutes that provide an in-place platform from which the EPA can change the specific requirement for control of methane emissions from landfills.[119] Both federal statutes have so-called "savings clauses" that allow the state governments to enact more stringent standards, if desired.[120] However, because methane and other greenhouse gases exert global rather than local effects, unlike other pollutants, the incentive for more stringent state and local regulations is not internalized to land area served by these subsidiary government authorities. The legal mechanism is in place, and could be tightened to reduce methane emissions. In 2014, the Obama administration released a national methane strategy targeting the largest sources of methane from oil and gas production and coal mines, as well as agriculture and landfills.[121] In 2015, the Obama administration also set a goal of reducing methane emissions from the oil and gas sector by 40-45% below 2012 levels by 2025.[122] In 2016, the EPA finalized the first standards for methane emissions from new and modified oil and gas facilities, and took a small step in the process of developing emissions standards for existing sources.[123]

i. Tightening the Resource Conservation and Recovery Act (RCRA)

Contrary to the Clean Air Act,[124] which regulates non-methane gas emissions, Subtitle D of RCRA establishes legal requirements to limit actual landfill methane emissions.[125] RCRA sets a minimum national design for landfills, as well as operating and closure criteria for municipal solid waste (MSW) landfills

and a costing methodology for determining the economic feasibility of development).

116 *Id.*

117 Cory M. Gonyo, *Landfill Gas/Methane Gas: A Liability and an Asset*, 1 GR. PLAINS NAT. RESOURCES J. 149, 152 (1996).

118 *Id.*

119 *See infra* Section III.A.2.

120 42 U.S.C. § 7604, 6929 (2012).

121 U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

122 *Id.*

123 *Id.*

124 *See* discussion *infra* Section III.A.2.b.

125 *See* Resource Conservation and Recovery Act, 40 C.F.R. § 258.40 (2017).

that were active on or after October 9, 1993.[126] RCRA requires that all MSW landfills maintain a methane gas concentration of less than "25 percent of the lower explosive limit for methane . . . (excluding gas control or recovery system components) . . . ." and a concentration of less than the lower explosive limit for methane at the facility boundary.[127] Methane gas is explosive between 5-15% concentrations.[128] Landfill operators or owners are required to monitor methane emissions to prevent or control any off-site migration, groundwater contamination, odors, and emissions of non-methane organic emissions.[129]

All large landfills in place and operational after 1991, must install a protective cover to control fugitive methane emissions.[130] All landfills constructed or modified in terms of capacity in the last 25 years after October 1993 are required by the RCRA to install a landfill lining between the landfill and the earth to retard lateral migration of landfill gas and eliminate groundwater contamination.[131] However, methane can still escape through cracks or joints of the containment structures. When methane is released and migrates to occupied structures or underground utility conduits in such concentration to be measured at 10% of the lower explosive limit, the RCRA identifies this as an "Imminent Hazard."[132] The RCRA sets standards at the landfill property boundary, limiting methane concentrations at the facility's property boundary to not exceed the lower explosive limit for methane.[133]

In order to know whether or not landfills are in compliance with these requirements, the owner/operators of the landfill must conduct a methane-monitoring program.[134]If the methane concentration levels exceed the limits, the owner/operator is required to initiate affirmative steps to correct the problem and

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[126] *Id.*

[127] *Id*. § 258.23 (defining "lower explosive limit" as "the lowest percent by volume of a mixture of explosive gases in air that will generate a flame at 25 degrees Celsius and atmospheric pressure.").

[128] JOHN BELL ET AL., CAL. DEP'T OF RES. RECYCLING AND RECOVERY, LANDFILL GAS TRAINING 15, http://www.calrecycle.ca.gov/LEA/Training/landfillgas/2005August/Presentation.pdf [https://perma.cc/BB7W-GZ3Z] (last visited Nov. 18, 2017).

[129] Curtis A. Moore, *Existing Authorities in the United States for Responding to Global Warming*, 40 ENVTL. L. REP. 10185, 10203 (2010).

[130] 40 C.F.R § 258.40.

[131] *Id.*

[132] 310 MASS. CODE REGS. § 40.0321 (2015).

[133] 40 C.F.R. § 258.23.

[134] *Id.* (demonstrating there are four factors that determine the type and frequency of the monitoring program: the soil conditions, the hydrogeologic conditions surrounding the facility, the hydraulic conditions surrounding the facility, and the location of the facility structures and property boundaries and that municipal solid waste landfill facilities must provide a report on their methane concentration levels quarterly).

to ensure the health and safety of the people surrounding the landfill.[135] A written record of the methane level and the steps taken to protect human health must be created within seven days of any detection of excess methane leaks.[136] The state can order assessment and remedial action.[137] Post-closure environmental monitoring is required.[138]

ii. Clean Air Act New Source Performance Standards for Landfills

Under the Clean Air Act, operators of large landfill sites may have to monitor, collect and dispose of landfill gases. Large landfills, sites with a design capacity greater than 2.5 million cubic meters, must install a landfill gas collection system.[139] If a landfill site releases more than 50,000 mega grams (MG) of NMOCs per year, the landfill site is subject to the regulation.[140] The system implemented must include an open flare design and a "control device capable of reducing NMOC emissions by 98 weight-percent."[141] Of note, these requirements do not apply to methane emissions.[142]

Compliance with most of the New Source Performance Standards (NSPS) of the Clean Air Act is necessary if landfills have accepted waste after November 8, 1987, have a design capacity of more than 2.5 million MG and 2.5 million cubic meters, and have a non-methane organic compound emission rate of fifty or more mega grams per year.[143] These apply to landfills that began modification or construction after May 30, 1991.[144] Landfills are becoming

[135] *See id.*

[136] *Id.* (requiring also that within sixty days of learning of the high methane concentration the owner/operator must devise and submit a corrective plan that addresses the methane gas release).

[137] *Id.*; *see also, e.g.*, MASS. GEN. LAWS. ch. 111, § 150A (2017) (demonstrating the state environmental regulatory agency's division of solid waste may require a plan application and approval).

[138] 310 MASS. CODE REGS. § 19.016 (2017) (showing the statute affords the state discretion in setting minimum reporting intervals for the levels of methane and that the alternative reporting schedule must take into account the unique characteristics of the particular community and the climate and hydrogeologic conditions in and surrounding the area).

[139] 40 C.F.R. § 60.752(b).

[140] *Id.* § 60.752(b)(2).

[141] *Id.* § 60.752(b)(2)(iii)(A)-(B).

[142] *See id.* § 60.752.

[143] *See id.* This weight and volume are equivalent to 2.75 million tons of solid waste. The collection and control system must (1) be capable of handling the maximum expected gas generation rate; (2) have a design capable of monitoring and adjusting the operation of the system; and (3) be able to collect gas effectively from all areas of the landfill that warrant control, and be capable of reducing NMOC emissions by 98 percent. *Id.* § 60.752(b)(2).

[144] *Id.* § 60.750(a). The owner or operator must calculate a NMOC emission rate and

fewer in number but larger in size over time.[145] This results in more landfills being subject to government regulation requiring capture and utilization or flare of landfill methane gas.[146] An owner must reduce NMOC by 98 weight-percent, or to less than 20 ppm by volume, dry basis as hexane at 3% O_2.[147] Separate rules apply to landfills that do not come under the NSPS.[148]

The owner/operator must test the above background level of methane concentration to ensure that level does not exceed 500 parts per million or more above background concentration.[149] Criminal liability can be imposed on the landfill owner who knowingly commits a violation of the Clean Air Act,

report it annually. *Id.* § 60.752(b). If the rate exceeds 50 mega grams then a collection and control system will be required to be installed. *Id.* § 60.752. The collection and control system must be designed in such a way to ensure capture of the gas generated by the landfill. *Id.* The NESHAP emission requirements applies to the owner or operator of any stationary source of any air pollutant listed. *Id.* § 61.01.

[145] Brian Palmer, *Go West, Garbage Can!*, SLATE (Feb. 15, 2011, 7:06 AM), http://www.slate.com/articles/health_and_science/the_green_lantern/2011/02/go_west_garbage_can.html [https://perma.cc/MSZ4-RN3Y].

[146] *See* 40 C.F.R. § 60.757. The report must contain a map indicating the size and location of the landfill and all areas where solid waste may be placed and the maximum design capacity of the landfill. *Id.* If the landfill expands from below the threshold to above it, the owner/operator must submit an amended design capacity report within 90 days of the increase in size so that it may now be treated as regulated. *Id.* Under NSPS, semi-annual reports must be submitted regarding air limit exceedances and gas bypass flow reports. *Id.* § 60.604.

[147] *Id.* § 60.752.

[148] *Id.* § 60.30c. Under 40 C.F.R. 51, 52, and 60, landfills that meet certain size and age requirements are required to install and operate an active or passive LFG collection system that meets specified performance criteria and install devices that combust and destroy at least 98 percent of the NMOCs in the collected LFG or reduce the NMOCs concentration in the combustion gases to less than 20 ppm, dry basis as hexane at 3% O_2. *Id.* § 51-52, 60. Specifically, landfills that commenced construction prior to May 30, 1991, accepted waste since November 8, 1987, have a design capacity to dispose of greater than 2.75 million tons of solid waste, and are projected to emit more than 50 tons per year of NMOCs without controls are subject to the requirements of Emission Guidelines. *Id.* § 60.33c.

[149] *Id.* § 60.755(c). The background concentration is calculated by measuring the methane levels around the perimeter of the landfill, at least 30 meters away from last perimeter wells. *Id.* Measurements are taken both upwind and downwind. *Id.* After establishing the background concentration, testing must be done in 30 meter intervals across the entire property. *Id.* § 60.755(c)(2). If the test results indicate a level higher than the 500 standard, a record of the exact area where the reading was taken must be documented. *Id.* Then, the nearest well must be adjusted so that its collection volume is increased. *Id.* Another reading must be taken 10 days after this corrective action. *Id.* The owner/operator has three chances and 30 days to correct the problem. *Id.* If after this time the readings still exceed the authorized levels, more invasive action must be taken to correct the problem. *See id.* This includes potentially replacing the well itself or installing an entirely new collection system. *Id.*

punishable by a sentence of up to five years in prison or knowingly releases hazardous air pollutants, a violation punishable by a sentence of up to fifteen years in prison.[150] The Clean Air Act also authorizes significant civil penalties of up to $44,539 for each violation for each day.[151]

The majority of landfills in the U.S. are owned by cities and towns.[152] Because private landfills have already cost-effectively developed LFG electricity generation projects the majority of remaining most cost-effective LFG-to-energy projects are located at municipally-owned landfills.[153] Some very small LFG projects are capable of yielding net revenues cost-effectively: From the author's experience with LFG projects, a landfill which comprises at least twenty acres in size containing approximately one million tons of MSW, closed somewhat recently, offers a potential cost-effective opportunity to capture methane.[154]

Each of the Clean Air Act and RCRA requirements for landfill methane control could be made more encompassing and more demanding to reduce methane release to the atmosphere and thereby further climate control goals. First, the control regulations could be applied to smaller landfills to include those that are cost-effective in terms or internal revenue and social benefit from methane control. Second, the required methane containment and destruction levels could be advanced to the point of the most cost-effective level in conjunction with U.S. commitments in the Kyoto Protocol and the Paris Agreement of 2015, from which the Trump Administration is now withdrawing. When Syria joined the Paris Climate Accord in late 2017, it left the United States as the only organized nation not to have joined or remained in the Accord.[155] The value of methane saved or captured has been estimated to be $1100 per

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150 42 U.S.C. § 7413 (2012).

151 40 C.F.R. § 19.4.

152 U.S. ENVTL. PROT. AGENCY, MUNICIPAL SOLID WASTE LANDFILLS: ECONOMIC IMPACT ANALYSIS FOR THE PROPOSED NEW SUBPART TO THE NEW SOURCE PERFORMANCE STANDARDS 2–2 (2014), https://www3.epa.gov/ttnecas1/regdata/EIAs/LandfillsNSPSProposalEIA.pdf [https://perma.cc/3V2M-UX3W] ("In 2004, 64 percent of MSW landfills were owned by public entities while 36 percent were privately owned.") (citation omitted); U.S. ENVTL. PROT. AGENCY, EPA-821-B-99-005, ECONOMIC ANALYSIS OF FINAL EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS FOR THE LANDFILLS POINT SOURCE CATEGORY 4-3 (1999).

153 *See* U.S. ENVTL. PROT. AGENCY, LANDFILL- AND PROJECT-LEVEL DATA (XLSX) (June 2017), https://www.epa.gov/lmop/landfill-technical-data [https://perma.cc/EMV5-NEBE].

154 Author's calculations from development experience. Waste in place totals are not available for all landfills. Landfill acreage can be used to estimate relative general volume.

155 Brady Dennis, *As Syria Embraces Paris Climate Deal, It's the United States Against the World*, WASH. POST (Nov. 7, 2017), https://www.washingtonpost.com/news/energy-environment/wp/2017/11/07/as-syria-embraces-paris-climate-deal-its-the-united-states-against-the-world/?utm_term=.9186adf4a655 [https://perma.cc/NX26-2XKC].

metric ton for health, climate, and other social benefits.[156]

Tightening existing regulations as to size and limitations is a straightforward mechanism. The Obama Administration took this step. In 2015, the U.S. Department of Agriculture and EPA announced a national target to reduce food waste 50% by 2030.[157] In 2016, the EPA finalized relatively demanding operating standards to install gas collection systems that capture methane from certain large landfills, both new and existing, to result in reductions of an additional eight million metric tons annually in 2025.[158]

In 2016, the EPA released new final Clean Air Act NSPS regulations for landfills built or modified after July 17, 2014,[159] effective September 15, 2016. Existing landfills' requirements to capture and contain methane would be lowered from fifty metric tons (equivalent to fifty MG) of non-methane organic compounds per year in the current regulations to thirty-four metric tons annually.[160] That is the same threshold the EPA is setting for new landfills. The EPA estimates that 115 new landfills and 731 existing facilities will thereunder be required to install additional pollution controls under the final rules, to reduce methane emissions by 334,000 metric tons at an annual cost to the industry of $6 million in 2025.[161]

As of July 14, 2016, EPA methane regulations were a part of the Obama Administration's strategy to act without Congressional change of statute,[162] and

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[156] Drew Shindell et al., *Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security*, 335 SCIENCE 183, 186 (2012).

[157] USDA Press Release, *supra* note 93.

[158] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 91.

[159] *See* Andrew Childers, *EPA Tightens Landfill Standards to Reduce Methane*, ENERGY & CLIMATE REP. (BNA) No. 136, July 15, 2016 (citing 40 C.F.R. §§ 60.750–60.759 (2017)).

[160] *See id.* (citing 40 C.F.R. § 60.33c) (stating "[u]pdated controls would need to be installed within thirty months of meeting that emissions threshold.").

[161] *Id.* ("The Tier 4 system would exempt a landfill from installing the required pollution controls if it can demonstrate that surface emissions are below 500 parts per million for four consecutive quarters even if other monitoring methods would indicate the emissions threshold has been exceeded.").

[162] 42 U.S.C. § 7411(d) (2017) (providing the establishment of emissions guidelines for a number of source categories in the United States); *see* 40 C.F.R. §§ 60.30f-60.41f, 60.760-60.769 (noting that the new Emissions Guidelines replaces 40 C.F.R. §§ 60.750-60.759, 60.30c-60.36c); *see also* Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills, 61 Fed. Reg. 9,905 *passim* (Mar. 12, 1996) (to be codified 40 C.F.R. §§ 60.750-60.759, 60.30c-60.36c); U.S. WHITE HOUSE, CLIMATE ACTION PLAN STRATEGY TO REDUCE METHANE (2014), https://obamawhitehouse.archives.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf [https://perma.cc/6RQW-8V5G]; U.S. WHITE HOUSE, THE PRESIDENT'S CLIMATE ACTION PLAN (2013), https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionpla

therefore can be undone by a subsequent administration that is not as concerned about methane control. The Obama Administration enacted two regulations applied to MSW landfills—the first a new Source Performance Standards for Municipal Solid Waste Landfills under the Clean Air Act; the second, Emissions Guidelines and Compliance Times for Municipal Waste Landfills (Emissions Guidelines).[163] The Emissions Guidelines apply to existing landfills that began construction, reconstruction or modification on or before July 17, 2014, and accepted waste after November 8, 1987.[164] These two aspects of the rules lower the emissions threshold for landfills at which levels they are required to install emission controls.[165] These guidelines reduce the prior standard of fifty metric tons per year of NMOC emissions to lower level of 34 metric tons per year. There is an exception to the new lower limit for landfills expected to close within thirteen months of the new rules, although they remain subject to the fifty metric tons per year threshold. To allow states time to comply, they were given nine months to develop and submit state plans in order to implement the guidelines.[166]

These additional Obama Administration landfill regulations, having taken effect in the final three months of the administration, were stayed by the Trump Administration EPA, pending review.[167] This stay restores in force the prior less stringent 1996 regulations.

B. Municipal Sewage Treatment Methane Generation

1. Methane Emissions

U.S. wastewater treatment facilities process approximately 34 billion gallons of wastewater every day.[168] Management of human sewer wastewater creates methane from the decomposition of organic matter in the waste.[169] While not as

n.pdf [https://perma.cc/4856-2WZR].

[163] *See* 40 C.F.R. §§ 60.30f-60.41f, 60.760-60.769.

[164] *Id.* § 60.33f.

[165] *See id.* §§ 60.30f-60.41f, 60.760-60.769.

[166] *See id.* § 60.23 (noting that States shall submit a plan to the Administrator "within 9 months after notice of the availability of a final guideline document . . .").

[167] Press Release, U.S. Envtl. Prot. Agency, *EPA Stays Landfill Methane Rules*, U.S. ENVTL. AGENCY (May 23, 2017), https://www.epa.gov/newsreleases/epa-stays-landfill-methane-rules [https://perma.cc/G3YW-PR82].

[168] The Sources and Solutions: Wastewater, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/nutrientpollution/sources-and-solutions-wastewater [https://perma.cc/GLJ4-EYTT] (last updated Mar. 10, 2017).

[169] *Municipal Wastewater Methane: Reducing Emissions, Advancing Recovery and Use Opportunities*, GLOBAL METHANE INITIATIVE (Jan. 2013), https://www.globalmethane.org/documents/ww_fs_eng.pdf [https://perma.cc/J3XX-8547]

significant as methane release from fossil fuel production, animal operations, and landfills, wastewater treatment operations release methane, which can be captured either for productive purposes or for destruction.[170] In the ongoing debate about which countries should participate in global warming gas emission reductions and which should be exempt, there is no reason that any country should receive exemption for management of its own human waste methane or landfill methane emissions.[171]

The amount of methane created from human biologic waste management (or lack of management) corresponds generally to the population size of a country or a region.[172] Therefore, responsibility to contain these types of fugitive methane emissions to the atmosphere from human waste is distributed across the world proportionately as the responsibility of every country is relative to its population. Methane emissions from human waste management do not directly correlate with the degree of development of a country, but rather with its population.

2. Wastewater Methane Management

There is a long way to go with improvements in developed countries, as well as in developing countries. According to most recent data, U.S. wastewater treatment systems emitted 2% of national methane emissions.[173] There are approximately 16,000 publicly owned wastewater treatment facilities in the U.S.[174] Of these, 1,269, or less than 10%, have anaerobic digesters on the site to extract methane gas forming from organic material, with only 860, or less than 6% of the total number of facilities, employing the captured methane as a reusable fuel.[175] Stated another way, less than 10% of facilities are capturing something as valuable as fuel, yet 94% of the facilities are wasting it rather than applying it productively. Moreover, 90% of all facilities emit the very climate-damaging methane, rather than flaring it to destroy the methane. There is no requirement for wastewater treatment to capture methane or to use it.

[hereinafter GLOBAL METHANE INITIATIVE].

170 *Id.*

171 *See generally* Steven Ferrey, *Changing Venue of International Governance and Finance: Exercising Legal Control over the $100 Billion per Year Climate Fund?*, 30 WIS. INT'L L.J. 26 (2012) (discussing the need for all countries to reduce greenhouse gas emissions).

172 GLOBAL METHANE INITIATIVE, *supra* note 169.

173 EPA, 1990-2015 INVENTORY OF EMISSIONS AND SINKS, *supra* note 38, at ES-6.

174 *Water and Wastewater Systems Sector*, U.S. DEP'T OF HOMELAND SEC. (July 6, 2017), https://www.dhs.gov/water-and-wastewater-systems-sector [https://perma.cc/6EEA-Q7UT].

175 AM. SOC. AMERICAN SOCIETY CIV. ENG'RS, 2017 INFRASTRUCTURE REPORT CARD: WASTEWATER (2017), https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Wastewater-Final.pdf [https://perma.cc/EN94-QZ8X].

However, there are technical possibilities to do so. An anaerobic digester collects the methane or "biogas" that bacteria converts when consuming organic material anaerobically.[176] The biogas produced is composed of about 60% methane, 40% CO_2, and approximately 0.2%-0.4% hydrogen sulfide.[177] The methane can be combusted for electricity or used as a thermal source of energy.[178]

There are other benefits of this energy extraction process: After extracting usable carbon, the amount of wastewater remaining for disposal is reduced and the removal of its volatile compounds reduces residual odor.[179] Sewage solids can be landfilled, burned, or recycled.[180] When sewage is heated with little or no oxygen, it combusts, becoming a gas mixture of carbon monoxide and hydrogen, known as syngas.[181] This syngas then mixes with oxygen and burns more efficiently than the original solids in the waste stream, and can produce electric energy and/or heat.[182] Plants that use biomass gasification have better energy capture efficiency than plants that burn the waste solids, and also convert sludge to ash, which consumes less landfill space then sludge.[183]

Sewage methane also can be used in advanced fuel cell technologies to produce direct current electricity.[184] For example, one New York sewage treatment facility employs a 200 Kw hydrogen fuel cell which supplies enough electricity to power sixty homes.[185] Advanced technology research regarding a

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[176] Michael Schirber, *Waste Not: Energy from Garbage and Sewage*, LIVE SCIENCE (Nov. 3, 2004, 4:00 AM), https://www.livescience.com/25-waste-energy-garbage-sewage.html [https://perma.cc/LXK8-D7DH].

[177] Christopher Henry & Richard K. Koelsch, *What is an Anaerobic Digester*, 7 MANURE MATTERS 1 (2001).

[178] *Gasification*, BIOMASS ENERGY RES. CTR., http://www.biomasscenter.org/what-we-do/our-expertise/gasification [https://perma.cc/F4WY-7QY7].

[179] Brendan McAuley et al., *A New Process for the Drying and Gasification of Sewage Sludge*, WATER AND WASTES DIGEST, at 20 (May 2011), https://www.wwdmag.com/sites/wwdmag.com/files/Drying_and_Gas_5_01.pdf [https://perma.cc/9PHZ-V8W8].

[180] *See* GAS TECH. INST., THE POTENTIAL FOR RENEWABLE GAS: BIOGAS DERIVED FROM BIOMASS FEEDSTOCKS AND UPGRADED TO PIPELINE QUALITY 19 (2011), http://www.gasfoundation.org/researchstudies/agf-renewable-gas-assessment-report-110901.pdf [https://perma.cc/A5W5-8LFC]; *see also infra* Section III.E (discussing agricultural manure management options).

[181] *Gasification*, *supra* note 178.

[182] *Id.*

[183] McAuley et al., *supra* note 179, at 18.

[184] Ferrey, *Brownfield Environmental Negatives*, *supra* note 114, at 433.

[185] Andrew C. Revkin, *Sewage Plant Alchemy: Foul Gases into Energy*, N.Y. TIMES (Feb. 7, 1999), http://www.nytimes.com/1999/02/07/nyregion/sewage-plant-alchemy-foul-gases-into-energy.html [https://perma.cc/8V7F-EV6R] (explaining that the only byproduct from the

microbial fuel cell is ongoing.[186]

Methane emissions created during wastewater treatment could be significantly reduced by the Obama Administration's 2050 goal by applying currently available technology options, such as anaerobic biomass digesters at centralized wastewater treatment facilities.[187] It would be possible to prescribe standards for existing and new wastewater management systems to capture and productively produce electricity needed for their wastewater treatment system operations. This could be a 'win-win' outcome long-term, since wastewater management is an ongoing challenge because continued production of waste material will continue. However, the Clean Water Act regulates treatment system discharges which don't focus on methane; the Clean Water Act does not address air emissions. To address methane capture and use in the U.S., either the U.S. Clean Air Act would need to be amended to address these issues or new statutory authority might be required.

C. Coal-Bed Methane Recovery

Methane exists in gaseous form in underground coal mines.[188] It is released to the atmosphere from both active and abandoned underground coal mines.[189] These fugitive emissions are significant, as 10% of all anthropogenic methane emissions originated from coal mines in 2012, aggregating in its total warming impact the effect equivalent to 56 million tons of carbon dioxide pollution.[190]

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process is hot water, which then is used to warm the bacteria, which decomposes the organic gas from the sewage and that the sewage treatment plant saves natural gas that they would otherwise use as fuel for this process). A plant in Renton, Washington, is using both the digesters and the fuel cells. Miguel Llanos, *Poop Power? Sewage Turned Into Electricity*, NBC NEWS: GREEN MACHINES, http://www.nbcnews.com/id/5335635/ns/us_news-environment/t/poop-power-sewage-turned-electricity/ [https://perma.cc/UL6X-RDAT] (last updated July 19, 2004).

[186] Gayle Ehrenman, *From Foul to Fuel*, MECHANICAL ENGINEERING, June 2004, at 32-33. The device is a single-chambered plexiglas device which is 6 inches long and 2.5 inches in diameter. *Id.* Inside of the chamber "eight graphite anodes surround a cathode that's made up of a carbon/platinum catalyst and proton exchange membrane layer fused to a plastic support tube." *Id.* A copper wire then connects to the circuit. *Id.* The MFC captures electrons which are released by the bacteria as they digest the organic matter and converts this into energy, and also removes about 80% of the organic matter from the wastewater. *Id.* Since there is no oxygen used in the process this means that the methane does not need to be burned to produce energy, and therefore there can be more energy extracted from the process. *Id.*

[187] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11 at 92.

[188] *Coal Mine Methane Sources*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/cmop/coal-mine-methane-sources#activeUndergroundMines [https://perma.cc/27AW-E4CB] (last updated Aug. 18, 2017).

[189] *Id.*

[190] U.S. WHITE HOUSE, CLIMATE ACTION PLAN STRATEGY TO REDUCE METHANE*, supra*

There are commercially available technologies which can be applied to recover and reduce emissions of methane. These technologies include: (1) methane drainage and recovery systems, which can remove methane from the coal seam before mining commences or from the air inside the mine post-mining, (2) ventilation and destruction of methane in the air, and (3) productive end-use application for recovered gas (including electricity generation or use as a fuel for on-site heating).[191]

In the United States, efforts to capture and utilize coal-bed methane gas intensified at the end of the twentieth century when coal-bed methane development became this country's fastest growing natural gas resource.[192] In 1991, 350 billion cubic feet (Bcfs) of coal-bed methane was produced; the production level had nearly doubled in the years since 1985 when only 11 Bcfs were produced.[193] More recently, coal-bed methane recovery declined during the most recent decade, from a high approaching 2 trillion cubic feet in 2008 to most recently a decline of more than one-third to approximately 1.2 trillion cubic feet in 2015.[194] This parallels the decline in use of coal as the fuel for electricity in the U.S. during the same period. Implementation of coal-bed methane recovery technology is economically viable because coal-bed methane is almost identical to natural gas and can be utilized as fuel for many purposes.[195] The technologies described above can reduce coal mining methane emissions. However, only 21 of 305 active underground coalmines in the U.S. have deployed methane drainage systems.[196]

A 2013 report identified regulation of coal mining emissions as one of several important methane control measures.[197] Implementation of these mitigation

note 162, at 5.

[191] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

[192] DINA W. KRUGER, U.S. ENVTL. PROT. AGENCY, EPA/430/R-94/007, THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF COALBED METHANE DEVELOPMENT IN APPALACHIA 6 (1994); *see also* Gary C. Bryner, *Coalbed Methane Development: The Costs and Benefits of an Emerging Energy Resource*, 43 NAT'L RESOURCE J. 519, 523-24 (2003).

[193] KRUGER, *supra* note 192, at 6 fig. 4.

[194] *U.S. Coalbed Methane Production*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/dnav/ng/hist/rngr52nus_1a.htm [https://perma.cc/U4C3-SQ4F] (last updated Dec. 14, 2016).

[195] *See* Bryner, *supra* note 192, at 520-27.

[196] EPA, 1990-2015 INVENTORY OF EMISSIONS AND SINKS, *supra* note 38, at 3-56, 3-59; *Coal Mine Methane (CMM) Recovery Opportunities Map*, COALBED METHANE OUTREACH PROGRAM, https://www.epa.gov/cmop/cmm-opportunities-map [https://perma.cc/P9PS-9CD7].

[197] Inst. For Governance & Sustainable Dev., *supra* note 34, at 39 (showing in Table 2 that the additional mitigation measures listed in the report include: (1) controlling fugitive emissions from oil and gas production, (2) controlling fugitive emissions from long distance gas transmission, (3) capturing gas from municipal waste and landfills, (4) capturing gas from

measures may reduce global methane emissions by an estimated 38%.[198] Half of the identified methane measures can be implemented with a net cost savings averaged globally.[199] Recent analysis even indicates that approximately 64% of potential reductions in methane from the identified measures can be achieved for less than $250 per metric ton, well below the estimated $1100 per metric ton value gained from climate mitigation, improved health outcomes, and crop production.[200]

The Obama Administration planned to cut methane released from coal.[201] The federal government, through the Interior Department's Bureau of Land Management, retains proprietary control over mining on federal land, and sought to exercise such authority at the end of the Obama Administration.[202] To address these issues, the Obama Administration's strategy was to work in conjunction with the Department of Interior's Bureau of Land Management (BLM) and the Environmental Protection Agency to capture, sell, or dispose of waste mine methane from federal leases for coal and other solid minerals.[203] This legal authority is safety-based, rather than designed for climate change mitigation. Methane concentrations in interior confinements are addressed, rather than ambient emissions. How this authority will be exercised in the Trump administration remains to be fully seen.

D. Animal Waste

Agricultural methane emissions are largely driven by livestock manure and enteric fermentation.[204] Since 2010, the EPA has attributed manure management as the fifth principal cause of methane releases.[205] Agriculture contributes more than 40% of U.S. non-CO_2 greenhouse gas emissions in the form of N_2O and methane, predominately from livestock manure and enteric fermentation.[206]

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livestock manure, and (5) and intermittent aeration of constantly flooded rice paddies.).

198 *Id.*

199 U.N. ENV'T PROGRAMME, NEAR-TERM CLIMATE PROTECTION AND CLEAN AIR BENEFITS: ACTIONS FOR CONTROLLING SHORT-LIVED CLIMATE FORCERS, at x (2011).

200 Inst. for Governance & Sustainable Dev., *supra* note 34, at 39 (citing Shindell, *supra* note 156, at 186 (2012)).

201 U.S. WHITE HOUSE, CLIMATE ACTION PLAN STRATEGY TO REDUCE METHANE, *supra* note 162, at 5-6.

202 Waste Mine Methane Capture, Use, Sale, or Destruction, Advance Notice of Proposed Rulemaking, 79 Fed. Reg. 23923 (Apr. 29, 2014).

203 *Id.* at 6 (stating further that the EPA will also continue to coordinate with the Department of Labor's Mine Safety and Health Administration to ensure that implementation of methane recovery projects at coal mines is consistent with all applicable safety standards).

204 EPA, 1990-2014 INVENTORY OF EMISSIONS AND SINKS, *supra* note 40, at 2-17.

205 *See id.* at ES-5 to -6.

206 U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

Cattle production in the United States is one of the primary causes of methane emissions.[207] In the U.S., 1.8 billion tons of manure from livestock are produced annually.[208] Anaerobic digesters can capture methane from agricultural waste and produce renewable electricity or heat.[209] Additionally, it is possible to utilize algae and safe food additives to significantly reduce methane production in livestock.[210]

The Obama Administration plan addressed methane emissions released by agriculture through voluntary actions, not through regulatory requirements.[211] The Obama Administration recognized the most important voluntary opportunities are through manure management with anaerobic digestion and biogas utilization.[212] Biogas systems are proven and effective technology to process organic waste and generate renewable energy.[213] They can reduce the risk of potential air and water quality issues while providing additional revenue for operation.[214] Nevertheless, there are still relatively few digesters in operation on farms across America.[215]

More than 225 anaerobic digesters in more than half of the states in the U.S. convert some of this waste to usable methane, which is then used to produce electricity.[216] To do so, manure is heated in an oxygen-free tank, where bacteria breaks down its chemical constituents.[217] After the methane is extracted, the manure and organic matter utilized in the process can still be used as fertilizer.[218]

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[207] *Id.* at 88.

[208] JOHN R. CAMPBELL, M. DOUGLAS KENEALY & KAREN L. CAMPBELL, ANIMAL SCIENCES: THE BIOLOGY, CARE, AND PRODUCTION OF DOMESTIC ANIMALS 14 (4th ed. 2009).

[209] *Id.* at 91 (suggesting implementing such practices may produce concerns regarding lower agricultural yields and profits).

[210] *See id.* (citing R. D. Kinley & A. H. Fredeen, *In Vitro Evaluation of Feeding North Atlantic Stormtoss Seaweeds on Ruminal Digestion*, 27 J. APPLIED PHYCOLOGY 2387, 2388 (2014)).

[211] *Id.* at 90.

[212] *See id.* at 91.

[213] *Id.*

[214] *Id.*

[215] U.S. DEP'T. AGRIC., U.S. ENVTL. PROT. AGENCY & U.S. DEP'T ENERGY, USDA BIOGAS OPPORTUNITIES ROADMAP: VOLUNTARY ACTIONS TO REDUCE METHANE EMISSIONS AND INCREASE ENERGY INDEPENDENCE 14 (2014), https://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf [https://perma.cc/CK5P-6F3C].

[216] *Id.*

[217] William F. Lazarus, *Economics of Anaerobic Digesters for Processing Animal Manure*, EXTENSION (Oct. 27, 2015), http://articles.extension.org/pages/19461/economics-of-anaerobic-digesters-for-processing-animal-manure [https://perma.cc/B29S-NWUL].

[218] *Id.*

The methane can be used as a medium-BTU gas.[219]

Traditionally, agricultural operations were not considered either human-made major stationary or mobile sources subject to regulation under the Clean Air Act, nor were they considered regulated point sources pursuant to the Clean Water Act. Nonetheless, in recent regulations, very large combined animal feeding operations (CAFOs) that fall under the Act's definition of a CAFO by housing a certain threshold number of animals, are considered point sources for discharge of pollutants into waterways requiring National Pollutant Discharge Elimination System (NPDES) permits under the Clean Water Act.[220]

The majority of agricultural operations are considered minor sources of air pollution that are not subject to regulation under the Clean Air Act. As of 2014, the rule applied to approximately 15,300 large animal confinement facilities in the United States, adding up to less than 6% of all large animal feeding operations in the country.[221] In 2012, for instance, North Carolina issued National Pollutant Discharge Elimination System (NPDES) permits to only 14 of the 1,222 CAFOs in the state, while the United States issued permits to only 6,572 of 18,622 estimated CAFOs in the country.[222]

Because of increasing world population and increasing demand for food, the prospect of reducing worldwide agricultural emissions of methane before 2050 in a very competitive world agricultural market must rely on technological innovation in animal diets, fertilizer use, and manure management.[223] However, the challenge here is that the agricultural sector of the economy is very competitive and, with a large number of actors, successful broad and even-handed implementation could be difficult.[224]

IV. FUEL SUPPLY AND METHANE LOSS TO A WARMING ATMOSPHERE

Fossil fuels are the dominant form of energy used in the world, comprising

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[219] *Biogas, Conversion/Clean-Up, Anaerobic Digestion*, SCS ENGINEERS, http://www.scsengineers.com/services/biogas-anaerobic-digestion-cng-energy-systems/biogas/ [https://perma.cc/TYX7-42KN] (last visited Feb. 10, 2018).

[220] *Agriculture: Laws and Regulations that Apply to Your Agricultural Operation by Statute*, U.S. ENVTL. PROT. AGENCY (Dec. 7, 2016), https://www.epa.gov/agriculture/agriculture-laws-and-regulations-apply-your-agricultural-operation-statute [http://perma.cc/G3K5-VALC].

[221] CLAUDIA COPELAND, CONG. RESEARCH SERV., RL33691, ANIMAL WASTE AND HAZARDOUS SUBSTANCES: CURRENT LAWS AND LEGISLATIVE ISSUES 10 (2014).

[222] *CAFO Rule Implementation Status*, U.S. ENVTL. PROT. AGENCY (Oct. 1, 2017), https://www3.epa.gov/npdes/pubs/afo_tracksum_endyear2012.pdf [http://perma.cc/AE3A-CFPZ].

[223] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

[224] *Id.* at 91.

87% of primary energy use in 2012.[225] During the prior decade, United States natural gas production increased by more than one-quarter[226] and U.S. oil production increased by more than 15%.[227] And associated with extraction, transportation, and use of fossil fuels, is the release of methane which warms the atmosphere. Almost one-third of America's methane emissions come from oil and gas production and distribution.[228] Where coal is used, coal production accounts for approximately 9% of methane emissions, mostly from releases at newly opened mines.[229]

However, power generation sources emitting methane are not limited to fossil fuels. Even dams exploiting hydropower produce methane.[230] Approximately two-thirds to three-quarters of a dam's total greenhouse gas emissions are in the form of methane when organic matter trapped under water decays and releases methane, with the remainder of dam emissions being CO_2.[231] Because methane is a relatively potent greenhouse gas, a single dam and hydroelectric project in Brazil was calculated to account for as much greenhouse gas emissions as those from the entire city of Sao Paulo, Brazil.[232]

[225] Milena Gonzalez & Matt Lucky, *Fossil Fuels Dominate Primary Energy Consumption*, WORLDWATCH INST. (Oct. 24, 2013), http://www.worldwatch.org/fossil-fuels-dominate-primary-energy-consumption-1 [https://perma.cc/6TRH-JFUB].

[226] *U.S. Dry Natural Gas Production*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/dnav/ng/hist/n9070us2A.htm [https://perma.cc/XM3U-YBEP] (last updated Dec. 29, 2017).

[227] *U.S. Field Production of Crude Oil*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus2&f=a [https://perma.cc/H889-SGGU] (last updated Dec. 29, 2017).

[228] Tripp Baltz, *States Lead on Regulating Gas Flaring, Venting, Leaks*, 121 DAILY ENV'T REP. (BNA) No. 112, June 23, 2016, at B-5 [hereinafter Baltz, *States Lead on Regulating Gas Flaring, Venting, Leaks*].

[229] *Reducing Methane Emissions From the Oil and Gas Sector*, CTR. FOR CLIMATE AND ENERGY, http://www.c2es.org/federal/executive/epa/reducing-methane-emissions-oil-gas-sector [https://perma.cc/2YSC-ELV5] (last visited Oct. 5, 2017) (pointing to a recent EPA study indicating that methane accounts for 9% of methane emissions from coal mining).

[230] *See Dams Attacked as Greenhouse Source,* 18 THE ELECTRICITY DAILY (2002).

[231] *Id.*

[232] *Id.*

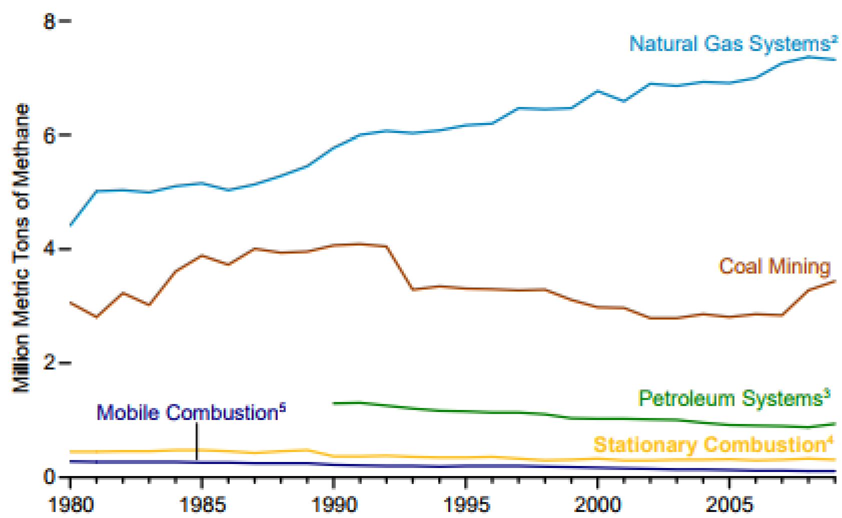

FIGURE 8: Energy Sources by Type, 1980-2009[233]

Figure 8 illustrates how significant methane is as an input to energy supply flows in the U.S. Methane emissions from the use of power generation facilities are not currently regulated by the Clean Air Act or the Clean Water Act.

A. The Power Sector and Greenhouse Gas Emissions

1. Electricity Production Modes

The Congressional Research Service concluded that "in 2010, fossil fuels accounted for 78.0% of U.S. Primary energy production,"[234] which is a smaller share than the 2012 average among all world economies.[235] "The oil-and-gas industry is the largest emitter of methane, and the U.S. is the world's largest oil-and-gas producer . . . [,]responsible for about 10% of global methane emissions."[236] The electric power sector is a critical energy sector, both in terms

233 U.S. ENERGY INFO. ADMIN., DOE/EIA-0384(2011), ANNUAL ENERGY REVIEW 2011 310 (2012).

234 MOLLY F. SHERLOCK, CONG. RESEARCH SERV., R41953, ENERGY TAX INCENTIVES: MEASURING VALUE ACROSS DIFFERENT TYPES OF ENERGY RESOURCES, at Summary (2012), https://www.hsdl.org/?view&did=722543 [https://perma.cc/4WQA-5D9J].

235 Gonzalez & Lucky, *supra* note 225 (stating that 87% of primary energy worldwide was from fossil fuels in 2012).

236 Eric Roston, *Obama Sets Stage for Huge Emissions Regs, Unless Trump Wins,* NEWSMAX (May 15, 2016, 8:13 AM), http://www.newsmax.com/Newsfront/obama-

of function and greenhouse gas emissions.

Using 2013 data, when natural gas contributed a smaller share of total U.S. electric power than it does today, natural gas was responsible for 444 million metric tons of CO_2 emissions, which was 22% of the total from all fossil fuels employed for power production, and had doubled over the prior two decades.[237] Natural gas combustion produces CO_2 at about 25% less per equivalent unit of energy than oil and almost half as much as coal; it produces less of four of the six criteria air pollutants regulated by federal law and EPA.[238] More gas at lower prices today will mean a rise of 50% in global demand for natural gas between 2010 and 2035, according to the International Energy Agency ("IEA").[239] This could raise atmospheric concentrations of CO_2 to 650 parts per million causing temperature to rise 3.5 degrees Celsius, which is more than many experts believe is tolerable for the Planet.[240]

Coal has been the dominant source of electricity production in the U.S. and the world since the first harnessing of electricity 135 years ago.[241] Coal use for electricity production has decreased significantly in the U.S.: currently, the electric system relies almost equally on coal-fired and natural gas-fired technology, each accounting for one-third of U.S. power production.[242] 406 U.S. coal-fired power plants produce about 95% of the coal-fired power in the United States, at an average cost of 3.2 cents/Kwh.[243] A small percentage of coal-fired power plants are responsible for a large share of

emissions-cuts-trump/2016/05/15/id/728888/ [https://perma.cc/47EG-JBA3].

[237] U.S. ENERGY INFO. ADMIN., DOE/EIA-0035(2017/9), SEPTEMBER 2017 MONTHLY ENERGY REVIEW 185 tbl.12.6 (2017), https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf [https://perma.cc/R43U-D8HC].

[238] *See* FERREY, ENVIRONMENTAL LAW, *supra* note 20, at 594 (showing these criteria pollutants are carbon monoxide (92 parts per billion compared to roughly 450 ppb for oil or coal), sulfur dioxide (1 ppb for gas versus versus 1,122 ppb for oil and 2,591 ppb for coal), almost no nitrogen oxide and no particulate matter which burning other fossil fuels does release).

[239] *An Unconventional Bonanza*, THE ECONOMIST, July 14, 2012, at 2, http://www.economist.com/sites/default/files/20120714_natural_gas.pdf [https://perma.cc/XYM8-68DH].

[240] Bill McKibben, *Why Not Frack?*, LIX NEW YORK REVIEW OF BOOKS 1, 14 (2012) [hereinafter McKibben, *Why Not Frack?*].

[241] John Muyskens et al., *Mapping How the United States Generates its Electricity*, WASH. POST (July 31, 2015), https://www.washingtonpost.com/graphics/national/power-plants/ [https://perma.cc/LR9G-4TTJ].

[242] *See*, *What Is U.S. Electricity Generation by Energy Source?*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3 [https://perma.cc/LRG3-5SGA] (last updated Apr. 18, 2017) [hereinafter *U.S. Electricity Generation*].

[243] *What Cost Energy? What Market Prices Fail to Reveal*, 22 THE ELECTRICITY J. 3 (Dec. 2009).

climate emissions. Approximately 10% of these older coal-fired power plants produce about 43% of the CO_2 emissions.[244] Fifty power plants accounted for 30% of CO_2 emissions from the U.S. power sector, despite only producing 16% of the nation's electricity.[245] The fifty largest emitting power plants account for more than 2% of global greenhouse gases from the world power sector.[246]

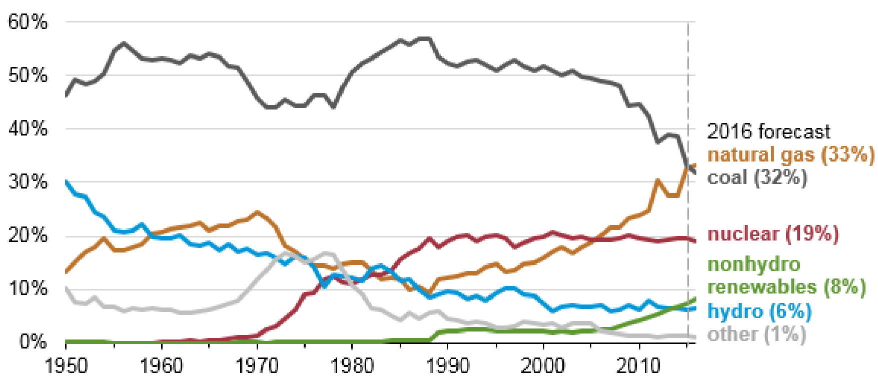

FIGURE 9: Annual Share of Total U.S. Electricity Generation by Source, 1950-2016[247]

However, the deployment of coal in the U.S. power sector has fallen in the last decade. The decreasing share of coal-fired power generation from almost 60% in the mid-1980s, to approximately one-third in recent months, counterbalanced by an increasing share of power generation from natural gas, is shown in Figure 9. Transitioning from fossil fuels to low-carbon energy not only diminishes the amount of CO_2 emitted during combustion but also reduces methane emissions associated with fossil fuel extraction.[248]

[244] *Id.*

[245] JORDAN SCHNEIDER ET AL., ENV'T AM. RES. & POL'Y CTR., AMERICA'S DIRTIEST POWER PLANTS: THEIR OVERSIZED CONTRIBUTION TO GLOBAL WARMING AND WHAT WE CAN DO ABOUT IT 5 (2013).

[246] *Id.*

[247] *Natural Gas Expected to Surpass Coal in Mix of Fuel Used for U.S. Power Generation in 2016*, U.S. ENERGY INFO. ADMIN. (Mar. 16, 2016), https://www.eia.gov/todayinenergy/detail.php?id=25392 [https://perma.cc/M4GL-FKNN] [hereinafter *Natural Gas Expected to Surpass Coal*].

[248] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11.

2. Competition From Renewable Power

While natural gas prices have been decreasing, the cost of key renewable power generation technologies has decreased even more. There has been a radical change in the cost of distributed renewable power generation. A big change is ushered in through the technological and cost declines of wind and solar photovoltaic ("PV") distributed generation. The cost to install photovoltaic solar panels has fallen dramatically by about 60% in 'hard' costs. PV module prices have experienced a decline from ~$1.90/watt in 2009 to $0.70/watt, and lower in some regions of the world.[249] Inverter prices, for the equipment necessary to convert photovoltaic direct current to alternating current so that it can be moved on the grid, have also declined by more than 60% in cost from $0.60-$1.00+/watt in 2005 to under $0.20/watt in 2013.[250]

This has allowed the solar photovoltaic market to grow at an average rate of 40% from 2010-2016.[251] Solar energy is forecasted to be cost-competitive with retail electricity prices in fifty U.S. states by 2016, with maintenance of current subsidies, according to Deutsche Bank.[252] Figure 10 also shows the recent increase in non-hydroelectric renewable energy use for power generation in the U.S. The projection of the U.S. Department of Energy, going forward, is that there will be a significant increase in U.S. natural gas usage with a corresponding significant decrease in coal use in the next twenty-five years, as shown in Figure 10.[253]

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[249] WILSON RICKERSON, INT'L ENERGY AGENCY – RENEWABLE ENERGY TECH. DEPLOYMENT, RESIDENTIAL PROSUMERS-DRIVERS AND POLICY OPTIONS (RE-PROSUMERS) 9 (2014).

[250] *Id.*

[251] FRAUNHOFER INST. FOR SOLAR ENERGY SYS., PHOTOVOLTAICS REPORT 5 (2017), https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf [https://perma.cc/LH54-ZJYD].

[252] *See* Giles Parkinson, *Solar Grid Parity in All 50 US States by 2016, Predicts Deutsche Bank*, CLEAN TECHNICA (Oct. 29, 2014), https://cleantechnica.com/2014/10/29/solar-grid-parity-us-states-2016-says-deutsche-bank/ [https://perma.cc/9HXJ-2D77]. This is based on the assumption that the cost of solar systems will decline by about 20% more, from less than $3 per watt installed to less than $2.50 per watt installed by 2016, resulting in a price in those states from 9-14 cents/Kwh, and lowered financing cost for solar projects. The average cost of residential electricity in the U.S. in 2013 was 12.12 cents/Kwh, and was 8.95 cents/Kwh in 2004. These assumptions factor in ongoing U.S. subsidies from the 30 percent investment tax credit for solar energy, which is scheduled to drop to 10 percent in the future.

[253] *See*, *Fossil Fuels Still Dominate U.S. Energy Consumption Despite Recent Market Share Decline*, U.S. ENERGY INFO. ADMIN (July 1, 2016), https://www.eia.gov/todayinenergy/detail.cfm?id=26912 [https://perma.cc/CDR3-EK7W].

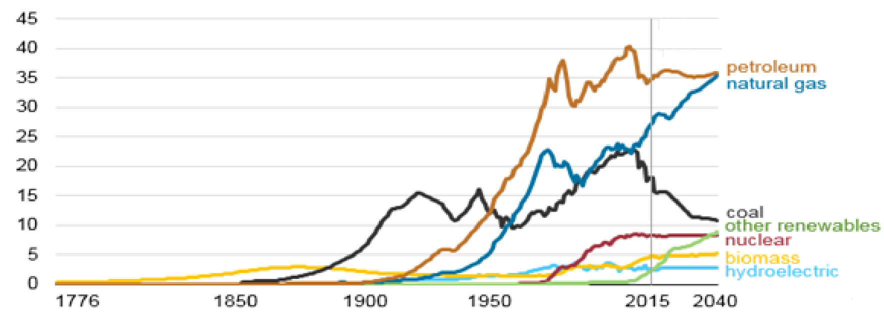

FIGURE 10: Energy Consumption in the United States, 1776-2040[254]

Even if natural gas were used less when producing electricity, it still is the primary source of heat energy in the United States, Canada, much of Europe, and in several other developed countries.[255] While there are several alternatives to produce heat energy, with the discovery to extract more natural gas through hydro-fracking technology,[256] it single-handedly altered the U.S. natural gas reserves from a couple of decades' duration to more than a century of reserves. This increased supply also lowers price, which will cause natural gas to remain as the heating fuel of choice at least for the foreseeable future. America now is forecasted to have 100 years or more of gas supplies at current consumption rates.[257]

Methane and ethane are the primary constituents of natural gas fuel.[258] The main byproduct when burning natural gas is CO_2, a major greenhouse gas.[259] However, the amount of CO_2 produced by natural gas is less than that oil and almost half as much as coal.[260] Methane is released in the fossil fuel gathering process, with emphasis now on the large number of new natural gas hydro-

[254] *Id.*

[255] *See*, *Everywhere But Northeast, Fewer Homes Choose Natural Gas as Heating Fuel*, U.S. ENERGY INFO, ADMIN. (Sept. 25, 2014), https://www.eia.gov/todayinenergy/detail.php?id=18131 [https://perma.cc/T9SJ-GWTE]; *Electricity and Heat Statistics*, EUROPA: EUROSTAT, http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics [https://perma.cc/LN49-2SB4] (last visited Jan. 4, 2018).

[256] *See infra* Section IV.B.2.

[257] *Gas Works*, THE ECONOMIST (July 14, 2012), http://www.economist.com/node/21558459 [https://perma.cc/6FDJ-EF88].

[258] Gordon I. Atwater et al., *Natural Gas*, ENCYCLOPEDIA BRITANNICA, https://www.britannica.com/science/natural-gas [https://perma.cc/QWU7-EZK5].

[259] *Natural Gas and the Environment*, NATURALGAS.ORG (Sep. 20, 2013), http://naturalgas.org/environment/naturalgas/ [https://perma.cc/M7WY-8YWV].

[260] UNION OF CONCERNED SCIENTISTS, *supra* note 58; *Gas Works*, *supra* note 257.

fracking wells being drilled to liberate gas trapped in underground shale formations.[261] Methane is also released to the atmosphere in the transportation of natural gas through leaking underground pipelines to its wholesale and retail destinations.[262]

Coal is in declining use in the U.S. where coal-fired power generation has decreased from approaching 60% of total U.S. generation a decade ago, to approximately 33% recently.[263] In the next five years, under increasing competition from shale gas and the Environmental Protection Agency's regulations on power plant emissions,[264] U.S. coal demand will fall to a 30-year low.[265] We next look at each of these aspects of the fossil fuel methane chain, and how better management of these releases can be achieved.

B. Accelerating Substitution of Natural Gas for Other Fossil Fuels

1. Fossil Fuel Substitutes

Figure 10 shows that natural gas was the last developed of the fossil fuels, but it is now enjoying a new source of extraction. Natural gas typically contains a relatively homogenous energy content of 70-95% methane along with a minority share of higher alkanes (ethane, propane, butane) and trace elements of other

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[261] *See* Mark Fischetti, *Fracking Would Emit Large Quantities of Greenhouse Gases*, SCIENTIFIC AMERICAN (Jan. 20, 2012), https://www.scientificamerican.com/article/fracking-would-emit-methane/ [https://perma.cc/LZB7-R85L] ("[P]ipeline leaks are the main culprit, but fracking is a quickly growing contributor."); *see also* Gayathri Vaidyanathan, *Methane Leaks from Oil and Gas Wells Now Top Polluters*, SCIENTIFIC AMERICAN (Apr. 16, 2015), https://www.scientificamerican.com/article/methane-leaks-from-oil-and-gas-wells-now-top-polluters/ [https://perma.cc/6YH7-ZZN7] [hereinafter Vaidyanathan, *Methane Leaks from Oil and Gas Wells Now Top Polluters*].

[262] Margaret F. Hendrick et al., *Fugitive Methane Emissions from Leak-Prone Natural Gas Distribution Infrastructure in Urban Environments*, 213 ENVTL. POLLUTION 710, 711 (2016); Martin Holladay, *Natural Gas Pipelines are Leaking*, GREEN BUILDING ADVISOR (May 19, 2017), http://www.greenbuildingadvisor.com/articles/dept/musings/natural-gas-pipelines-are-leaking [https://perma.cc/98K5-CB8V].

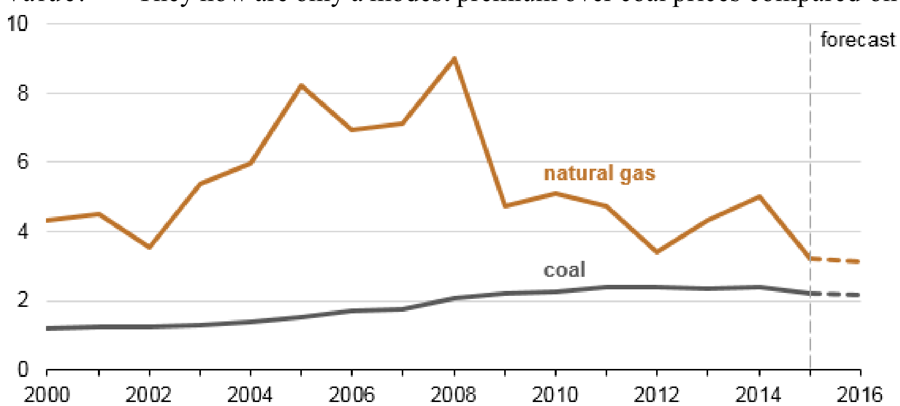
[263] *U.S. Electricity Generation*, *supra* note 242; Stephen Lacey, *U.S. Coal Generation Drops 19 Percent in One Year, Leaving Coal with 36 Percent Share of Electricity*, THINKPROGRESS (May 14, 2012), https://thinkprogress.org/u-s-coal-generation-drops-19-percent-in-one-year-leaving-coal-with-36-percent-share-of-electricity-4b06091d4cde/ [https://perma.cc/Y9ES-W7L9].

[264] *See* Steven Ferrey, *Presidential Executive Action: Unilaterally Changing the World's Critical Technology and Infrastructure*, 64 DRAKE L. REV. 43, 59 (2016).

[265] Rick Mitchel, *IEA Says Climate Pledges Won't Halt Global Growth in Coal Demand to 2019*, ENV'T & ENERGY REP. (BNA), Dec. 15, 2014, https://www.bna.com/iea-says-natural-n57982063725/ [https://perma.cc/L5N4-MTS4].

atoms.[266] Natural gas is the feedstock of a number of chemical syntheses to produce synthetic nitrogen and certain plastics.[267]

Hydro-fracking technology greatly increases the recoverable amount of underground natural gas in the U.S. and this technology is now spreading slowly to other countries.[268] Until recently, natural gas was notably more expensive than coal per unit of energy.[269] Starting in 2009, however, large amounts of natural gas produced from shale formations increased supply and decreased gas prices, leaving gas only narrowly more expensive than coal per unit of energy value.[270] With more supply of natural gas methane, the price of gas in the U.S. market has dropped dramatically, and demand for it has increased commensurately.[271] Figure 11 illustrates that in a recent five-year period, natural gas prices have fallen precipitously to one-third of their prior value.[272] They now are only a modest premium over coal prices compared on



[266] Kevin A. Boudreaux, *Molecular Gallery*, ANGELO STATE UNIV., https://www.angelo.edu/faculty/kboudrea/molecule_gallery/01_alkanes/00_alkanes.htm [https://perma.cc/B7QZ-MZPE].

[267] *How Plastics Are Made*, AM. CHEMISTRY COUNSEL (2016), https://plastics.americanchemistry.com/How-Plastics-Are-Made [https://perma.cc/L92L-YUCB].

[268] Brad Plumer, *Fracking, Explained: Do Other Countries Use Fracking?* (July 30, 2015), https://www.vox.com/cards/fracking/do-other-countries-use-fracking [https://perma.cc/FXB5-LGQC].

[269] *Natural Gas Expected to Surpass Coal*, *supra* note 247.

[270] *Id.*

[271] *The Outlook for U.S. Natural Gas Prices 2018-2019*, SEEKING ALPHA (Oct. 25, 2017), https://seekingalpha.com/article/4116380-outlook-u-s-natural-gas-prices-2018minus-2019 [https://perma.cc/ZZL5-ZQDT].

[272] *See generally* Gail Tverberg, *Why U.S. Natural Gas Prices Are So Low – Are Changes Needed?*, OUR FINITE WORLD (Mar. 23, 2012), https://ourfiniteworld.com/2012/03/23/why-us-natural-gas-prices-are-so-low-are-

an equivalent energy value of both fuels, as shown in Figure 11.

FIGURE 11: Average Fuel Receipt Costs at Electric Generating Plants, 2000-2016[273]

As shown in Figure 11, natural gas is now cost-competitive with the traditionally much cheaper cost of coal for power generation, and has the added benefit of producing only approximately one-half as much CO_2 emissions as coal, no particulate matter criteria pollutants, no SO_2 criteria pollutant emissions, and the ability to emit less NO_x.[274] Because of this new shale gas supply, the real price of natural gas in 2016 was lower than its price twenty years earlier in 1996, as shown in Figure 12.[275]

New combined-cycle gas turbines, a spin-off technology from the aviation industry, have transformed the economics of the industry by providing a more efficient means to convert energy inputs to electric output.[276] Gas-fired units burn a "cleaner" fuel than coal, typically causing less maintenance expenses for units which burn gas compared to coal or oil.[277]

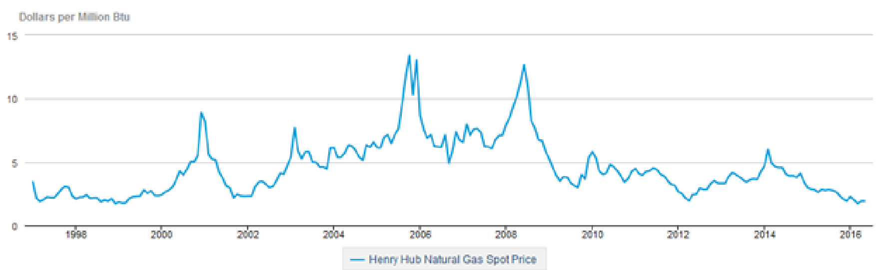


FIGURE 12: Henry Hub Natural Gas Spot Price[278]

However, if even a small amount of methane leaks into the atmosphere in the drilling process, the gas " can cause even more global warming effect

changes-needed/ [https://perma.cc/67XW-FEDQ].

[273] *Natural Gas Expected to Surpass Coal*, *supra* note 247.

[274] *Environmental Benefits of Natural Gas*, AM. GAS ASS'N, https://www.aga.org/environmental-benefits-natural-gas [https://perma.cc/R7JM-HANE].

[275] *Henry Hub Natural Gas Spot Price*, U.S. ENERGY INFO. ADMIN. (2017), https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm [https://perma.cc/F652-QFMX].

[276] *See* 1 STEVEN FERREY, LAW OF INDEPENDENT POWER § 2:9 (40th ed. 2017).

[277] Kevin Begos, *Electric Plants Shift from Coal to Natural Gas,* NC CLEAN ENERGY TECH. CTR. https://nccleantech.ncsu.edu/electric-plants-shift-from-coal-to-natural-gas/ [https://perma.cc/22KG-UXZW] (last visited Nov. 12, 2017).

[278] *Henry Hub Natural Gas Spot Price*, *supra* note 275.

than coal."[279] While EPA has considered methane gas twenty-five times as potent as CO_2 for global warming on a 100-year time scale, scientists now dispute whether methane gas isn't much more damaging than this 25:1 ratio for warming when calculated using real compared to time CO_2.[280]

2. The Unexpected Greater Supply of Methane – Fracking Technology

The U.S. now produces more gas than the two major suppliers of Russia and Saudi Arabia.[281] Hydraulic fracturing, or "fracking," is a well-stimulation technique that employs high pressure fluids consisting of water, sand, and a mixture of chemicals to create and maintain small fissures in shale rock, which provides a path for methane gas trapped in underground formations to move to perforated wellbores for extraction.[282] The practice is advanced by combining fracking with new horizontal drilling techniques, which allows the well to reach deep supplies of shale gas that in the past would have not been physically or economically feasible.[283]

The Marcellus Shale is a sedimentary rock formation deposited over 350 million years ago near the Appalachian Mountains.[284] It stretches across southern New York, Pennsylvania, West Virginia, eastern Ohio, and Western Maryland, and contains significant quantities of natural gas trapped in shale in an estimated basin area of 95,000 square miles, making it the second largest reserve of natural gas in the world, second only to a gas field that stretches through Iran and Qatar.[285] The Marcellus Shale may contain 84 trillion cubic feet of undiscovered, technically recoverable natural gas, and 3.4 billion barrels

279 McKibben, *Why Not Frack?*, *supra* note 240.

280 Gayathri Vaidyanathan, *Climate: Methane's Warming Potential Rises in Latest Report*, E&E NEWS: ENERGYWIRE (Oct. 1, 2013), https://www.eenews.net/energywire/stories/1059988104/ [https://perma.cc/Y5X5-VLFZ].

281 *U.S. Overtakes Saudi Arabia and Russia as Largest Oil Producer*, INST. FOR ENERGY RES. (July 10, 2014), http://instituteforenergyresearch.org/analysis/u-s-overtakes-saudi-arabia-russia-worlds-biggest-oil-producer/ [https://perma.cc/2VAQ-56G7].

282 *The Process of Hydraulic Fracking*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/hydraulicfracturing/process-hydraulic-fracturing [https://perma.cc/PM9M-QCQ6] (last updated Jan. 9, 2017). Perforated wellbore refers to a hole punched in the casing of a well to connect it to the reservoir.

283 *Id.*

284 *Gas Works*, *supra* note 257.

285 Joel Burcat et al., *Nuts and Bolts of Marcellus Shale Drilling and Hydraulic Fracturing*, 41 ENVTL. L. REP. NEWS & ANALYSIS 10587, 10590 (2011); James R. Ladlee, *Why Does Marcellus Shale Hold So Much Natural Gas?*, CLINTON CTY. GOV'T (Dec. 23, 2010), http://www.clintoncountypa.com/resources/CCNGTF/pdfs/articles/12.23.10%20-%20Why%20does%20Marcellus%20Shale%20Hold%20so%20much%20Natural%20Gas.pdf [https://perma.cc/9YDJ-J88B].

of undiscovered, technically recoverable natural gas liquids.[286] United States consumers use about twenty-seven and one-half trillion cubic feet (TCF) of natural gas per year.[287] As such, this one shale deposit could supply U.S. gas requirements at current levels for several years.

Recently exploited shale gas now already contributes one-third of America's annual gas supplies at relatively low prices.[288] The U.S. now has the second largest supply of gas in the world, significantly based on shale deposits and second only in gas supplies to Russia.[289] However, using more natural gas commensurately increases the risk of methane leakage to warm the atmosphere.[290] Researchers at Harvard University claim that if 3% or more of hydro-fracked methane leaked, that leaked methane would contribute more to climate damage than CO_2 from coal burning.[291] Their preliminary data showed leak rates of 3.6-7.9% of methane gas from shale-drilling; fracking basins in Utah found leakage rates as high as 9%.[292]

In terms of leak detection and repair technologies, in the Bakken shale deposits in North Dakota, gas is a by-product of oil production and is flared rather than captured for export.[293] When gas is flared, the producer loses that energy resource, and American taxpayers lose the royalty payments made on all harvested fossil fuel resources extracted from public lands.[294] Properly regulated, preventing leaks is a 'win-win-win' solution: the producers recover more salable energy, the public receives more royalties, and the environment vents less greenhouse gases to the atmosphere.[295] To arrest this waste of energy, North Dakota set a regulatory requirement in 2015 to attempt to reduce flared

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[286] *How Much Gas is in the Marcellus Shale?*, U.S. GEOLOGICAL SURVEY, https://www.usgs.gov/faqs/how-much-gas-marcellus-shale?qt-news_science_products=7#qt-news_science_products [https://perma.cc/Z5WE-YYF6] (last visited Jan. 4, 2018).

[287] *Frequently Asked Questions: How Much Natural Gas is Consumed in the United States?* U.S. ENERGY INFO. ADMIN., https://www.eia.gov/tools/faqs/faq.php?id=50&t=8 [https://perma.cc/7GLL-SSUQ] (last visited Jan. 4, 2018).

[288] *Gas Works*, *supra* note 257.

[289] *Natural Gas Reserves*, THE ECONOMIST (June 5, 2012), https://www.economist.com/blogs/graphicdetail/2012/06/focus [https://perma.cc/Y7X8-TUKU].

[290] Ramón A. Alvarez et al., *Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure*, 109 PROC. NAT. ACAD. SCI. 6435, 6435 (2012).

[291] McKibben, *New Chemistry*, *supra* note 26.

[292] *Id.*

[293] Baltz, *States Lead on Regulating Gas Flaring, Venting, Leaks*, *supra* note 228.

[294] *Id.*

[295] *Id.*

gas to less than 10% of all extracted gas by 2020.[296] This was achieved ahead of schedule in 2016.[297]

Under proposed U.S. Department of the Interior, Bureau of Land Management (BLM) rules, oil and gas producers would need to pay royalties on the gas lost through leaks, venting, or flaring, not only on gas productively recovered.[298] This altered past federal policy collecting royalties on gas recovered and sold. This regulation is being reviewed by the Trump Administration.[299] When not on federal lands, state law controls the venting or recapture of methane from fossil fuel extraction.[300] States often receive severance taxes or royalties on extraction from in-state land.[301] Existing state regulations on methane leaks exist in Wyoming, Colorado, New Mexico, Oklahoma, Kansas, Ohio, and North Dakota.[302] Proposed regulations on methane leaks are proposed in California and Pennsylvania.[303]

As gas is extracted, transported, and sold, there is the possibility of methane leaks at each phase in each of the countries. Natural gas was used for 34% of the United States total energy production,[304] and more recently 33.8% of electric production.[305]

If various obstacles can be overcome, more gas supply causes lower prices in gas markets and a rise of 50% in global demand for gas between 2010 and 2035, according to the International Energy Agency (IEA).[306] Due to greater abundance and lower prices, a 50% increase in international gas demand by 2040 is predicted.[307] The IEA forecasts that abundant use of gas could raise

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296 *Id.*

297 *Id.*

298 Tripp Baltz, *Major Oil, Gas States Adopting Rules on Methane Emissions*, ENV'T & ENERGY REP. (BNA), June 23, 2016, https://bnanews.bna.com/environment-and-energy/major-oil-gas-states-adopting-rules-on-methane-emissions [https://perma.cc/W3N3-K72A] [hereinafter Baltz, *Major Oil, Gas States Adopting Rules on Methane Emissions*].

299 Exec. Order No. 13,783, 82 Fed. Reg. 16093 (Mar. 28, 2017).

300 Baltz, *Major Oil, Gas States Adopting Rules on Methane Emissions*, *supra* note 298.

301 *Id*.

302 *Id*.

303 *Id*.

304 John Muyskens et al., *Mapping How the United States Generates its Electricity*, THE WASH. POST, https://www.washingtonpost.com/graphics/national/power-plants/?utm_term=.79e34a738e07 (last updated Mar. 28, 2017).

305 *U.S. Electricity Generation*, *supra* note 242.

306 *An Unconventional Bonanza*, *supra* note 239.

307 INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2016: EXECUTIVE SUMMARY 1 (2016), https://www.iea.org/Textbase/npsum/WEO2016SUM.pdf [https://perma.cc/4QNE-5UM6]. The IEA estimates are consistent with forecasts that have predicted a 43 percent rise in gas consumption between 2015 and 2040. *See* U.S. ENERGY INFO. ADMIN., INTERNATIONAL

atmospheric concentrations of CO_2 to 650 parts per million causing temperature to rise 3.5 degrees Celsius, which is more than many experts believe is tolerable for the health of the Planet.[308] The switch in the U.S. from coal to natural gas for electricity production[309] and all energy fuels,[310] which began during the Obama administration, and is continuing now reduces at the burner tip the emission of greenhouse gases per unit of electricity supplied.[311] However, this is only at the point of combustion, and does not account for natural gas methane being released to the environment during its transportation through the underground interstate pipeline system, a significant issue discussed next.

C. Transportation of Gas and Significant Leaks to the Atmosphere

To a lesser degree than the production of coal and oil, methane is released into the atmosphere when natural gas is transported and stored. Natural gas pipelines of 3 million miles cross significant areas of the United States; some are interstate and some are in-state, as shown in Figure 13.[312]

ENERGY OUTLOOK 2017, at 49 (2017), https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf [https://perma.cc/GJS8-VQVP].

308 McKibben, *Why Not Frack?*, *supra* note 279.

309 *See supra* Figure 9.

310 *See supra* Figure 10.

311 *See supra* Section IV.B.1.

312 *See Natural Gas Explained*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_pipelines [http://perma.cc/Z7MV-QS2L] (last updated Nov. 21, 2017).

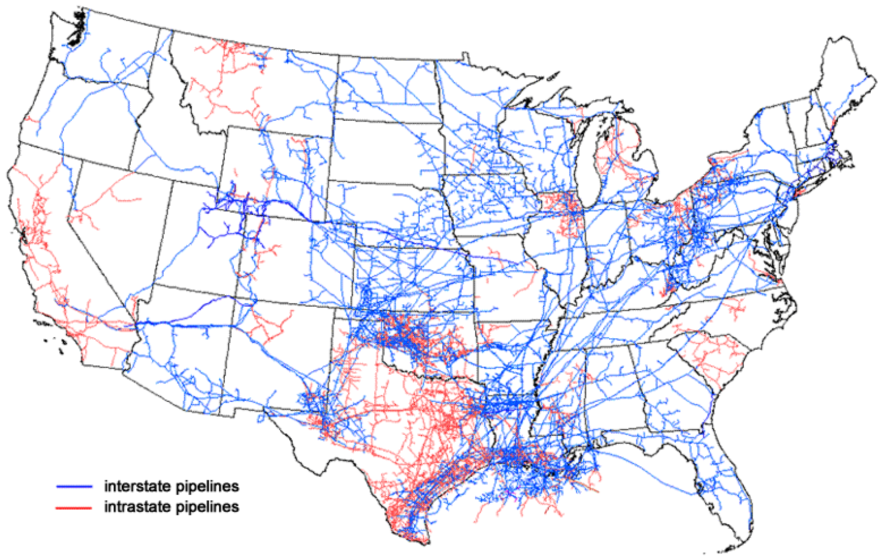

FIGURE 13: Interstate and Intrastate U.S. Natural Gas Pipeline Infrastructure[313]

Transporting methane gas is distinct from oil: one can't see methane. It is estimated by the EPA that less than 1%—0.35% to 0.70%—of the gas transported in gas pipelines leaks to the atmosphere, with a large amount of this leakage attributed to older cast iron and steel pipes.[314] This is an extremely modest amount of less than 1% estimated by the EPA. Methane also leaks from upstream oil and gas extraction.[315] Here is the tipping point: taking as true the EPA's 2009 total gas leakage rate of 2.4% in the whole mining and consumption chain, new natural gas-fired combined cycle power generation plants would reduce total climate impacts when replacing new coal-fired power generation plants, only if the total methane leakage is under 3.2%.[316] A report by Boston University and the Conservation Law Foundation, looking only at the moderate-sized city of Boston, found:

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[313] *Id.*

[314] Gayathri Vaidyanathan, *METHANE: DOE Discloses First Steps to Curb Leaks in Natural Gas Systems*, E&E NEWS (July 30, 2014), http://www.eenews.net/stories/1060003765 [http://perma.cc/8MDN-TXPG] [hereinafter Vaidyanathan, *METHANE: DOE Discloses First Steps to Curb Leaks in Natural Gas Systems*].

[315] *See* Vaidyanathan, *Methane Leaks from Oil and Gas Wells Now Top Polluters*, *supra* note 261.

[316] *The Climate Impacts of Methane Emissions*, ENVTL. DEF. FUND (Apr. 2012), https://www.edf.org/energy/methaneleakage [http://perma.cc/98CP-5V83].

- Natural gas is escaping from more than 3300 leaks in Boston.
- Most leaks are tiny - although six had gas levels higher than the threshold at which explosions can occur.
- In 2010, Massachusetts saved 1097 million cubic feet of natural gas through energy efficiency programs. But in the same time period, Massachusetts lost more gas through leaks than it saved.
- The costs of these leaks – about $38.8 million a year – are passed on to gas customers in Massachusetts. . . .
- Almost one-third of the natural gas pipelines in Massachusetts are made of cast iron or unprotected steel, materials that are highly prone to leaks. Fifty percent of the cast iron pipelines in the U.S. are concentrated in Massachusetts and only three other states: New Jersey, New York, and Pennsylvania.[317]

It is no secret that leaks cost money. For the city of Boston, the fugitive escaping natural gas is estimated at $90 million worth of product annually.[318] A study found leaks in Manhattan occurring at an average rate of 4.25 leaks per mile — nearly ten times greater leak density than the same study found in Cincinnati, Ohio, where a project to replace old cast-iron pipes with reinforced steel pipe was recently completed.[319] Looking at natural gas leaks in a medium size city like Boston, there was nearly 3% loss of gas through cracks in underground gas pipes.[320] Moreover, a Harvard University study documented atmospheric methane concentrations in Boston 200% to 300% greater than previous estimates.[321]

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[317] Mariella Puerto, *The Invisible Elephant in the Room: Gas Leaks and Climate*, BARR FOUND. (Jan. 28, 2013), https://www.barrfoundation.org/blog/the-invisible-elephant-in-the-room-gas-leaks-and-climate [http://perma.cc/6LD2-T893]; *see* Rich Barlow, *Boston's Street-Level Gas Leaks: 3,300-Plus*, BU TODAY: SCI. & TECH (Dec. 7, 2012), http://www.bu.edu/today/2012/boston-street-level-gas-leaks-3300-plus/ [http://perma.cc/6732-42SM]; Ben Carmichael, *New Report Shows Lost Natural Gas Emissions Costing Millions to Massachusetts's Gas Customers and Harming Environment*, CONSERVATION L. FOUND. (Nov. 28, 2012), https://www.clf.org/newsroom/new-report-shows-lost-natural-gas-emissions-costing-millions-to-massachusettss-gas-customers-and-harming-environment/ [http://perma.cc/T6EZ-X3TZ].

[318] Judith Lewis Mernit, *With New Tools, a Focus on Urban Methane Leaks*, YALE ENV'T 360 (Apr. 4, 2016), http://e360.yale.edu/feature/with_new_tools_focus_on_urban_methane_leaks/2979 [http://perma.cc/NZX5-7Z76].

[319] *See* Morgan E. Gallagher et al., *Natural Gas Pipeline Replacement Programs Reduce Methane Leaks and Improve Consumer Safety*, 2 ENVTL. SCI. & TECH. LETTERS 286, 289-90 (2015).

[320] Mernit, *supra* note 318.

[321] *Id.*

The technology exists to locate and repair methane leaks across the entire natural gas process chain, from hydraulic fracturing well pads to pipelines carrying gas to consumers. In 2010, Picarro, a technology company based in Santa Clara, California, unveiled a special kind of sensor, called a "cavity ring-down spectrometer" to detect atmospheric concentrations of greenhouse gases in finer detail than before.[322] The sensor "draws air into a partial vacuum and reveals its precise chemical makeup" by employing a laser pulse that pings off mirrors.[323] Even if the U.S. achieves a reduction in leakage rates, the U.S. many not be able to achieve the targeted 80% reduction in greenhouse gas emissions by 2050 if there is an increased dependency on natural gas as an energy source for heating homes and providing electricity[324] Over time, arresting a significant portion of 3% leakage could pale in comparison to a larger than that increase in gas usage and resulting methane escape.

D. Management of Transportation Methane Leakage

Managing methane leakage is an area where additional sustainable regulatory requirements could result in a net financial gain to stakeholders commensurate with gains for climate mitigation. In 2011 alone, gas distribution companies reported releasing sixty-nine billion cubic feet of natural gas into the atmosphere.[325] It is cost-effective to repair gas transportation pipeline system methane leaks.[326] The U.S. Department of Energy (DOE) began a regulatory process during the Obama administration that if continued, could eventually require mandatory energy efficiency standards for natural gas compressors, which compresses gas and pushes it forward in pipelines, which now uses up to 7% of the gas consumed in the United States.[327] The Federal Energy Regulatory

[322] *Id.*

[323] *Id.* ("The process slows down, or decays, depending on what kind of gas is in the chamber.").

[324] *See supra* Figure 9.

[325] DEM. STAFF OF H. NAT. RESOURCES COMM., AMERICA PAYS FOR GAS LEAKS 1 (2013), https://www.markey.senate.gov//documents/markey_lost_gas_report.pdf [https://perma.cc/9AK7-PV4C].

[326] CRAIG AUBUCHON & PAUL HIBBARD, SUMMARY OF QUANTIFIABLE BENEFITS AND COSTS RELATED TO SELECT TARGETED INFRASTRUCTURE REPLACEMENT PROGRAMS, http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/benefits_costs_tirf_jan2013.pdf [https://perma.cc/CW96-SC5Z] (stating a reduction in leaks generates economic benefits by reducing the social impact of higher greenhouse gas emissions and the amount of gas that utilities buy and charge ratepayers for).

[327] *Department of Energy Announces Steps to Help Modernize Natural Gas Infrastructure*, DEP'T OF ENERGY (July 29, 2013) https://energy.gov/articles/department-energy-announces-steps-help-modernize-natural-gas-infrastructure [https://perma.cc/3XPH-8DJA].

Commission (FERC) has the authority to oversee and regulate the cost recovery of replacing older interstate gas pipelines.[328] Advanced infrared sensors, developed initially for military use, are now used to detect methane leaks from oil-and-gas infrastructure in real time.[329]

While the FERC has authority under the National Gas Act to regulate interstate gas sales and interstate pipelines, gas distribution companies are subject only to state jurisdiction over retail transactions and activities.[330] Ultimately, leak prevention must also be implemented through decisions of utilities and state energy regulatory agencies. Since the enactment of the Natural Gas Act, the Supreme Court has held that rates for transportation of natural gas are required to include the costs of that gas not accounted for from pipeline leakage, and state regulators must pass these through in retail rates as operating expenses.[331]

In the vast majority of states, ratepayers are accountable for paying utilities for lost and unaccounted for natural gas lost during distribution. Forty-eight states allow utility companies total recovery for lost and unaccounted for natural gas through rate adjustment clauses, which allow for periodic rate adjustments absent a formal hearing in front of an energy regulatory commission.[332] Texas and Pennsylvania cap the amount of lost and unaccounted for natural gas utility companies can charge to their consumers, creating a marginal economic incentive to repair older infrastructure.[333] Natural gas utilities will only make these leak-prevention improvements if costs can be recovered by passing them on in retail rates, and if the rates that retail natural gas distribution companies receive are regulated and approved by state energy regulatory agencies.[334]

However, methane emissions are economically and legally distinct from CO_2 emissions; the former have resale value if captured, while the latter do not.[335] Additionally, the business-as-usual gas supply scenario passes $20 billion per decade in costs of lost leakage of gas on to existing captive customers.[336] Risk

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328 *See* 15 U.S.C. § 717 (2012).

329 Roston, *supra* note 236.

330 *The Market Under Regulation*, NATURALGAS.ORG (Sept. 20, 2013), http://naturalgas.org/regulation/market/ [https://perma.cc/BLZ9-UXNK].

331 West Ohio Gas Co. v. Pub. Utils Comm'n, 294 U.S. 63, 70, 73 (1935).

332 CLEAN WATER ACTION, GAS LEAKS: COSTING OUR CLIMATE, POCKETBOOK, AND SAFETY 328 (2016).

333 *Id*. at 331.

334 *See* 16 U.S.C. § 824 (2006).

335 Jayni Foley Hein, *Capturing Value*, INST. FOR POL'Y INTEGRITY 7 (2014), http://policyintegrity.org/files/publications/Capturing_Value_-_Methane_Policy_Brief.pdf [https://perma.cc/B6LR-FQTH].

336 DEM. STAFF OF H. NAT. RESOURCES COMM., *supra* note 325 (stating consumers in Massachusetts alone have paid up to $1.5 billion in extra charges from 2000-2011).

is associated with gas leakage: from 2002 to 2012, there were almost 800 reported significant accident incidents on gas distribution pipelines including several hundred explosions, which killed 116 people and caused more than $800 million in property damage.[337]

Captured methane can be sold to consumers as burnable natural gas. And whether captured or allowed to escape, the cost of leaked gas is absorbed as a delivery operating cost passed through to customers in existing natural gas retail rates.[338] There are federal regulations affecting minimum standards for leak detection and repair in all interstate and intrastate gas distribution system leakage by the Pipeline and Hazardous Materials Safety Administration, pursuant to the Natural Gas Pipeline Safety Act.[339] States retain jurisdiction to impose additional or more stringent requirements on intrastate pipelines, if they choose. Senator Edward Markey drafted legislation to address some of the shortfalls in federal and state policies, in order to accelerate gas utilities' cost recovery of pipeline leak repairs.[340]

To attempt to mitigate methane natural gas leakage, President Obama instructed both the EPA and DOE to explore initiatives to reduce pipeline methane leakage, with the goal of reducing the national methane leak rate by 40% to 45% from 2012 levels by 2025.[341] In April 2014, the EPA released five reports seeking input on strategies to reduce methane emissions.[342] The Obama administration issued three rules on May 12, 2016, requiring the natural gas industry to decrease natural gas leakage in new and existing infrastructure.[343]

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[337] *Id.*

[338] *Id.*

[339] 49 U.S.C. §§ 60101-60141 (2012).

[340] DEM. STAFF OF H. NAT. RESOURCES COMM., *supra* note 325.

[341] USDA Press Release, *supra* note 93.

[342] Andrew Restuccia, *W.H. Methane Strategy Next Step in Climate Plan*, POLITICO, http://www.politico.com/story/2014/03/wh-methane-strategy-next-step-in-climate-plan-105178_Page2.html [https://perma.cc/SH39-6USN]; USDA Press Release, *supra* note 93.

[343] U.S. ENVTL. PROT. AGENCY, EPA'S ACTIONS TO REDUCE METHANE EMISSIONS FROM THE OIL AND NATURAL GAS INDUSTRY: FINAL RULES AND DRAFT INFORMATION COLLECTION REQUEST (2016), https://www.epa.gov/sites/production/files/2016-09/documents/nsps-overview-fs.pdf [https://perma.cc/3CPN-YC5L]; *see also* Robert S. Eshelman, *Obama Admin. Issues New Rules on Methane Emissions from Oil and Gas Industry,* VICE NEWS (May 12, 2016, 2:40 PM), https://news.vice.com/article/the-obama-administration-issues-new-rules-on-methane-emissions-from-the-oil-and-gas-industry [https://perma.cc/XL3H-QXDJ] (noting the Obama Administration's final set of directives targeting methane emission reduction in the oil and gas industry, and stating that Obama had "committed to cutting US methane emissions from the oil and gas sector by 40 to 45 percent from 2012 levels by 2025. The EPA estimates that the new rule will reduce methane emissions by 510,000 tons in 2025, which is equivalent to the greenhouse gas emissions produced by nearly 2.5 million automobiles in a year.").

In theory, depending on implementation, this could be societally neutral in terms of net cost, because the gas saved by reducing leakage may be worth over $100 million in recovered value, which would cover the capital cost of these programs.[344] Approximately 70% of the expense for natural gas companies implementing the new rules, if not repealed by the Trump Administration, could be expected to be associated with the cost of finding and fixing the leaks.[345] The new rules would require technology that is already developed and available.[346] The EPA has estimated that the value of environmental benefits from less methane emissions would outweigh the costs of compliance imposed on private industry by as much as $160 million by the year 2025.[347]

Ultimately, this savings of the physical methane gas, which has a value should reduce charges to repair leaks for consumers who absorb currently the cost of this lost gas product. However, President Obama's Methane Strategy offered no new federal initiatives for the energy distribution sector.[348] The state energy regulatory authorities that set the retail price and allow recovery of utility costs in all fifty states, as well as the utilities which own the pipe and compressor

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[344] Andrew Childers & Anthony Adragna, *New Wells Regulated, EPA Eyes Methane from Existing Sources*, 47 ENV'T REP. (BNA) 1474 (May 12, 2016) (stating "As part of the final rule, the EPA chose not to exempt low production well sites—those that produce less than 15 barrels of oil equivalent per day—from the leak detection requirements. . . . The final rule amends 40 C.F.R. Part 60, Subpart OOOO and adds a new 40 C.F.R. Part 60, Subpart OOOOa. The agency estimates it will reduce 510,000 short tons of methane in 2025 while providing climate benefits of $690 million in 2025, outweighing the estimated costs of $530 million in 2025").

[345] Roston, *supra* note 236 (stating "[t]he initial regulations proposed in August 2015 would have incurred less cost than the final rules which require more frequent monitoring and repairs."). The rule requires new wells to develop leak monitoring plans and mandates that well site operators conduct an initial leak survey within a year or within sixty days of startup and twice annually after that. U.S. ENVTL. PROT. AGENCY, SUMMARY OF REQUIREMENTS FOR PROCESSES AND EQUIPMENT AT NATURAL GAS WELL SITES (2016), https://www.epa.gov/sites/production/files/2016-10/documents/nsps-gas-well-fs.pdf [https://perma.cc/EG29-ZX93]. The rule also requires that operators scan for leaks using optical gas imaging equipment or comparable monitoring methods. *Id.*

[346] Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources, 81 Fed. Reg. 35,824, 35,825 (Jun. 3, 2016) (to be codified at 40 C.F.R. pt. 60) ("Pressurized natural gas powers all sorts of pneumatic devices throughout the oil-and-gas industry which 'high-bleed' instruments can be replaced with new 'low-' or 'no-bleed' alternatives.").

[347] Roston, *supra* note 236.

[348] RICK BEUSSE ET AL., OFFICE OF INSPECTOR GENERAL, U.S. ENVTL. PROT. AGENCY, REPORT NO. 14-P-0324, IMPROVEMENTS NEEDED IN EPA EFFORTS TO ADDRESS METHANE EMISSIONS FROM NATURAL GAS DISTRIBUTION PIPELINES (2014), https://www.epa.gov/sites/production/files/2015-09/documents/20140725-14-p-0324_0.pdf [https://perma.cc/3U67-962X].

distribution network, will need to be key players in any successful strategy. And even though the U.S. may be responsible for approximately 10% of world methane emissions,[349] other countries will also need to contribute to arresting methane leakage to the environment. In March 2016, Canadian Prime Minister Justin Trudeau, who heads the fourth-largest oil-and-gas producing nation in the world, committed to coordinate similar regulatory limits with President Obama's EPA.[350]

In 2016, EPA promulgated the first standards for methane emissions from new and modified oil and gas facilities, and advanced development of emissions standards for existing sources.[351] The Obama Administration also moved through unilateral executive action of the Clean Power Plan toward 30% reduction of annual CO_2 emissions from large power generation facilities by 2030, compared to a baseline of 2005 emission levels, with a glide path toward this goal to be in place by 2022.[352]The rules would affect 1,600 existing power plants, primarily those approximately 600 remaining generating coal power facilities.[353] This unilateral executive action, made without seeking any legislative approval, was stayed by the Supreme Court, pending a challenge now before the D.C. Circuit Court of Appeals.[354] In addition, Executive Order 13,783 issued in March 2017 by the Trump Administration ordered the EPA to eliminate the Clean Power Plan, and the EPA proposed repeal regulations in October 2017.[355]

The availability of coal is not affected by new hydro-fracking technology, which liberates liquid and gaseous hydrocarbons but not solid coal hydrocarbons. According to experts, "[i]f the Harvard data hold up and we keep on fracking, it will be nearly impossible for the United States to meet its promised goal of a 26-28% reduction in greenhouse gases from 2005 levels by 2025."[356] This possible U.S. failure to achieve goals because of greater methane

349 Roston, *supra* note 236.

350 Dean Scott, *Obama, Trudeau Pledge Quick Paris Deal Implementation*, 47 ENV'T REP. (BNA) 754, (Mar. 11, 2016).

351 U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

352 Amy Harder et al., *EPA Sets Big Cuts for Power Emissions*, WALL STREET J., June 2, 2014, at A1; *see also* Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,662, 64,673 (Oct. 23, 2015) (to be codified at 40 C.F.R. pt. 60).

353 Suzanne Goldenberg, *US Set to Unveil Rules to Cut Carbon Pollution from Power Plants by 30%*, THE GUARDIAN (June 1, 2014), https://www.theguardian.com/environment/2014/jun/02/us-emissions-rules-aim-cut-carbon-pollution-power-plants-30-per-cent [https://perma.cc/4PM2-SVJS].

354 West Virginia v. EPA, 136 S. Ct. 1000 (2016).

355 Exec. Order No. 13,783, *supra* note 299.

356 McKibben, *New Chemistry*, *supra* note 26.

leaks through fracking, could be replicated in countries around the globe as this technology proliferates in its use internationally.

V. INVERSION OF INTERNATIONAL RESPONSIBILITY FOR METHANE: LEGAL METHANE AND GREENHOUSE GAS CONTROL MECHANSIMS

Methane is a larger and more prominent carbon climate change emission in the Earth's actual real-time warming than the conventional calculations of policymakers have calculated. At the end of 2016, rather than assuming responsibility for the EPA's underestimating the much more substantial impact of methane emissions in real time, the White House stated that the "oil and gas industry have indicated that methane emissions are much higher than previously understood."[357] The White House described the EPA's role, not as the regulatory agency making the calculation, but instead as a reporter, stating that the "EPA updated the U.S. GHG Inventory with . . . a large increase in its estimates."[358]

Unlike recent CO_2 emission increases that are principally caused by increasing fossil fuel use in *developing* countries, recent increases in methane emissions are substantially a U.S. phenomenon, with U.S. emissions constituting a stunning 30-60% of the recorded global growth in methane emissions in the most recent decade.[359] Methane presents an entirely different phenomenon than CO_2. The United States is responsible for a significant slice of recent increases and must lead in demonstrating reductions in methane emissions to meet climate goals.

A. Legal Implementation Post-Paris

In December 2015, the Paris Agreement agreed to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[360] However, the Paris Agreement guidelines may be moot before they are implemented. The world is already on track to reach a temperature increase of at least 4ºC, far in excess of the Paris Agreement's 1.5-2ºC increase limit.[361] There are now atmospheric concentrations of greenhouse gases at levels that have not been seen for almost a million years.[362]

[357] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

[358] *Id*.

[359] *Id*. at 88-96.

[360] *Paris Agreement*, *supra* note 18.

[361] SDSN & IDDRI, *supra* note 3, at 4.

[362] IPCC, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 9 (2013) [hereinafter 2013 IPCC Report].

Fire was one of the original forms of energy use. Fire produces CO_2. There is no immediate prospect yet to stop lighting matches to burn biomass and fossil fuels. When every molecule of greenhouse gas release matters, American and international legal policy cannot overlook that up to 40% of the immediate global warming impact is from release of methane molecules.[363] Methane molecules are distinct from all other greenhouse gases in that they are not a waste product to be discarded, but are a valuable energy resource powering the modern economy.

In the history of the use of "modern" energy sources, natural gas, methane, was the last of the fossil fuels to be harnessed and developed.[364] Figure 10 tracks the use of all energy sources over the last 240 years, dating back to the time of the founding of the country.[365] Natural gas did not become a significant energy source until after World War II. Prior to that, natural gas emerging from oil wells was allowed to escape to the atmosphere, or in certain instances, to be flared.[366] It was not sought for its own energy value.

Effectiveness of mitigation also matters. Unlike CO_2, which is produced by simply lighting a match to anything combustible, the volume of gas handled in countries that extract and/or consume large amounts of pipeline-distributed natural gas pose a risk of methane leakage.[367] Technological mitigation solutions abound, and the challenge is to implement them before the Earth warms more. First, there is a choice between burning natural gas or other fossil fuels. Second, much of the methane lost to the environment is a function of the method of drilling and maintaining natural gas wells and the integrity of the gas distribution pipelines transporting gas from wells to consumers.[368]

Flaring natural gas at the wellhead wastes the energy value of the gas, but it does accomplish a 95-99% reduction of the warming impact of the released gas on global warming because flaring natural gas converts the methane, with a real-

[363] *See supra*, notes 6, 8 and accompanying text.

[364] 15 U.S.C. § 717 (2015) (demonstrating the Natural Gas Act, imposing federal regulation over interstate gas pipelines to distribute gas, was not enacted until 1938).

[365] *See supra* Figure 10.

[366] CHRISTOPHER JAMES CASTANEDA, REGULATED ENTERPRISE: NATURAL GAS PIPELINES AND NORTHEASTERN MARKETS, 1938-1954 16 (1993).

[367] *See*, *Natural Gas*, INT'L ENERGY AGENCY, https://www.iea.org/about/faqs/naturalgas/ [https://perma.cc/R93U-CLYN] (last visited Feb. 10, 2018). The United States, Russia, China and Iran, in order, are the world's largest consumers of natural gas. *Id.* The largest producers of natural gas are Russia, the United States, Canada, Qatar and Iran, and with each well there is the risk of methane leakage. *Id.* Chinese gas consumption increased by in excess of two-thirds between 2009 and 2014. *Id.*

[368] *See* Clifford Krauss, *Exxon Aims to Cut Methane Leaks, a Culprit in Global Warming*, N.Y. TIMES (Sept. 25, 2017), https://www.nytimes.com/2017/09/25/business/energy-environment/exxon-methane-leaks.html [https://perma.cc/XMC6-C2YV].

time warming value per molecule of 86 to 105, to CO_2, which has a warming value of only 1.[369] Since methane is at least thirty times to one hundred times more damaging in terms of retaining heat in the atmosphere than is CO_2, this chemical conversion by combusting methane reduces methane's warming potential by 95-99%.[370]

Methane has been the critical missing chemical variable in national climate policy. Although the gross chemical impact of CH_4 is in second place to CO_2, methane is in a particularly critical second position. Methane is light years ahead in its global warming impact compared to the four lesser regulated greenhouse gases.Its thermal relationship vis-à-vis CO_2 has been significantly underestimated by policymakers. Rather than being responsible for about 15% of climate problems as EPA previously maintained, methane may actually be two to three times this magnitude when analyzed in real time.[371] Analyzing through the fourth dimension of actual real time elevates methane policy to the front line of national climate change law. It can be mitigated with known technology in developed nations; and it can be accomplished within the market framework of 21st century economies, at the interface of law, economics, and science.

While there is commercial value to capturing methane because of its value as an energy source, there is not similar potential value in retained CO_2. Although CO_2 is used industrially to carbonate soft drinks,[372] there is no commercial use for the billions of tons of CO_2 released from the combustion of fossil fuels. Capturing or retaining methane that otherwise is leaked to the environment preserves a fossil fuel with commercial value in any economy that distributes and uses natural gas as an energy source. The United States and many industrialized countries have gas pipe distribution systems into which methane is injected for transportation, storage, and use.[373] There is already a price on

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[369] McKibben, *New Chemistry*, *supra* note 26.

[370] Morgan Kelly, *A More Potent Greenhouse Gas than CO2, Methane Emissions Will Leap as Earth Warms (Nature)*, PRINCETON UNIVERSITY: RESEARCH AT PRINCETON (Mar. 26, 2014), https://blogs.princeton.edu/research/2014/03/26/a-more-potent-greenhouse-gas-than-co2-methane-emissions-will-leap-as-earth-warms-nature/ [https://perma.cc/R8Z2-9H2F].

[371] *See* U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11.

[372] Eric Roston & Bill Chameides, *CO2: They Should Bottle That Stuff*, TIME (Apr. 17, 2008), http://content.time.com/time/specials/2007/article/0,28804,1730759_1731383_1731989,00.html [https://perma.cc/UN7V-CSZL].

[373] *See* RENEWABLE ENERGY ASS'N, USE OF GASEOUS FUELS IN TRANSPORT 10-11 (2016), http://www.r-e-a.net/upload/rea_use_of_gaseous_fuels_in_transport_report-_april_2016-_final.pdf [https://perma.cc/U924-VQDZ]; *see also* DEP'T. OF ENERGY AND CLIMATE CHANGE, THE UK RENEWABLE ENERGY STRATEGY (2009) (discussing how biomethane injection into the gas grid is also recognized as a technology that could offer significant levels of renewable heat).

CH_4 in every country with a natural gas pipeline distribution infrastructure – it is traded as a valuable fossil fuel resource. Methane control is a cost-effective solution waiting to be deployed.

As with CO_2 emissions, there is a need for deep decarbonization of climate through reduction of methane emissions. Unlike with CO_2, however, captured methane has useful value as a burnable fuel source. Methane can be used directly as a gas fuel or to produce electric power. Therefore, methane enjoys some market advantages, and some segments of its emissions are from regulated utility industries, which allows more government influence over decisions and operations. With cost-effective policy choices, it should be possible to achieve 50% or greater reductions of methane in the U.S. over baseline business-as-usual scenarios.

However, each sector of methane emissions is distinct. Gas distribution by utility pipelines is regulated and requirements for methane leakage can be imposed by multiple state regulatory agencies, along with at the federal level with FERC and DoE, must all take action.[374] With the increase in oil and gas development in the U.S. from hydro-fracking, there is more extraction methane release risk. Wastewater treatment is state- and locally-regulated, and, to date, few states have taken action to control methane releases. Much more attention has been paid to waste water odor control, than to the impact of waste water on the climate.

With landfills, there is existing RCRA and Clean Air Act jurisdiction, for which regulatory control can be significantly ramped up in terms of size of landfills covered and degree of methane control required. Several states are now taking the lead in control of organic food waste placed in landfills, which is a significant source of landfill methane.[375] In the agricultural sector, the reach of law is less robust. Large CAFO manure management is regulated.[376] However, the impact of control is mixed and uneven in the agricultural sector. Here, a competitive market distracts from regulatory uniformity and compliance with methane management.

Because of increasing world population and increasing demand for food, the prospect of reducing worldwide agricultural methane emissions before 2050 in

374 OFFICE OF FOSSIL ENERGY, *Natural Gas Regulation - Other Gas-Related Information Sources*, DEP'T OF ENERGY, https://energy.gov/fe/natural-gas-regulation-other-gas-related-information-sources [https://perma.cc/C4YJ-ECRB].

375 Kate Abbey-Lambertz, *These 4 States Are Doing Something Truly Revolutionary with Food*, HUFFINGTON POST (July 29, 2016, 09:32 AM), https://www.huffingtonpost.com/entry/states-food-waste-policies_us_5798a40ce4b0d3568f853698 [https://perma.cc/EM74-RPZQ].

376 U.S. ENVTL. PROT. AGENCY, EPA 833-G-02-014, CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFO) RULE, https://www3.epa.gov/npdes/pubs/cafo_themes.pdf [https://perma.cc/893M-JLD2].

a very competitive world agricultural market must rely on technological innovation in animal diets, fertilizer use, and manure management.[377] If there is any prospect for success in time to meaningfully mitigate climate change by 2050, agencies in the U.S. must now take the lead to implement new goals through legal requirements. EPA regulations could cover the upstream oil and gas sector; the DOE during the Obama Administration talked with stakeholders, including labor unions, industry, and nongovernmental organizations, regarding leaks from gas distribution pipelines.[378] This, however, has met some resistance.[379] The technology to capture methane is available to reduce methane emissions in the fossil fuel, agriculture, and waste management sectors. The issue is not technology; the missing link is the legal structure and regulation to motivate and accomplish methane recovery.

B. The New U.S. Policy Initiatives

In 2014, the Obama Administration rolled out its strategy to start cutting methane emissions released by landfills, cattle, and leaks from coal, oil and natural gas production.[380] With the implementation of the plan, the Administration estimated that the strategy would deliver approximately 90 million metric tons of greenhouse gas reductions by 2020.[381]

The Obama Administration acknowledged that "municipal solid waste landfills are the third-largest source of human-related methane emissions in the United States, . . . equivalent to approximately 100 million metric tons of carbon dioxide pollution."[382] First, the landfill methane strategy is to "capture this gas and use it as a source of clean energy."[383] Second, "[o]ne of the most important co-benefits to reducing methane emissions at coal mines is increasing mine

[377] U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 90.

[378] Vaidyanathan, *METHANE: DOE Discloses First Steps to Curb Leaks in Natural Gas Systems*, *supra* note 314.

[379] Roston, *supra* note 236; Letter from James M. Inhofe, Chairman, Comm. on Env't and Pub. Works, to The Hon. Dan Utech, Spec. Ass't to the President (May 24, 2016). Republican Senator James Inhofe wrote to the President that this new U.S. methane control rule would shift U.S. jobs across borders to other parts of the world which are not restricting methane release: "EPA fails to recognize that the extraordinary aggregate costs associated with its newly finalized methane rules will have the unintended consequence of shifting production to other parts of the world, where there is less technology and fewer environmental regulations in place." *Id.*

[380] *See* U.S. WHITE HOUSE, CLIMATE ACTION PLAN STRATEGY TO REDUCE METHANE, *supra* note 162, at 1-2.

[381] *Id.* at 1.

[382] *Id.* at 5.

[383] *Id.*

safety since uncontrolled methane emissions can cause fires and explosions."[384]

In order to address these issues, the Obama Administration's strategy was to work in conjunction with the Department of Interior's BLM and the Environmental Protection Agency, "to capture, sell, or dispose waste mine methane from Federal coal leases and Federal leases for other solid minerals."[385] In 2015, the U.S. Department of Agriculture and the EPA announced a national target to reduce food waste 50% by 2030.[386] In 2016, the EPA finalized relatively demanding operating standards to install gas collection systems that capture methane from certain large landfills, both new and existing, to result in the reduction of an additional 8 million metric tons annually in 2025.[387]

The Obama Administration strategy also suggested voluntary actions that could be taken to reduce methane emissions released by agriculture.[388] The Obama Administration highlighted opportunities with manure management employing anaerobic digestion of the waste and utilization of resulting biogas as important voluntary options.[389] Biogas production and utilization technologies have been effective to convert organic waste to renewable energy.[390] Moreover, they mitigate the risk of potential air and water contamination, and in parallel generate added income for the facility.[391] Nevertheless, despite these financial benefits, given the number of points of significant fugitive methane escape, there are still relatively few anaerobic digesters in operation on farms across America to utilize captured methane.[392]

The most detailed section of the Obama Administration's Climate Action Plan addressed oil and gas sector methane emissions.[393] The Obama Administration plan was to cut methane emissions from the oil and gas sector by 40-45% from 2012 levels by 2025, along with a suite of actions to achieve this target.[394] However, that Obama Administration strategy applied only to modified and new oil and gas systems, rather than existing infrastructure.[395] The proposed standards identified ways to directly reduce methane emissions from the oil and

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384 *Id.*

385 *Id.* at 5-6.

386 USDA Press Release*, supra* note 93.

387 U.S. WHITE HOUSE, DEEP DECARBONIZATION, *supra* note 11, at 91.

388 *Id.* at 90.

389 *Id.* at 91.

390 *Id.* at 91.

391 *Id.* at 91-92.

392 *Id.* at 90-91.

393 *See id.* at 89-90.

394 *Id.* at 90.

395 Mark Belleville, *Gaping Hole in EPA's Methane Rules*, LEGAL PLANET (Oct. 9, 2015), http://legal-planet.org/2015/10/09/gaping-hole-in-epas-methane-rules/ [https://perma.cc/7D98-PFFU].

gas sector by finding and repairing leaks, capturing natural gas from the completion of hydraulically fractured oil wells, limiting emissions from new and modified pneumatic pumps, and limiting emissions from several types of equipment used at natural gas transmission compressor stations, including compressors and pneumatic controllers.[396]

The U.S. mining industry opposed the proposal to require underground coal mines to measure methane emissions more frequently—saying that it is unnecessary, given the small contribution of mines to the broader released methane picture.[397] In 2017, the EPA attempted to stay elements of the Clean Air Act NSPS for gas and oil extraction,[398] but the stay was vacated by the United States Court of Appeals for the D.C. Circuit.[399] Until further developments, the EPA will be required to continue application and implementation of the NSPS.[400]

A study of shale gas wells in the U.S. found that capturing otherwise fugitive methane emissions can produce net profits over costs in as much as 95% of the instances.[401] The technology exists now to locate and repair methane leaks across the entire natural gas process chain, from hydraulic fracturing well pads to pipelines carrying gas to consumers. It is cost-effective to repair gas transportation pipeline system methane leaks.[402] However, even if a greatly reduced leak rate of natural gas could be achieved, an increased dependency on natural gas as an energy source for heating homes and providing electricity, could result in not achieving the target 80% reduction in greenhouse gas emissions by 2050.

This ultimately presents not a technical or engineering challenge; it is a matter of implementing new law that effectively addresses significant methane emissions. Regulatory law must step up. Time and space matter: The time is

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396 *Id.*

397 Amanda Reilly, *Coal Mines Resist EPA Plan to Boost Methane Reporting,* E&E NEWS: GREENWIRE (Apr. 2016), http://www.eenews.net/stories/1060035237 [https://perma.cc/8UWL-9LDX].

398 Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources: Grant of Reconsideration and Partial Stay, 82 Fed. Reg. 25,730 (June 5, 2017) (to be codified at 40 C.F.R. pt. 60).

399 Clean Air Council v. Pruitt, 862 F.3d 1, 4 (D.C. Cir. 2017).

400 *See* Exec. Order No. 13,783, *supra* note 299 (requiring the EPA to review and revise the methane NSPS as needed).

401 Francis O'Sullivan & Sergey Paltsev, *Shale Gas Production: Potential Versus Actual Greenhouse Gas Emissions*, 7 ENVTL. RES. LETTERS 1, 4-5 (Nov. 2012), http://iopscience.iop.org/article/10.1088/1748-9326/7/4/044030/pdf [https://perma.cc/PB9Z-KZ88].

402 AUBUCHON & HIBBARD, *supra* note 326 (stating that reducing leaks generates economic benefits by (1) reducing the amount of gas that utilities buy and charge ratepayers for, and (2) reducing the social impact of higher greenhouse gas emissions).

now to implement a coordinated capture and re-use policy for the second element, methane.