Building an Effective Climate Regime While Avoiding Carbon and Energy Stalemate

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> In physical science the first essential step in the direction of learning any subject is to find principles of numerical reckoning and practicable methods for measuring some quality connected with it. I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.[1]
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> - Lord Kelvin

> It must be considered that there is nothing so difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who would profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from fear of their adversaries, who have the laws in their favor; and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it.[2]
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> - Niccolo Machiavelli

I. INTRODUCTION

The world needs a new approach to achieving international progress on climate change. Despite prodigious diplomatic efforts over two decades aimed at limiting emissions of climate change pollutants, relatively little in the way of effective global governance has been achieved. This lack of progress has led some, including the U.S. government, to seek climate deals outside of the climate negotiations, leading to fragmentation of the Climate Regime. In Part II, I present one of the key dilemmas faced by U.S. climate negotiators over the past decade—whether to pursue reductions of a super-greenhouse gas within the Ozone Regime or within the Climate Regime. In Part II, I also argue that this dilemma is a symptom of a larger problem—the structure of climate negotiations. The negotiations currently place a narrow legal, economic, and political focus on the hardest part of the climate change problem—energy-related carbon dioxide emissions. This

1. William Thomson Kelvin, *Electrical Units of Measurement*, *in* 1 POPULAR LECTURES AND ADDRESSES 80–81 (1889).

2. NICCOLO MACHIAVELLI, THE PRINCE 123 (Oxford Univ. Press, 1998).

focus developed due to scientific understanding of climate at the time that legal and policy frameworks were put in place. However, scientific developments since then have significantly undercut the view that carbon and energy should be the sole focus of efforts to avoid climate change. Part III explains key scientific developments over the past two decades and how these have reshaped the scientific view of human impacts on climate. Studies aimed at resolving the remaining uncertainties in climate projections have resulted in a dramatically improved understanding of the importance of short-lived climate pollutants in causing current and medium-term climate change. This new science justifies a shift away from legal and policy frameworks that focus on energy and carbon dioxide emissions towards more flexible frameworks that aim to produce meaningful reductions in other, shorter-lived global warming pollutants. In Part IV, I argue that such a shift in focus could produce more effective outcomes. Developed and developing countries have much more experience in abatement of short-lived pollutants than carbon dioxide. Also, focus on short-lived pollutants often leads to near-term air pollution-related benefits that will help to change the cost-benefit calculus and improve the political acceptance of greenhouse gas reductions. Abatement of short-lived pollutants is something we know how to do and which creates benefits that can be captured today by the countries that undertake it, while still reducing the risks of climate change. In Part V, I provide an account of how short-lived climate pollutants might form a path toward more comprehensive international greenhouse gas limits in the future. Near-term international success with short-lived pollutants might generate a cooperative multilateral dynamic within the broader Paris Agreement framework. Parties can improve and consolidate their climate change related reputations for compliance using short-lived climate pollutants, increasing the likelihood of more costly agreements on carbon dioxide. This new process, the reputations for compliance it would generate, and the robust institutions that result from it are a necessary, but currently lacking, precondition of any global agreement to limit energy-related carbon emissions. While other authors have suggested pursuit of reductions in short-lived pollutants via bilateral or plurilateral approaches, or outside of the Climate Regime, only the multilateral Climate Regime as implemented within the Paris Agreement framework is likely to provide the legitimacy as well as the financial resources necessary for deep and effective cuts in carbon dioxide emissions. Short-lived climate pollutants provide a path forward to deepening strategic cooperation on climate. Thus rather than cutting deals outside of the Climate Regime, the United States should seek to bring agreements for deep cuts of super-greenhouse pollutants inside it—as much for their strategic as their environmental benefits.

II. THE ORIGINS OF THE CARBON AND ENERGY FOCUS IN EFFORTS TO REDUCE GREENHOUSE GAS EMISSIONS

Much of the focus in discussions of how to limit the damage from climate change centers on efforts to reduce emissions of carbon dioxide produced when fossil fuels are burned and energy is produced. Indeed, the casual, and even not so casual, observer of policy debates on climate change could be forgiven for thinking that energy-related carbon dioxide emissions are its sole cause.[3] Over the past decade, there has been somewhat greater attention

3. For example, in response to written questions regarding climate change, both President Obama and Republican presidential candidate Romney discussed emission reductions exclusively in terms of carbon dioxide emissions from the energy sector. *See The Top American Science Questions: 2012*, SCI. DEBATE, http://www.sciencedebate.org/2012/debate12/ [https://perma.cc/SYG2-U2QM] (last visited Mar. 16, 2016). The same was true during the 2008 presidential election cycle, when both candidates Obama and McCain, to the extent that they discussed specifics, focused on carbon emissions from energy use. *See Presidential Answers to the Top 14 Science Questions Facing America*, SCI. DEBATE, http://www.sciencedebate.org/2012/debate08.html [https://perma.cc/ 3DVA-QEPW] (last visited Mar. 16, 2016). Perhaps even more striking is the near total absence of non-CO_2 gases from recent remarks by Todd Stern, U.S. State Department Special Envoy for Climate Change. Stern does mention a promising new initiative to combat short-lived greenhouse gases but it is relegated to a bullet point in his discussion of "informal groupings" aimed at "getting something done." Stern fails to mention what is by far the most significant non-CO_2 climate-related initiative—efforts to ban hydrofluorocarbons ("HFCs") under the auspices of the Montreal Protocol. Todd Stern, U.S. Special Envoy for Climate Change, Remarks at Dartmouth College (Aug. 2, 2002), http://www.state.gov/e/oes/rls/remarks/2012/196004.htm [https://perma.cc/52H6-MKTX]. Finally, it is worth noting that the reason that both presidential nominees and Stern neglect non-CO_2 gases in their discussions of climate change may be that most of the models utilized to estimate the costs of reducing greenhouse gas emissions do not explicitly include them, and if they do, focus exclusively on methane and nitrous oxide. *See, e.g.*, William Nordhaus, *Economic Aspects of Global Warming in a Post-Copenhagen Environment*, 107 PROC. NAT'L ACAD. SCI. 11,721 (2010), http://www.pnas.org/content/107/26/11721.full [https://perma.cc/J8LL-M46Z] (calibrating the model using CO_2 and incorporating sulfate aerosols and other GHGs at a later stage, but not mentioning reductions in non-CO_2 gases except to note that estimates of these are included in the estimates of total radiative forcing and hence warming, but not in the model itself); *see also* Alan Manne & Richard Richels, *US Rejection of the Kyoto Protocol: The Impact on Compliance Costs and CO_2 Emissions*, 32 ENERGY POL'Y 447, 448–49 (2004) (employing an economic model to estimate Kyoto Protocol compliance costs that estimates CO_2 emissions within the energy sector but no other GHG emissions in any other sector).

and focus placed upon another source of carbon dioxide emissions—deforestation.[4] Academic attention has likewise been focused on these two areas of climate mitigation: reducing carbon dioxide emissions from the energy and forestry sectors.[5] Perhaps in response to the relative lack of progress on climate mitigation, academic attention has also begun to shift towards legal frameworks to support adaptation to climate change and away from efforts to prevent it.[6] More recently, a smaller cohort of academics has shifted focus towards the set of pollutants upon which this Article will focus, arguing for both greater attention to and a shift away from the dominant UNFCCC process because of its high costs and lack of effectiveness.[7]

4. *See, e.g.*, U.N. Framework Convention on Climate Change, *Bali Action Plan*, U.N. Doc. FCCC/CP/2007/6/Add.1, Dec. 1/CP.13 (Mar. 14, 2008) [hereinafter UNFCCC, *Bali Action Plan*]; *see also* John Vidal, *Copenhagen: Barack Obama Backs Norway-Brazil Forest Protection Plan*, GUARDIAN (Dec. 10, 2009), http://www.guardian.co.uk/environment/2009/dec/10/obama-backs-norway-brazil-forest-plan [https://perma.cc/YGM5-H9H7].

5. *See, e.g.*, Eric Posner & Cass Sunstein, *Climate Change Justice*, 96 GEO. L.J. 1565, 1568 (2008) (describing problems of distributive justice in terms of a forty dollar per ton carbon tax); *see also id.* at 1603 (describing the "facts" of global warming in terms of energy-related carbon dioxide emissions); William Boyd, *Climate Change, Fragmentation, and the Challenges of Global Environmental Law: Elements of a Post-Copenhagen Assemblage*, 32 U. PA. J. INT'L L. 457, 460–62 (2010) (describing climate change mitigation as concerning the energy and land use sectors); Ann Carlson, *Designing Effective Climate Policy: Cap and Trade and Complimentary Policies*, 49 HARV. J. ON LEGIS. 207, 239–40 (2012) (describing a GHG trading program that interacts with complementary policies aimed at reducing CO_2 emissions); David Hodas, *Imagining the Unimaginable: Reducing U.S. Greenhouse Gas Emissions by Forty Percent*, 26 VA. ENVTL. L. REV. 271, 276–77 (2008) (discussing potential reductions in U.S. GHG emissions if all states were to implement California's energy and energy efficiency policies); Elinor Ostrom, *A Polycentric Approach for Coping with Climate Change* 3 (World Bank Policy Research Paper No. 5095, 2009) (describing the problem of climate change in terms of carbon dioxide concentration in the atmosphere).

6. *See* Alejandro Camacho, *Adapting Governance to Climate Change: Managing Uncertainty Through a Learning Infrastructure*, 59 EMORY L.J. 1, 9 (2009); Daniel A. Farber, *The Challenge of Climate Change Adaptation: Learning from National Planning Efforts in Britain, China, and the United States*, 3 J. ENVTL. L. 359, 361–63 (2011); Robin Kundis Craig, *Stationarity is Dead—Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 HARV. ENVTL. L. REV. 9, 16–17 (2010); J. B. Ruhl, *Climate Change Adaptation and the Structural Transformation of Environmental Law*, 40 ENVTL. L. 363, 382–87 (2010).

7. *See* Richard Stewart, Michael Oppenheimer & Bryce Rudyk, *Building Blocks for Global Climate Protection*, 32 STAN. ENVTL. L.J. 341, 343–44 (2013) (discussing small scale strategies aimed at non-climate benefits that incidentally result in GHG emissions reductions); David G. Victor, Charles Kennel & Veerabhadran Ramanathan, *The Climate Threat We Can Beat*, FOREIGN AFF., May–June 2012 (arguing for a focus on short-lived climate pollutants including black carbon, methane, and HFCs and for the United States to focus on negotiating deals outside of the UNFCCC); Durwood Zaelke, Stephen O. Andersen & Nathan Borgford-Parnell, *Strengthening Ambition for Climate Mitigation: The Role of the Montreal Protocol in Reducing Short-lived Climate Pollutants*, 21 REV. EUR. COMMUNITY & INT'L L. 231, 237–38 (2012) (discussing the use of non-UNFCCC institutions to increase climate ambition

From the start, the legal and political science discussion of international cooperation on climate change has recognized the inherent challenges in crafting a workable and effective agreement.[8] The climate change problem presents a number of difficult challenges from both a political science and an international law perspective. Costs of an agreement must be borne today while most benefits will accrue many years hence.[9] The types of changes required to avoid the worst effects of climate change are likely to be costly and costs will grow the longer we wait to deal with the problem.[10] Those who will suffer the greatest damages from climate change are not necessarily those that will cause the problem or bear the costs of avoiding it.[11] Because climate change is primarily caused by greenhouse gases ("GHGs") that are well mixed in the atmosphere and that persist for decades to centuries, all nations that emit them must cooperate in crafting a solution.[12] Finally, because of the costs and global nature of the problem, nations may be tempted to free-ride on the efforts of others to address the problem.[13] The problem is a daunting one.

One set of suggested responses to the challenges posed by climate change emphasizes the need to secure credible commitments at the international level that are self-enforcing, incent broad participation via side payments, and minimize costs by increasing compliance flexibility with emissions trading.[14] A second literature, concluding that a global agreement to control greenhouse gas emissions along these lines is unlikely, has emphasized the need to re-conceptualize treaty architecture and

and providing an example of negotiating a deal within the Montreal Protocol to reduce HFC emissions, a potent GHG).

8. *See, e.g.*, Richard J. Lazarus, *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future*, 94 CORNELL L. REV. 1153, 1159–61 (2009); *see* Scott Barrett, *Self-Enforcing International Environmental Agreements*, 46 OXFORD ECON. PAPERS 878, 891–92 (1994) (discussing the potential limitations of the self-enforcing mechanism found in international environmental agreements).

9. *See* Lazarus, *supra* note 8, at 1174.

10. *Id.* at 1160.

11. *Id.*; Posner & Sunstein, *supra* note 5, at 1568.

12. RICHARD B. STEWART & JONATHAN B. WIENER, RECONSTRUCTING CLIMATE POLICY: BEYOND KYOTO 37 (2003).

13. Scott Barrett & Robert Stavins, *Increasing Participation and Compliance in International Climate Change Agreements*, 3 INT'L ENVTL. AGREEMENTS 349, 350 (2003).

14. *See* Barrett, *supra* note 8, at 878; Barrett & Stavins, *supra* note 13, at 360; *see also* STEWART & WIENER, *supra* note 12, at 54.

the negotiation context in order to facilitate agreement.[15] Interestingly, many of the analyses that tackle the Climate Regime's full complexity do not directly engage with the international relations literature[16] aimed at explaining how treaty regimes develop over time[17] and how these regimes evolve into effective institutions for creating international cooperation.[18]

In what follows, and while drawing from these literatures, I take a different tack.

My central theses are that nations need to modernize the legal framework devised in 1990 to frame the problem of climate change in order to make progress on the problem, and that they should consider adopting a framework that is more likely to spur strategic collaboration. Scientific understanding developed in the intervening two decades allows for a reinterpretation of this framework in ways that are likely to facilitate progress. Scientists during this period have shown that there are a large number of conventional air pollutants that, in addition to making people sick, are an important cause of global warming.[19] By crafting agreements to sharply reduce emissions of these short-lived climate pollutants ("SLCPs"),[20] nations can enhance their reputations for

15. *See* DAVID G. VICTOR, GLOBAL WARMING GRIDLOCK: CREATING MORE EFFECTIVE STRATEGIES FOR PROTECTING THE PLANET 240–53 (2011); *see generally* ARCHITECTURES FOR AGREEMENT: ADDRESSING GLOBAL CLIMATE CHANGE IN THE POST-KYOTO WORLD (Joseph E. Aldy & Robert N. Stavins eds., 2007).

16. *See, e.g.*, ABRAM CHAYES & ANTONIA HANDLER CHAYES, THE NEW SOVEREIGNTY: COMPLIANCE WITH INTERNATIONAL REGULATORY AGREEMENTS 1–4 (1995) (discussing, without mentioning the origin and later evolution of many treaties, the ineffective enforcement in such treaties that often results in lack of cooperation).

17. Robert Keohane & David Victor, *The Regime Complex for Climate Change*, 9 PERSP. ON POL. 7, 9 (2011) (observing that international regimes are derived from "rights and rules that have evolved over time").

18. ANDREW T. GUZMAN, HOW INTERNATIONAL LAW WORKS 180–81 (2008) (noting the success "soft law" agreements can have in compelling party cooperation); ROBERT KEOHANE, AFTER HEGEMONY: COOPERATION AND DISCORD IN THE WORLD POLITICAL ECONOMY (1984). *But see* Robert Keohane & Kal Raustiala, *Toward a Post-Kyoto Climate Change Architecture: A Political Analysis*, *in* POST-KYOTO INTERNATIONAL CLIMATE POLICY: IMPLEMENTING ARCHITECTURES FOR AGREEMENT 372 (Joseph E. Aldy & Robert N. Stavins eds., 2010).

19. *See generally* Drew Shindell et al., *Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security*, 335 SCIENCE 183 (2012) (arguing for certain emission control measures that would reduce the emission of "two agents known to cause both warming and degraded air quality").

20. By short-lived, I mean pollutants that do not persist long in the atmosphere in comparison to carbon dioxide. All the pollutants discussed here have atmospheric residence times of twenty years or less. HFCs are slightly more complicated because they have a variety of atmospheric lifetimes depending on their chemical stability. One intuitive way to understand the difference is that short-lived pollutant concentration in the atmosphere is

compliance with climate change commitments.[21] This in turn will strengthen confidence in both individual parties and in the overall Climate Regime in ways that may ultimately facilitate agreement to deeper cuts in long-lived greenhouse gases.

This work, by combining new information regarding the science of climate change with insights from international relations and international law scholarship, suggests a novel approach to negotiating effective international agreements on climate change. By explaining how the legal framework that underlies the climate policy regime came to be, I more fully motivate a shift to at least a temporary focus on non-CO_2 greenhouse gas pollutants. But, unlike other recent scholarship on SLCPs, I articulate a practical strategy that leverages existing climate institutions rather than suggesting that the international community either repurpose other non-climate institutions or develop new ones from scratch.[22] As a preliminary matter, it is worthwhile to describe how and why the current framework was agreed to during negotiation of the United Nations Framework Convention on Climate Change ("UNFCCC")[23] and the subsequent Kyoto Protocol to the UNFCCC.[24]

In order to address the problem of climate change, international negotiators recognized that they would need to develop some sort of metric with which to evaluate its causes. Since Arrhenius' path-breaking work, carbon dioxide had been recognized as an important contributor to the greenhouse effect.[25] But by the early

largely a function of current and recent emissions while long-lived pollutant concentrations in the atmosphere are largely a function of total emissions since the industrial era. Of course, the difference between short-lived and long-lived pollutants is a matter of degree. *See* Piers Forster et al., *Changes in Atmospheric Constituents and in Radiative Forcing*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 129 (S. Solomon et al. eds., 2007) [hereinafter CLIMATE CHANGE 2007], https://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4_wg1_full_report.pdf [https://perma.cc/B62W-WNE6].

21. *See, e.g.*, GUZMAN, *supra* note 18, at 34–36; KEOHANE, *supra* note 18, at 105–08.

22. International relations theory tends to emphasize the high costs of creating new institutions and the desirability of adapting existing institutions to new objectives. *See* KEOHANE, *supra* note 18.

23. United Nations Framework Convention on Climate Change, July 1992, 31 I.L.M. 849 (1992) [hereinafter UNFCCC].

24. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 22 (1998) [hereinafter Kyoto Protocol].

25. Arrhenius was the first scientist to understand and estimate the impact of atmospheric carbon dioxide on Earth's surface temperature. *See generally* Svante Arrhenius, *On the Influence of Carbonic Acid upon the Temperature on the Ground*, 41 PHIL. MAG. & J. SCI. 237 (1896) (suggesting that carbon dioxide concentration might influence climate change).

1990s, it was clear to both scientists and policymakers that other gases were also important causes of climate change.[26] It was also known that the different climate-altering gases each had different heat-capturing abilities and different atmospheric lifetimes.[27] A given amount of carbon dioxide would contribute to the global warming problem to some degree over a given time frame; a similar amount of methane would result in warming to a different degree and with a different temporal pattern. In this Part, I explain the science underlying metrics of comparison for climate-altering pollutants. I then explain how and why these metrics were utilized to develop the standard for measurement and reporting of greenhouse gases in international agreements: 100-year global warming potential ("GWP"). Finally, I conclude with a discussion of the endurance within the Climate Regime and spread of the 100-year GWP metric as a legal rather than a scientific framework.

Nations could have bargained and attempted to structure cooperative agreements to reduce emissions of each individual greenhouse gas. At an even more granular level, parties to the negotiation could have negotiated to reduce emissions of particular gases within particular industries. Instead, the choice was made to implement a common metric for comparison of all gases that contribute to climate change and to articulate commitments in terms of that framework. This choice had numerous perceived benefits—most importantly, in terms of the economic efficiency of policies, to reduce emissions. Unfortunately, it has also dramatically impeded the ability to reach agreements to reduce the emission of GHGs because the standard adopted by the Climate Regime, 100-year GWP, ultimately requires cooperation on energy policy, which few states are willing to agree to at present. Next, I argue that abandoning this framing of the problem may facilitate meaningful agreement to cut emissions of other global warming pollutants and that by doing so the international community might develop the trust and strong institutional regime that will ultimately be required to commit to the more costly and hence difficult cuts in energy-related CO_2 emissions. The Paris Agreement is an important partial step in this direction in that it encourages

26. *See* K.P. Shine et al., *Radiative Forcing of Climate*, *in* CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT 41, 45 (J.T. Houghton et al. eds., 1990); *see also* Thomas Schelling, *Some Economics of Global Warming*, 82 AM. ECON. REV. 1, 1 (1992) (noting carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons are "greenhouse" gases that warm the atmosphere).

27. Shine et al., *supra* note 26, at 45.

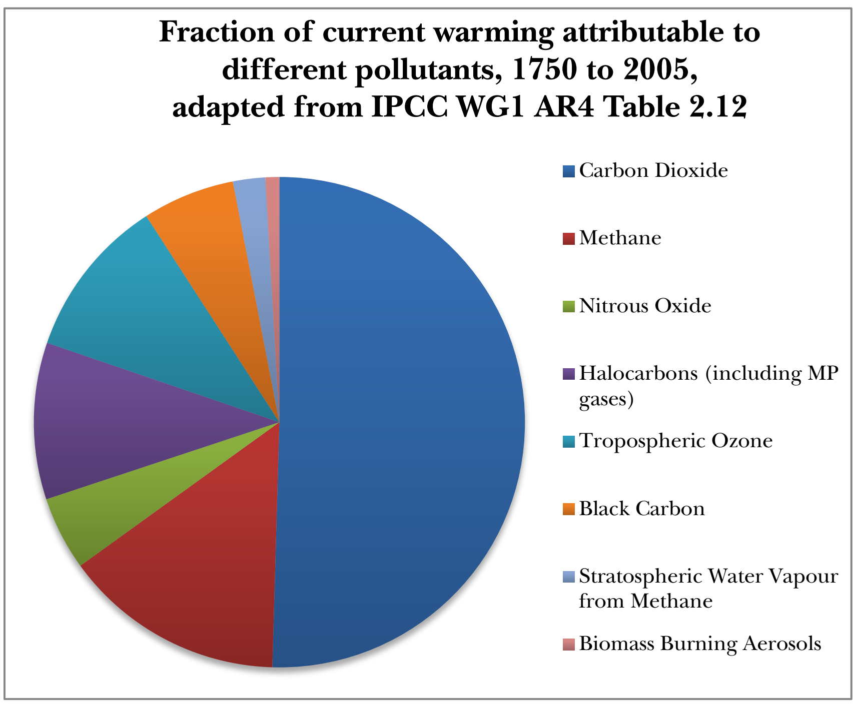
commitments by countries to specify in detail what actions they will take to reduce GHG emissions from various sectors, but it maintains a focus on total emissions quantified in terms of 100-year GWP.

A. Conceptual Underpinnings

1. Multiple Pollutants Cause Climate Change on Multiple Time Scales

While carbon dioxide is the most important man-made greenhouse gas, it is by no means the only one.[28] In fact, numerous atmospheric pollutants have been warming and will continue to warm the atmosphere and hence contribute to climate change.[29] And the contribution of other pollutants to the climate change problem is substantial—consensus estimates are that they contribute slightly less than half of the current warming.[30]

Figure 1: The fraction of radiative forcing attributable to various climate change causing pollutants. Adapted from Forster et al., *supra* note 20, at 204.



29. *Id.*
30. *Id.*; *see infra* Figure 1.

Complicating the picture of man's influence on global climate is the fact that these pollutants persist in the atmosphere for widely differing amounts of time.[31] Some are washed out by rain in a matter of days to weeks.[32] Others are broken down in the atmosphere over one to two decades.[33] Others persist in the atmosphere for centuries to millennia.[34]

Further complicating this picture is the fact that a number of other common atmospheric pollutants, most notably sulfur dioxide emitted when coal is burned, actually cool the Earth by a substantial amount.[35] Thus a more accurate way to think about mankind's influence on global climate is as a changing balance of warming and cooling pollutants with widely varying atmospheric lifetimes in which the net impact is a modest but growing warming. The final complexity is that individual sources, such as a coal-fired power plant, emit both warming (CO_2, black carbon) and cooling (sulfur dioxide) pollutants in complex mixtures.[36]

Metrics for evaluating human impact on Earth's climate all begin with a concept called radiative forcing.[37] Radiative forcing is the extent to which a change in a gas's atmospheric concentration relative to the preindustrial era (before 1750) alters the flow of energy into or out of the troposphere.[38] Radiative forcing, whether

31. CLIMATE CHANGE 2007, *supra* note 20, at 77.

32. *Id.* at 24.

33. *Id.* at 77.

34. *Id.* at 24. Sulfur dioxide and black carbon are generally removed quickly via either rain or dry deposition. *Id.* Methane is broken down by OH radical and has an atmospheric half-life of about twelve years. *Id.* at 552. Most carbon dioxide persists in the atmosphere for centuries. *Id.* at 77.

35. *Id.* at 504.

36. *Id.*

37. *Id.* at 2; *see also* Veerabhadran Ramanathan & Yangyang Xu, *The Copenhagen Accord for Limiting Global Warming: Criteria, Constraints, and Available Avenues*, 107 PROC. NAT'L ACAD. SCI. 8055, 8055 (2010), http://www.pnas.org/content/107/18/8055.full.pdf [https://perma.cc/EP78-QDX2]. An alternative framing of the total impact of atmospheric pollutants that either cool or warm the Earth is possible for long-lived greenhouse gases by comparison of their potential to warm the atmosphere relative to carbon dioxide. *See infra* Section II.A.2.

38. *See* CLIMATE CHANGE 2007, *supra* note 2028, at 2. The troposphere is the 10–20 km thick layer of the Earth's atmosphere closest to the surface and within which weather systems occur. In the troposphere, temperature decreases with height until it reaches a minimum, at a level known as the tropopause. Above the tropopause is the stratosphere, where temperature increases with altitude above the Earth's surface. *See Troposphere*, AM. METEOROLOGICAL SOC'Y GLOSSARY METEOROLOGY, http://glossary.ametsoc.org/wiki/Troposphere [https://perma.cc/V9U6-HKKL] (last visited Feb. 5, 2016).

positive or negative, is an estimate of the change to the balance between incoming sunlight and outgoing heat.[39] If addition of a gas tends to help the atmosphere retain heat, then it has a positive radiative forcing.[40] If, instead, addition of a gas causes energy to be released more readily from the atmosphere to space, it has a negative radiative forcing.[41] Radiative forcing is typically expressed in Watts per square meter (Wm^{-2}).[42] Consensus model estimates place the sensitivity of atmospheric temperature to changes in radiative forcing at approximately 0.8°C per Wm^{-2}.[43] Thus, an increase in global average radiative forcing of 1.25 Wm^{-2} is predicted to lead to a warming of 1°C in average surface temperature.

Using the metric of radiative forcing, scientists have developed estimates for current human impacts to the global climate.[44] One way to think about these positive and negative impacts on atmospheric temperature is as a balance sheet.[45] On one side are human influences that act to heat the atmosphere, on the other, those that act to cool it. Today, carbon dioxide added to the atmosphere by humans adds approximately 1.66 Wm^{-2} to the radiation budget of the earth.[46] Mankind's emissions to the atmosphere of greenhouse gases other than carbon dioxide such as methane, nitrous oxide, and halocarbons add another 0.98 Wm^{-2}.[47] Finally, emissions of short-lived atmospheric pollutants, such as black carbon and tropospheric ozone, add another 0.65 Wm^{-2}.[48] Thus, radiative forcing of non-CO_2 greenhouse pollutants sums to 1.63 Wm^{-2}—indistinguishable, given uncertainties in the estimates,

39. *See* CLIMATE CHANGE 2007, *supra* note 20, at 2.

40. *Id.*

41. *Id.*

42. *Id.*

43. Gerald A. Meehl et al., *Global Climate Projections*, *in* CLIMATE CHANGE 2007, *supra* note 20, at 747.

44. *See* CLIMATE CHANGE 2007, *supra* note 20, at 2.

45. *See infra* Table 1.

46. *See* CLIMATE CHANGE 2007, *supra* note 20, at 25.

47. *Id.* at 131.

48. I use the IPCC estimate for black carbon, 0.2 Wm^{-2}, but more recent research suggests that the correct value is much higher—likely closer to 0.9 Wm^{-2} or more than fifty-five percent of CO_2 forcing. If this estimate is correct, it implies a much greater cooling effect from aerosol-induced changes to clouds. *See* V. Ramanathan & G. Carmichael, *Global and Regional Climate Changes Due to Black Carbon*, 1 NATURE GEOSCIENCE 221, 222 (2008), http://www.nature.com/ngeo/journal/v1/n4/ pdf/ngeo156.pdf [https://perma.cc/9X9M-6FQJ].

from the current impacts from carbon dioxide emissions.[49] Carbon dioxide emissions and the sum of the other greenhouse pollutants each contribute about half of the warming that we experience today. CO_2 emitted when fossil fuels are burned is not the only manmade pollutant that warms the earth; not even close.

In addition to the man-made atmospheric pollutants that warm the Earth's climate, there are several that tend to cool it.[50] The most important are sulfate aerosols, nitrogen oxides, and organic carbon.[51] All are the byproducts of fossil fuel or biomass combustion to varying degrees.[52] Sulfate aerosols are primarily emitted by coal-fired power plants that lack flue gas desulfurization scrubbers.[53] Nitrogen oxides are created by many combustion processes in varying amounts and can be removed from flue gas via catalytic reduction.[54] The primary sources of organic carbon aerosols are biomass and fossil fuel combustion.[55] Aerosols also act to cool the atmosphere via secondary effects.[56] To greatly oversimplify, the presence of aerosol mixtures in the atmosphere is thought to alter the propensity of different cloud types to form.[57] By doing so aerosols tend to change the reflectivity of clouds, leading to a pronounced cooling effect equal to -0.7 Wm^{-2}, offsetting almost half of the warming due to carbon dioxide.[58] Finally, the ocean acts to cool the atmosphere by acting as a giant heat sink. Were it not for this ocean cooling effect, earth would experience 0.98 Wm^{-2} of additional warming—sixty percent of the warming due to carbon dioxide.[59]

Many of these compounds are co-emitted with the warming pollutants[60] but can be removed using pollution control equipment. This means that as societies implement effective local

49. *See infra* Table 1; *supra* Figure 1.

50. *See* CLIMATE CHANGE 2007, *supra* note 20, at 3.

51. *Id.*

52. *Id.* at 160–69.

53. *Id.* at 160–01.

54. *Id.* at 167.

55. Ramanathan & Xu, *supra* note 37, at 8057.

56. *See* CLIMATE CHANGE 2007, *supra* note 20, at 172 (explaining the relationship between aerosols and cloud chemistry).

57. *Id.*

58. *Id.* at 132.

59. *Id.* at 522.

60. *Compare id.* at 25 (asserting that fossil fuel use has led to the increase of atmospheric carbon dioxide), *with id.* at 160 (noting that most sulfate emission comes from fossil fuel burning). The report notes carbon dioxide's role in global warming and sulfate's role in global cooling. *Id.* at 25, 160.

air pollution control, the mixture of warming and cooling pollutants they emit shifts towards more net warming. In essence, effective pollution controls at power plants that avoid morbidity and mortality associated with smog and soot remove the fraction of the pollution mixture that causes cooling but leave in the mixture of constituents that causes warming.

Finally, international agreements unrelated to climate change have significantly altered the radiative forcing values presented in Table 1.[61] The impact of non-CO_2 greenhouse pollutants would be even more significant but for the phase out of various refrigerant gases under the Montreal Protocol on Substances that Deplete the Ozone Layer.[62] Estimates of the impact of the phase out of four common chlorofluorocarbons ("CFCs") on climate indicate that were it not for the Montreal Protocol, halocarbon forcing would be approximately twice as large as at present (0.65 Wm^{-2} rather than 0.32 Wm^{-2}).[63] This reduction in radiative forcing is roughly four times as large as the reductions that the Kyoto Protocol would have produced had the United States participated.[64] It dwarfs reductions due to the Kyoto Protocol as implemented without U.S. participation. Without the CFC phase out under the Montreal Protocol, non-CO_2 pollutants would be a significantly larger cause of current warming than carbon dioxide.[65] In addition, CFCs would be the second most important greenhouse gas, surpassing methane.

61. *See generally* Montreal Protocol on Substances that Deplete the Ozone Layer, art. 2, Sept. 16, 1987, S. Treaty Doc. No. 100-10, 1522 U.N.T.S. 29 [hereinafter Montreal Protocol].

62. CLIMATE CHANGE 2007, *supra* note 20, at 29–41.

63. Guus J.M. Velders et al., *The Importance of the Montreal Protocol in Protecting Climate*, 104 PROC. NAT'L ACAD. SCI. 4815, 4816 (2007).

64. *Id.* at 4818. An even larger difference is obtained if one compares estimates of Kyoto Protocol associated reductions without U.S. participation to reductions in halocarbons associated with the Montreal Protocol. *Compare* William Nordhaus, *Global Warming Economics*, 294 SCIENCE 1283 (2001), *with* Velders et al., *supra* note 63, at 4818.

65. *See* Velders et al., *supra* note 63, at 4814.

Table 1: A balance of warming and cooling pollution. The effects of air pollution on global climate in terms of radiative forcing and temperature change. Included are all emissions from 1750 to 2005. Adapted from CLIMATE CHANGE 2007, *supra* note 20, at 204.

Warming the Climate			**Cooling the Climate**		
Warming Pollutant	**Radiative Forcing (Wm^{-2})**	**Implied ΔT (°C)**	**Cooling Pollutant**	**Radiative Forcing (Wm^{-2})**	**Implied ΔT (°C)**
Carbon Dioxide	1.66	1.33	Sulfate Aerosol	-0.40	-0.32
Methane	0.48	0.38	Organic Carbon	-0.05	-0.04
Nitrous Oxide	0.16	0.13	Nitrate Aerosol	-0.10	-0.08
Halocarbons	0.34	0.27	Mineral Dust	-0.10	-0.08
Tropospheric Ozone	0.35	0.28	Aerosol Impacts on Cloud Formation	-0.70	-0.56
Black Carbon	0.20	0.16	Ocean Heat Uptake	-0.99	-0.79
Stratospheric Ozone	0.07	0.06			
Biomass Burning	0.03	0.02			
Warming	**3.29**	**2.63**	**Cooling**	**-2.34**	**-1.87**
Net Warming	**0.76**				

The net of the various man-made influences to climate and the ocean's buffering of these changes is radiative forcing of approximately 0.76 Wm^{-2}. This suggests a warming associated with man-made emissions of 0.6°C in 2005, which is roughly consistent with observations.[66]

This discussion of basic climate physics is not intended to suggest that carbon dioxide is unimportant when it comes to changing Earth's climate. Obviously, it is very important.[67] But one might also conclude that opportunities to dramatically reduce other

66. *See, e.g.*, CLIMATE CHANGE 2007, *supra* note 20, at 5 (noting the linear warming trend has doubled over the last century).

67. *See supra* Table 1, Figure 1.

sources of greenhouse pollution—rather than just carbon dioxide need to be looked at closely. After all, to the extent that there have been successes in reducing mankind's contribution to climate change, it has been due to reductions in emissions of another gas—chlorofluorocarbons.[68] This is especially true given the fact that all of the non-CO_2 compounds listed in Table 1 have shorter atmospheric lifetimes than does CO_2.[69] This means that in contrast to CO_2, where changes in emissions now will not lead to reductions in atmospheric concentrations or warming for decades to centuries, cuts in other compounds can cause, and have caused (as was the case with CFCs), much faster changes in climate.

Of course, as and if emissions of non-CO_2 warming pollutants are reduced, the warming caused by carbon dioxide will remain and become an increasingly important fraction of the climate change problem. Moreover, carbon dioxide, once released to the atmosphere by human activities, has an extremely long lifetime—on the order of hundreds of years.[70] The level of carbon dioxide that we have released to date, if not masked by the various cooling agents listed in Table 1, is sufficient on its own to cause warming of approximately 1.3°C.[71] This is more than half of the warming the international community has deemed acceptable under recent agreements and approaches the level preferred by many.[72] And carbon dioxide emissions will continue growing, and the pollutant will continue accumulating in the atmosphere, unless substantial steps are taken to shift away from fossil fuel-based energy. On the other hand, it should be clear from the radiation balance presented above that we cannot avoid climate change without confronting the non-CO_2 greenhouse gases as well. Because we need to address both problems, it does not follow that we should address them both using the same legal and regulatory tools or at

68. *See, e.g.*, Velders et al., *supra* note 63, at 4814 (discussing the effectiveness of the Montreal Protocol).

69. *See* CLIMATE CHANGE 2007, *supra* note 20, at 204.

70. The residence time of carbon dioxide in the atmosphere is in part a function of the rate at which it is changing and so is scenario dependent but in any case is on the order of hundreds of years. *Id.* at 211.

71. *See supra* Table 1.

72. *See* U.N. Framework Convention on Climate Change, *The Cancun Agreements: Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action Under the Convention*, U.N. Doc. FCCC/CP/2010/7/Add.1, Dec. 1/CP.16, art. 3 (Mar. 25, 2011) [hereinafter UNFCCC, *Cancun Agreement*]; *see also* U.N. Framework Convention on Climate Change, *Adoption of the Paris Agreement*, U.N. Doc. FCCC/CP/2015/L.9/Rev.1, art. 2 (Dec. 12, 2015) [hereinafter UNFCCC, *Paris Agreement*].

the same time. Yet that is the approach that has been taken, so far unsuccessfully, for more than twenty years, due to the legal framework developed and implemented by the Climate Regime.

2. Choice of Comparison Metric

From estimates of radiative forcing due to various compounds, and knowledge of a particular compound's atmospheric lifetime, it is possible to estimate the impacts due to emission of a greenhouse gas over some period of time.[73] There are two basic approaches. The most common approach, global warming potential, estimates the radiative forcing impacts over a given time frame of an emission today of one ton of a particular GHG.[74] This time integration provides the cumulative impact over the relevant time window, and by implication ignores any impacts that occur outside of the window. This approach to adding a time dimension to estimating impacts of climate change is commonly known as absolute global warming potential.[75] In order to compare the cumulative impacts of one gas to another, a common approach is to divide all absolute global warming potentials by the absolute global warming potential of carbon dioxide.[76] This normalization produces an estimate of relative global warming potential. The normalization allows intercomparison of emissions of different greenhouse gas pollutants on a common scale.

There are numerous alternative approaches to developing comparative impacts estimates for emissions of greenhouse gases.[77] The most commonly suggested alternative approach, called Global Temperature Potential, estimates the impact at a point in the future of a particular quantity of greenhouse pollutant emitted today.[78] This might provide a policymaker with a particular future temperature target in mind, a reference point for considering a given level of emissions in the present. In recent years, dissatisfaction with GWP within the scientific community has led to

73. *See supra* Table 1. The Table lists several greenhouse gases, their radiative forcing, and subsequent estimated-effect on global temperature. *Id.*

74. *See* CLIMATE CHANGE 2007, *supra* note 20, at 31.

75. *See, e.g.*, Olivier Boucher et al., *The Indirect Global Warming Potential and Global Temperature Change Potential Due to Methane Oxidation*, ENVTL. RES. LETTERS, Oct.–Dec. 2009, at 1 (defining absolute global warming potential).

76. *Id.*

77. *See* CLIMATE CHANGE 2007, *supra* note 20, at 211 (explaining the difference between Global Temperature Potential and GWP).

78. *Id.* at 215–16.

a proliferation of alternative proposals for comparing future estimates of current emissions.[79] Despite this, as will be described below, 100-year GWP has remained the sole criterion for evaluating emissions or reductions of greenhouse gases within the Climate Regime or related national-level greenhouse gas regulatory systems.

3. Choice of Time Frame

Even after a decision to use GWP has been made in evaluating impacts on climate, a scientist or policy maker must choose the time frame over which to integrate impacts. Common choices are 20, 100, and 500 years.[80] Table 2 shows current estimates of GWPs for three atmospherically well-mixed GHGs.

Table 2: Global warming potential of the most abundant well-mixed greenhouse gases as reported by the IPCC in 2007. CLIMATE CHANGE 2007, *supra* note 20, at 212.

Greenhouse Gas	**20-year GWP**	**100-year GWP**	**500-year GWP**
Carbon dioxide	1	1	1
Methane	72	25	7.6
Nitrous Oxide	289	298	153

As is evident from Table 2, time frame matters a great deal in estimating GWP. Care must be taken in the use of GWP as a comparison metric because the time horizon over which the cumulative impacts are judged can have enormous impacts on the estimated impacts of different emissions.[81] Consider for example a gas that for five years has twenty times the impacts of CO_2 but is then rapidly removed from the atmosphere. An emission of one unit of the gas would have a GWP for a five-year time frame of twenty—in other words, it would cause twenty times the change in time-integrated radiative forcing as an emission of the same amount of CO_2. But an estimate of this same gas's GWP for a twenty-year time frame would fall to approximately five. Over a century timescale, its GWP would be one—or equal to the impact of emitting an equal amount of CO_2 at the same time.

79. For a recent survey, see T.C. Bond et al., *Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment*, 118 J. GEOPHYSICAL RES. 5380, 5511–15 (2013).

80. *See* CLIMATE CHANGE 2007, *supra* note 20, at 212 (presenting a chart that depicts GWP time horizons of 20, 50, and 100 years).

81. *See supra* Table 2.

Because different GHGs have different atmospheric lifetimes, choice of a timeframe over which to integrate GWP can have dramatic consequences to estimates of climate impacts of various activities. This is particularly true for greenhouse pollutants that, compared with CO_2, are relatively short-lived but have significantly greater near-term radiative forcing.[82] In Table 2, methane is an important example of this phenomenon. If a twenty-year time frame is used to evaluate its impacts relative to CO_2, then it is seventy-two times more effective at warming the atmosphere. By contrast, if instead, a 100-year time frame is used, the impact is almost two-thirds less. As will be seen, these differences have large implications for agreements to limit emissions using GWP as a means of comparing commitments to reduce emissions of various gases.

B. Development of the Climate Regime's Legal Framework

The need for and the general concept of GWP was borrowed from the earlier and highly successful international effort to protect the stratospheric ozone layer from destruction by chlorofluorocarbons and like compounds.[83] Ozone Depleting Potential, a similar method for comparing the harm to the ozone layer posed by various substances, had been utilized by negotiators in the lead up to the Montreal Protocol negotiations and to a limited extent in the agreement itself to provide for compliance flexibility.[84]

At a preparatory scientific meeting to the Montreal Protocol negotiations, international scientists settled on Ozone Depleting Potential as a means of comparison between different CFCs.[85] The

82. *See, e.g.*, CLIMATE CHANGE 2007, *supra* note 20, at 211 (discussing the shortcomings of GWPs and how gases might need to be assessed individually).

83. *See, e.g.*, MICHAEL GRUBB, CHRISTIAAN VROLIJK & DUNCAN BRACK, THE KYOTO PROTOCOL: A GUIDE AND ASSESSMENT 72 (1999).

84. *See* RICHARD ELLIOT BENEDICK, OZONE DIPLOMACY: NEW DIRECTIONS IN SAFEGUARDING THE PLANET 78 (enlarged ed. 1998); EDWARD A. PARSON, PROTECTING THE OZONE LAYER: SCIENCE AND STRATEGY (2003). Ultimately, other metrics proved superior in the Montreal Protocol negotiations, especially, Chlorine Loading Potential. PARSON, *supra*, at 160–61. In any case, the uses of these metrics in the Montreal Protocol are quite different than in the Kyoto Protocol. Within the Montreal Framework, reductions are required from within different groups of compounds (e.g. CFCs). Within each group, Ozone Depleting Potential is utilized to compare compounds impacts to stratospheric ozone. *See id.*

85. *See generally* U.N. Environment Programme, *Ad Hoc Scientific Meeting to Compare Model Generated Assessments of Ozone Layer Change for the Various Strategies for CFC Control*, U.N. Doc. UNEP/WG.167/INF.I/Add.1 (Apr. 24, 1987); BENEDICK, *supra* note 84, at 78. Ted Parson

scientific advice provided to negotiators ultimately recommended this approach in considering CFC reductions.[86] An ability to compare the relative merits of cuts to different CFCs went a long way towards resolving concerns about substitutes for particular industries and parties to the initial agreement.[87]

Global warming potential was first proposed as an analogue to Ozone Depleting Potential in the preparatory negotiations to the Rio Summit at which the UNFCCC was negotiated.[88] An alternative Brazilian proposal to allocate emission reductions in proportion to observed temperature change that would be traced back to emissions, was also floated at the time but ultimately rejected by the parties.[89] Nations opted for the GWP approach because control of non-CO_2 gases might be easier and cheaper, thus facilitating stronger targets. Unexplained is the choice of 100-year GWP as opposed to some shorter or longer timeframe.[90] One is left to wonder whether the choice had as much to do with the fact that the GWP's of various gases were presented to negotiators in a table that included 20-year, 100-year, and 500-year GWPs[91] and that negotiators opted for the mid-range value. From these origins, global warming potential has grown to take on a much greater significance within the Climate Regime than has Ozone Depleting Potential within the Ozone Regime.

Once the decision to base negotiations on a basket of greenhouse gases utilizing 100-year GWP for intercomparison had

also argues that an important factor in breaking the deadlock was the movement of the U.S. negotiating position beyond requiring that all parties take the steps that the United States had already taken—banning aerosols—to a position that required all parties to make cuts in emissions below what they had already done. In essence, breaking the deadlock required all parties to bear costs under the new agreement, even if some had unilaterally imposed costs on themselves at an earlier date. PARSON, *supra* note 84, at 140.

86. BENEDICK, *supra* note 84, at 78.

87. *Id.*

88. *See* GRUBB, VROLIJK & BRACK, *supra* note 83, at 72; *see also* Daniel A. Lashof & Dilip R. Ahuja, *Relative Contributions of Greenhouse Gas Emissions to Global Warming*, 344 NATURE 529 (1990); Henning Rodhe, *A Comparison of the Contribution of Various Gases to the Greenhouse Effect*, 248 SCIENCE 1217 (1990).

89. U.N. Framework Convention on Climate Change, Ad Hoc Group on the Berlin Mandate, *Implementation of the Berlin Mandate: Additional Proposals from Parties*, U.N. Doc FCCC/AGBM/1997/Misc.1/Add.3, at 4 (May 30, 1997); *see also* GRUBB, VROLIJK & BRACK, *supra* note 83, at 74.

90. One participant in preparatory meetings to the UNFCCC negotiations reports that the 100-year value was selected simply because it was the middle value in a table presented by the IPCC. Personal Communication from David Victor, Professor, School of Global Policy and Strategy, U.C. San Diego (Feb. 8, 2014).

91. GRUBB, VROLIJK & BRACK, *supra* note 83, at 74; Shine et al., *supra* note 26, at 60.

been made, the issue of which gases to include still required resolution.[92] During the Kyoto Protocol negotiations, the European Union ("EU") initially supported including carbon dioxide, methane, and nitrous oxide.[93] The United States pushed for expansion of the basket to include halocarbons, perfluorocarbons, and sulfur hexafluoride.[94] The EU and Japan were opposed to this and favored a two-basket approach, similar to the approach taken for the Montreal Protocol.[95] Apparently, U.S. industry feared more stringent controls if high GWP gases were regulated separately.[96] The European chemicals industry took the opposite view.[97] As on so many other issues regarding cost-control during the Kyoto Protocol negotiations, the U.S. position, aimed at lowering the costs of reductions of and weakening commitment to cut energy-related carbon dioxide emissions, was adopted by the parties.[98] In the end, each party adopted a single emissions target for a basket of six key GHGs, expressed in terms of their 100-year global warming potentials.[99]

In addition to the six-gas, 100-year GWP structure, and again at the United States' urging, the Kyoto Protocol provided for multiple types of emissions trading. Emissions trading allowed reductions to occur where they are cheapest rather than within the territory of the country that commits to them, thus allowing for substantial efficiency gains, at least according to theory.[100] In combination, the United States hoped that these trading programs would create significant compliance savings as the country outsourced emissions reductions to low cost suppliers—other countries with either non-CO_2 abatement options or with low-cost carbon reduction possibilities.

Overall, the United States' concern regarding its compliance costs led to the maximum use of flexibility measures in the UNFCCC and the Kyoto Protocol. A key consequence of this

92. *See, e.g.*, GRUBB, VROLIJK & BRACK, *supra* note 83, at 75–76 (discussing the types of gases the negotiating parties desired to have included in the agreement).

93. *Id.*

94. *Id.*

95. *Id.*

96. *Id.*

97. *Id.* at 76.

98. *Id.*

99. *Id.*

100. *See, e.g.*, Lawrence Goulder & William Pizer, *The Economics of Climate Change*, *in* NEW PALGRAVE DICTIONARY OF ECONOMICS (Steven N. Durlauf & Lawrence E. Blume eds., 2d ed. 2008) (discussing how trading programs can promote flexibility).

strategy was to link reductions in all six GHGs in all countries, inextricably, to reductions in carbon dioxide emissions within the countries that committed to limiting their emissions. Since this legal framework was established, future discussions of emissions reductions in the Climate Regime have been almost exclusively in terms of the basket of six gases.[101] Further, because of the use of 100-year global warming potential as the reference point for comparing reductions, there has been no concrete discussion of reductions in short-lived pollutants even though, as will be described below, the scientific understanding of their role has developed in the ensuing two decades.

C. The Focus on Carbon Dioxide

The placement of 100-year GWP at the center of the Kyoto Protocol framework inevitably focused attention on CO_2 emissions over those of other, shorter-lived compounds.[102] There were at least three reasons justifying the choice of a GWP that tended to emphasize long-lived gases such as carbon dioxide over short-lived compounds such as methane and halocarbons. First, scientists had much greater confidence in their knowledge of CO_2's role in warming. Second, governments had better knowledge of past and current CO_2 emission rates by parties to the Kyoto Protocol. Third, economists had far greater experience in estimating the costs of CO_2 abatement.

1. Understanding of CO_2 Relative to Other Gases' Impact on Climate

At the time of the Kyoto Protocol negotiations, the understanding of CO_2's role in changing climate was relatively well understood while there were fundamental uncertainties in the science of the non-CO_2 greenhouse pollutants. The concentration of CO_2 in the atmosphere along with most details of its sources and

101. For example, commitments under the Copenhagen Accord are in terms of the six-gas 100-year GWP framework. U.N. Framework Convention on Climate Change, *Copenhagen Accord*, U.N. Doc. FCCC/CP/2009/11/Add.1, Dec. 2/CP.15, at 3 (Mar. 30, 2010) [hereinafter UNFCCC, *Copenhagen Accord*]. So too are commitments under the second phase of the Kyoto Protocol, recently agreed to at the Doha Conference of the Parties. U.N. Framework Convention on Climate Change, *Amendment to the Kyoto Protocol Pursuant to Its Article 3, Paragraph 9 (the Doha Amendment)*, U.N. Doc. FCCC/KP/CMP/2012/13/Add.1, Dec. 1/CMP.8 (Feb. 28, 2013) [hereinafter UNFCCC, *Doha Amendment*].

102. *See* Kyoto Protocol, *supra* note 24, at art. 3.

cycling in the atmosphere had been understood since the 1970s.[103] Its heat trapping properties had been well understood since the time of Arrhenius' path-breaking work.[104] In combination, these three types of information—concentration, cycling, impacts on warming—gave climate scientists confidence in the IPCC Second Assessment Report in their understanding of carbon dioxide's effects on climate.

By contrast, scientific understanding of other climate change pollutants was far less developed. The global budgets of sources and sinks for methane and nitrous oxide were much less well constrained. There were significant uncertainties even as to explanations of trends in atmospheric concentration over the decade leading up to the report.[105] Furthermore, the role of aerosols in climate change was just beginning to be understood but observations were sparse and models of their interaction with climate were simplistic at best.[106] Indeed, a major accomplishment of the IPCC Second Assessment Report was the first incorporation of the cooling effects of sulfate aerosols into model estimates of the temperature response to anthropogenic emissions over the twentieth century.[107] This significantly improved the fit of models and observations and increased confidence in projections of future warming.[108] Still, inclusion of aerosols other than sulfate and of aerosols' suspected impacts on cloud formation was primitive to nonexistent.[109] Thus, the current state of scientific understanding

103. The key missing piece in understanding of the carbon cycle was the regrowth of northern hemisphere forests, especially in North America, but this uncertainty was of smaller magnitude than the uncertainties in atmospheric cycling of other gases. *See* W.S. Broecker, T. Takahashi, H.J. Simpson & T.H. Peng, *Fate of Fossil Fuel Carbon Dioxide and the Global Carbon Budget*, 206 SCIENCE 409, 416 (1979); D. Schimel et al., *Radiative Forcing of Climate Change*, *in* CLIMATE CHANGE 1995: THE SCIENCE OF CLIMATE CHANGE, CONTRIBUTION OF WORKING GROUP I TO THE SECOND ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 65, 78–79 (1996) [hereinafter CLIMATE CHANGE 1995], https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf [https://perma.cc/62AM-KS9K].

104. S*ee supra* note 25 and accompanying text; CLIMATE CHANGE 1995, *supra* note 103, at 109.

105. *See* CLIMATE CHANGE 1995, *supra* note 103, at 87–88.

106. *Id.* at 103–08.

107. *Id.* at 23 (noting the inclusion of sulfate aerosols in emission estimations).

108. *See, e.g.*, A. Kattenberg et al., *Climate Models—Projections of Future Climate*, *in* CLIMATE CHANGE 1995, *supra* note 103, at 285, 297.

109. *See supra* Table 1; *see, e.g.*, Shine et al., *supra* note 26, at 64 ("In view of the above uncertainties on the sign, the affected area and the temporal trend of the direct impact of aerosols, we are unable to estimate the change in forcing due to tropospheric aerosols."); *see*

at the time of the Kyoto negotiations tended to bias thinking towards a focus on carbon dioxide.

2. Knowledge of National Emissions of CO_2 Versus Other GHGs

An additional reason for focusing on CO_2 at the Kyoto Protocol negotiations had to do with knowledge that the parties had of historical emissions. The Kyoto Protocol placed binding limits on emissions of developed country parties. Prior to the agreement, nations had had little reason to measure emissions of GHGs for their own sake. For carbon dioxide, accurate estimates of emissions could be derived from the careful records that all industrialized countries had long maintained of fossil fuel consumption.[110] On the other hand, for gases such as methane and nitrous oxide, there were no accepted methodologies for creating national emissions inventories, let alone reconstructing past emissions levels. Further, national emissions inventories for these gases depended critically on poorly understood processes, such as the rate of emissions from fertilized soils, rice cultivation, and biomass burning.[111] Prior to the Kyoto Protocol, most countries did not have much experience in measuring these emissions and so were understandably reluctant to make binding legal promises to reduce them. By contrast, levels of carbon dioxide emissions from major sources, except for land use,[112] could be estimated based on high quality fossil fuel production and consumption data collected for other reasons.

3. Experience with Modeling the Impacts and Costs of CO_2 Abatement

Yet another reason that negotiations focused on CO_2 was much greater confidence in estimates of abatement costs. This confidence was due to the use of computed general equilibrium models of the energy system to estimate the costs of reducing emissions of greenhouse gases. These models emerged from efforts to model the energy sectors of major economies in response to the energy crises of the 1970s. As such, they suffered from the

also CLIMATE CHANGE 1995, *supra* note 103, at 112 ("There is a large uncertainty range particularly for the radiative forcing due to the effect of aerosols on cloud properties.").

110. *See, e.g.*, INT'L ENERGY AGENCY, KEY WORLD ENERGY STATISTICS 44–45 (2012) (presenting CO_2 emissions from fossil fuel combustion by fuel and region from 1971 to 2010).

111. CLIMATE CHANGE 1995, *supra* note 103, at 87–88.

112. *Id.* at 78–79.

same bias as did the emissions data—a focus on fossil fuels and CO_2 and a consequent neglect of non-CO_2 gases. In fact, until surprisingly recently, the most widely accepted models for estimating the costs of mitigating greenhouse gas emissions did not explicitly model non-CO_2 greenhouse gases.[113] This is only now beginning to change as explicit marginal abatement cost curves for methane, nitrous oxide, and halocarbons have been developed for use in economic models of climate change.[114] Still, even today, no existing energy-economic models aimed at the climate change problem incorporate potential abatement options from SLCPs such as black carbon or tropospheric ozone.[115] Thus at the time that key legal and policy decisions were being made in the formation of the Climate Regime, modeling of the costs of various policy options did not consider non-CO_2 gases.[116] While there was some confidence that low-cost abatement strategies using these gases would be available, the commitments being offered by various nation states were not informed by any sort of detailed knowledge of these options. This inevitably focused attention on what was known—the cost of reducing energy-related carbon emissions.

D. Lock in of the Carbon and Energy Focus

After the conclusion of the Kyoto Protocol negotiations and the eventual entry into force of the treaty, implementation of the agreement via national policies and measures has been shaped in important ways by the articulation of targets in terms of 100-year GWP. Even as the science of climate change has evolved, the legal structure for understanding the climate change impacts of GHGs has remained stable. There are many causes.

113. *Compare* Nordhaus, *supra* note 3, at 11,722 (addressing greenhouse gases other than CO_2 in their model), *with* Manne & Richels, *supra* note 3, at 5 (asserting that CO_2 is the most important greenhouse gas and that movements of the other greenhouse gases will not impact the article's general insights).

114. *See* John Weyant et al., *Overview of EMF 21: Multigas Mitigation and Climate Policy*, ENERGY J., Special Issue 2006, at 1, 2.

115. *See supra* Table 1.

116. Interestingly, compliance with the protocol, especially via the Clean Development Mechanism, has depended heavily on abatement obtained via non-CO_2 gases outside of the energy sector, a development which the models used by negotiators could not have predicted. *See CDM Projects by Type*, UNEP DTU CENTRE, http://www.cdmpipeline.org/cdm-projects-type.htm [http://perma.cc/W9AF-R66S] (last visited Feb. 2, 2016).

1. Emissions Trading

One reason for the stability of the legal frameworks created by the Kyoto Protocol may have to do with the design of the treaty itself. As mentioned above, at U.S. insistence, the Kyoto Protocol contained numerous features allowing for trading of emissions permits and offsets.[117] Over time, as these instruments have changed hands, they have created large numbers of stakeholders, both public and private, with an interest in seeing the current accounting scheme for GHGs maintained. Governments and private parties have invested large sums in creating, selling, and purchasing credits from other countries that they can use in lieu of self-produced reductions.[118] Changes to the GWP accounting system would disrupt expectations in these emissions trading markets.

A remarkable example of the pressure exerted for what amounts to a sort of exchange rate stability for compliance instruments under the Kyoto Protocol is the case of methane's 100-year GWP. The Kyoto Protocol incorporated the most current GWPs produced by the Intergovernmental Panel on Climate Change ("IPCC").[119] The estimated 100-year GWP for methane at this time was twenty-one.[120] By the time of the fourth assessment report in 2007, and since that time, scientists had developed a better understanding of the processes by which methane is removed from the atmosphere and hence its atmospheric residence time. This in turn has led to a revision in methane's 100-year GWP from twenty-one to twenty-five.[121] In the terms of emissions trading, the currency of methane had appreciated relative to CO_2, at least so far as the science is concerned. And yet, no changes have been proposed to methane's legally recognized GWP in response to these scientific changes, largely because to do so would upset the property rights regime that has grown up within the UNFCCC's framework. This is true even for negotiations recently concluded for a second commitment period to the Kyoto Protocol that extends from 2013 to 2020.[122]

117. *See* Kyoto Protocol, *supra* note 24, at arts. 7, 12.

118. *See, e.g.*, *AAU*, EVOLUTION MKTS., http://www.evomarkets.com/environment/carbon_markets/aaus [https://perma.cc/6XXE-H6UX] (last visited Feb. 2, 2016) (describing Assigned Amount Units and their role within the Kyoto Protocol).

119. Kyoto Protocol, *supra* note 24, at art. 5, § 3.

120. *See* CLIMATE CHANGE 1995, *supra* note 103, at 121.

121. *See* Forster et al., *supra* note 20, at 212.

122. *See generally* UNFCCC, *Doha Amendment*, *supra* note 101.

2. National and Subnational Implementation of GHG Reduction Programs

Another reason for the lock-in of the legal framework established at Kyoto has been the growth of numerous national and subnational schemes aimed at reducing emissions of GHGs. Some of these programs are part of a national effort at compliance with an international target while others are not. The largest is the European Union Emissions Trading Scheme, a cap and trade program for greenhouse gases that regulates large industrial sources in the EU.[123] The Emissions Trading Scheme adopted the Climate Regime's legal framework in order to facilitate EU compliance with the Kyoto Protocol and to be compatible with the broader international markets fostered by the agreement. In order to accomplish both aims, the Emissions Trading Scheme had to adopt the 100-year GWP framework enshrined in the Kyoto Protocol. Further, while international obligations under the Kyoto Protocol have concluded, the Emissions Trading Scheme is set to continue at least until 2020, further cementing the Climate Regime's current legal framework.[124] Altering the GWPs in the post-Kyoto environment would amount to changing the expected value of investments in emission reducing technologies and of emission allowances that have been banked for use in future compliance periods.

Even countries and sub-national governments not subject to obligations under the Kyoto Protocol have adopted its framework, perhaps with the intent of one day participating in some form of international emissions trading or at least coordination. For example, the California climate change program utilizes the Kyoto Protocol's six-gas 100-year GWP framework.[125] In addition, U.S. Environmental Protection Agency regulatory activities including the GHG mandatory reporting rule,[126] the GHG endangerment

123. *See* Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 Establishing a Scheme for Greenhouse Gas Emissions Allowance Trading Within the Community and Amending Council Directive 96/61/EC, 2003 O.J. (L 275) 32.

124. *See* Directive 2009/29/EC of the European Parliament and the Council of 23 April 2009 Amending Directive 2003/87/EC so as to Improve and Extend the Greenhouse Gas Emission Allowance Trading Scheme of the Community, 2009 O.J. (L 140) 63.

125. *See* California Global Warming Solutions Act of 2006,
Cal. A.B. 32, 2006 Cal. Stat., ch. 488 (codified at CAL. HEALTH & SAFETY CODE §§ 38,500–99).

126. Mandatory Reporting of Greenhouse Gases, 74 Fed. Reg. 56,260, 56,395 tbl.A-1 (Oct. 30, 2009).

finding,[127] and the GHG tailoring rule,[128] have adopted the same six-gas 100-year GWP framework.

3. Follow-on Negotiations to the Kyoto Protocol

The 100-year GWP framework for assessing the impacts of GHG emissions has been further cemented by two rounds of follow-on negotiations within the Climate Regime focused on developing successor policies to the Kyoto Protocol.[129] Although both take very different approaches to multilateral cooperation on climate change and GHG emissions than did the Kyoto Protocol, they maintain a focus on and consequent understanding of the climate change problem in terms of the 100-year GWP and a deal to cut emissions of the six-gas basket.

At the Conference of the Parties ("COP") to the UNFCCC that took place in Bali in late 2007, parties to the Climate Regime agreed on what came to be called the Bali Action Plan.[130] The Bali Action Plan specified a set of issue areas and objectives that were to frame negotiations for a successor agreement to the Kyoto Protocol, to be adopted in late 2009.[131] While the Bali Action Plan was primarily focused on an extension of the basic Kyoto Framework, it did focus upon another source of carbon dioxide emissions—deforestation.[132] Still, non-CO_2 gases were subsumed within the broader 100-year GWP basket. Ultimately, the outcome of the Bali Action Plan was an agreement known as the Copenhagen Accord, which included pledges from various developed and developing country governments to reduce emissions by 2020. Pledges were articulated using the existing legal framework of six gases and 100-year global warming potentials.[133] Interestingly, almost nothing beyond this core legal framework was retained from the Kyoto Protocol into the Copenhagen Accord.

127. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,496, 66,499 (Dec. 15, 2009).

128. Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31,514, 31,522 (June 3, 2010) (citing Mandatory Reporting of Greenhouse Gases, 74 Fed. Reg. at 56,395 tbl.A-1).

129. Compliance obligations under the Kyoto Protocol ended on December 31, 2012. *See* Kyoto Protocol, *supra* note 24, at art. 3.

130. UNFCCC, *Bali Action Plan*, *supra* note 4.

131. *Id.*

132. *See, e.g.*, *id.* § 1(b)(iii); *see also* Vidal, *supra* note 4.

133. UNFCCC, *Copenhagen Accord*, *supra* note 101, at 6 ("Annex 1 Parties that are Party to the Kyoto Protocol will thereby further strengthen the emissions reductions initiated by the Kyoto Protocol." (referencing Kyoto Protocol, *supra* note 24)).

Most notably, some countries, including the United States, opted to shift to a different reference year from the Kyoto Protocol's choice of 1990. The choice of reference year is critical, because it is the reference point against which to judge emissions reductions in 2020 and against which their reduction pledge is to be measured.[134] Also, the trading regimes that were a hallmark of the Kyoto Protocol were not preserved in the new agreement. Finally, commitments were expressed in a variety of ways, rather than as a percentage reduction in emissions relative to a single baseline emissions year, as at Kyoto. For example, the United States' commitment under the Kyoto Protocol was articulated as a single number "93," committing the United States to reduce its emissions of GHGs to ninety-three percent of 1990 emissions. At Copenhagen, the United States' commitment was to reduce emissions "[i]n the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation."[135] The Copenhagen Accord commitments thus contained both an output—the reduction in terms of 100-year GWP, and an input, the means by which the reduction would be achieved. Commitments made as a part of the Copenhagen Accord were formalized and elaborated upon in the Cancun Agreements, concluded one year later.[136]

More recently, the Durban Platform was adopted at the 2012 Conference of the Parties to the UNFCCC.[137] The Durban Platform aimed to negotiate a new treaty that would be adopted by 2015 and would enter into force by 2020.[138] Negotiations were planned along a two-track process. Durban Platform Track One was focused on the 2015 deadline and development of a set of proposals to limit emissions of greenhouse gases in the post-2020 period.[139] Durban Platform Track Two negotiations were oriented at increasing the extent of reductions in the lead up to 2020.[140]

134. *See id.* at app. I.

135. *Id.*

136. UNFCCC, *Cancun Agreement*, *supra* note 72.

137. U.N. Framework Convention on Climate Change, *Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action*, U.N. Doc. FCCC/CP/2011/9/Add.1, Dec. 1/CP.17 (Mar. 15, 2012).

138. *Id.* at 1.

139. *Id.*

140. *Id.*

The outcome of Durban Platform Track One negotiations is the Paris Agreement, which cements a new framework for international commitments to reduce GHG emissions in the post-2020 period.[141] The Paris Agreement adopts a very different dynamic structure than the Kyoto Protocol, and extends the changes in the structure of commitments begun under the Copenhagen Accord while still maintaining its focus on outputs quantified in terms of 100-year GWP. Parties to the Paris Agreement submitted Intended Nationally Determined Contributions—their commitments—prior to the final negotiating rounds. These commitments took widely varying forms, often laying out broad plans for national energy policy and deployment strategy including regulations to achieve these ends before stating an emissions target that the listed measures would achieve. Developed country targets generally took the form of economy-wide emissions targets in the style of the Kyoto Protocol while developing country targets varied widely in the form they took.[142] While other aspects of the Paris Agreement will be discussed below, here, it is worth noting that economy-wide targets articulated in terms of 100-year GWP are specifically called out as "taking the lead" in article 4 of the Agreement, which focuses on emission reduction commitments.[143] Still, the Agreement represents a further step towards a focus on inputs as well as outputs to its ultimate goal—emissions reductions—in terms of how commitments are articulated. Also, notably, it preserves flexibility for developing country parties to offer commitments in future negotiating rounds that provide detail on national policies and activities to reduce emissions but do not specify a multi-gas target in terms of 100-year GWP.[144]

Durban Platform Track Two negotiations, because they were additional to whatever nations had committed to undertake under the Copenhagen Accord, may have presented the best opportunity within the recent negotiations of adopting a different approach to emissions reductions. In the end, Durban Platform Track Two

141. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at art. 2.

142. *See, e.g.*, UNITED STATES, U.S. COVER NOTE, INDC AND ACCOMPANYING INFORMATION (2015), http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf [http://perma.cc/YH3K-DY8Q] (listing nine regulatory measures and executive actions that cumulatively will achieve its emissions reduction target, along with said target).

143. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4.

144. *Id.*

resulted in commitments to assess mitigation opportunities in the 2016–2020 period rather than in new and additional commitments to make reductions beyond those of the Copenhagen Accord.[145]

Before addressing the options presented by the Paris Agreement and their relevance to the SLCPs in Part V, I will first briefly summarize current understanding of the importance of SLCPs—a scientific understanding that has only crystalized since 2000—and then describe the political, economic, and regulatory possibilities associated with reducing emissions of these potent warming pollutants.

III. THE NEW SCIENCE OF SHORT-LIVED CLIMATE POLLUTANTS

A. Sulfate Aerosol and the Twentieth Century Temperature Record

It is a common perception among advocates for stronger policies to address global warming that the science has been clear for some time.[146] This Section aims to complicate this belief. On the one hand, the basic picture of Earth's sensitivity to emissions of carbon dioxide has not changed substantially since Arrhenius's first estimate of the impact of doubling carbon dioxide concentrations. Arrhenius estimated that doubling carbon dioxide concentration in the atmosphere would lead to an average warming of 5–6°C.[147] He later reduced that estimate to 4°C.[148] The later estimate falls on the high end of the accepted range of climate sensitivity to a CO_2 doubling of 1.5–4.5°C that all IPCC reports have estimated.[149] So in at least one important sense, the science on climate change has not changed terribly much over the past 116 years.

But as Table 1 and Figure 1 indicate, there is much more that humans are doing to influence climate, either to warm or to cool, than just emitting carbon dioxide by burning fossil fuels. This

145. *Id.* at para. 74.

146. For a recent articulation of this view, see President Barack Obama, Address at Georgetown University (June 25, 2013) (transcript available at http://www.bloomberg.com/news/articles/2013-06-25/-we-need-to-act-transcript-of-obama-s-climate-change-speech [http://perma.cc/Z3J9-7GKA]).

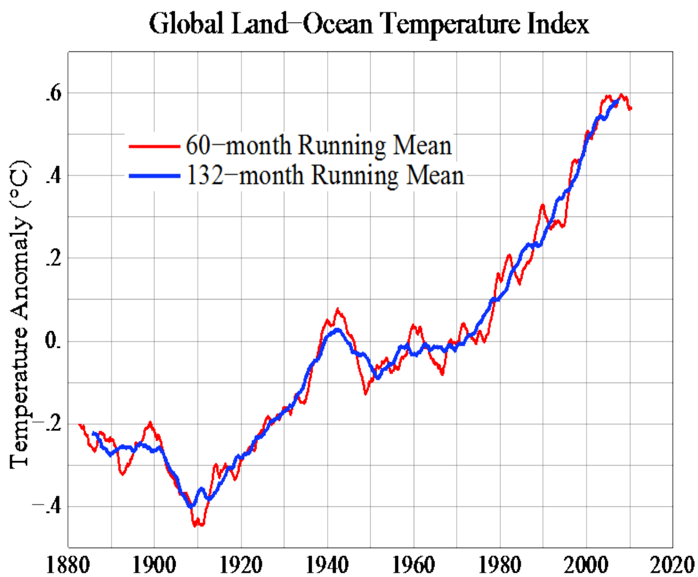
147. Arrhenius, *supra* note 25, at 266.

148. SVANTE ARRHENIUS, WORLDS IN THE MAKING: EVOLUTION OF THE UNIVERSE 53 (H. Borns trans., 1908).

149. *See, e.g.*, Lisa Alexander et al., *Summary for* Policymakers, *in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 14 (Thomas F. Stocker et al. eds., 2013), https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WGIAR5_SPM_brochure_en.pdf [https://perma.cc/799X-QXYW].

Section will highlight the role of major short-lived climate pollutants—black carbon, tropospheric ozone, methane, and hydrofluorocarbons. But the history of scientific understanding of SLCPs really begins with one that actually cools the atmosphere—sulfur dioxide.

Figure 2: Global average temperature anomaly from 1885 to 2012 relative to the 1951–1980 base period; five and eleven year running means. From James Hansen, Makiko Sato & Reto Ruedy, *infra* note 156, at 1 fig.1.



The path of temperature increase during the twentieth century was not monotonic. Temperature warmed during the first half of the century, up until the end of World War II, then cooled for several decades, then began a pronounced period of warming beginning in the late 1970s that continues more or less up to the present.[150] The IPCC Second Assessment Report was the first to explain the mid-century cooling period.[151] It did so by attempting for the first time to model the climate impacts of a SLCP that acts to cool the planet—sulfur dioxide ("SO_2").[152] By including sulfur

150. *See supra* Figure 2.

151. *See* CLIMATE CHANGE 1995, *supra* note 103, at 6–7 (describing the cooling effect of anthropogenic aerosols).

152. *See supra* note 20.

dioxide, a common pollutant emitted by coal-fired power plants, in the emissions scenarios used as inputs to climate models, scientists were able to explain the interruption in the warming trend at mid-century and to model the global and regional temperature trends of the twentieth century.[153] SO_2 had long been recognized as an important local and regional air pollutant and as one of the causes of acid rain.[154] Further, for some time, it had been recognized qualitatively by climate scientists that emissions of SO_2 aerosol could cool the climate.[155] Still, moving from that qualitative understanding to realistic simulation of the spatiotemporal distribution of sulfur dioxide in the atmosphere and its cooling effects on climate was a major breakthrough. The mystery of post-war cooling followed by late-1970s warming had a relatively simple explanation—a post-war boom in coal-fired combustion that temporarily overwhelmed the warming effects of CO_2 and other gases. This was followed in the 1970s by the adoption of pollution control laws in Europe and the United States that acted to significantly reduce SO_2 emissions in the global atmosphere, at least until the boom in Chinese coal-fired power plant construction during the last decade. In effect, part of the warming due to carbon dioxide had been masked by sulfur emissions until pollution controls unmasked it.[156]

B. Black Carbon, Ozone, and Other Short-Lived Climate Pollutants

The success with sulfate aerosols spurred scientists to study other aerosols during the early part of the twenty-first century. In 2000, Mark Jacobsen and Jim Hansen and colleagues simultaneously published papers showing that another aerosol—black carbon—might be warming the atmosphere a third as much as carbon dioxide.[157] At the same time, results of field campaigns using

153. B.D. Santer et al., *Detection of Climate Change and Attribution of Causes*, *in* CLIMATE CHANGE 1995, *supra* note 103, at 415.

154. *See* Gene E. Likens & F. Herbert Bormann, *Acid Rain: A Serious Regional Environmental Problem*, 184 SCIENCE 1176, 1176 (1974).

155. Bob Allen, *Atmospheric Aerosols: What Are They, and Why Are They so Important?*, NASA (Aug. 1, 1996), http://www.nasa.gov/centers/langley/news/factsheets/Aerosols.html [https://perma.cc/7784-JJVB] (explaining the impact sulfur dioxide can have on global climate).

156. *See* JAMES HANSEN, MAKIKO SATO & RETO RUEDY, GLOBAL TEMPERATURE UPDATE THROUGH 2012, at 1 (2013); *supra* Figure 2.

157. Bond et al., *supra* note 79, at 5384–88; Mark Z. Jacobsen, *A Physically-Based Treatment of Elemental Carbon Optics: Implications for Global Direct Forcing of Aerosols*, 27 GEOPHYSICAL RES.

aircraft over the Indian Ocean by Veerabhadran Ramanathan confirmed that aerosols from biomass and coal burning in South Asia were a major contributor to the radiation balance over a large part of the atmosphere.[158] In the decade that followed, the significance of black carbon aerosol in causing global warming was only reinforced such that, by 2010, one assessment placed it second only to CO_2 in its influence on global climate and more important than CO_2 in certain regions of the world in terms of its contribution to current warming.[159]

At the same time as the significance of black carbon was revealed, other workers discovered the contribution to climate change of tropospheric ozone, another local air pollutant. Tropospheric ozone is formed when volatile organic carbon compounds such as methane and carbon monoxide react with nitrogen oxides in the presence of sunlight and heat. In high concentrations tropospheric ozone is a serious public health concern. As such, it has long been regulated as a local air pollutant.[160] In the decade after 2000, scientists realized that it also was a significant contributor to global radiative forcing.[161] The fact that ground-level ozone was important to climate also tended to magnify the importance of its precursors, especially methane. Thus, acting to reduce methane and other ozone precursors would reduce the direct radiative forcing from both methane—over a period of decades—and from ozone—over a period of days to weeks—all while improving public health.[162]

LETTERS 217 (2000); James Hansen et al., *Global Warming in the Twenty-First Century: An Alternative Scenario*, 97 PROC. NAT'L ACAD. SCI. 9875 (2000).

158. Bond et al., *supra* note 79, at 5384–88; S.K. Satheesh & V. Ramanathan, *Large Differences in Tropical Aerosol Forcing at the Top of the Atmosphere and Earth's Surface*, NATURE, May 2000, at 60.

159. Ramanathan & Xu, *supra* note 37, at 8056.

160. Kristin Rypdal et al., *Tropospheric Ozone and Aerosols in Climate Agreements; Scientific and Political Challenges*, 8 ENVTL. SCI. & POL'Y 29, 36 (2005) (describing the history of tropospheric ozone regulation).

161. *Id.*; Forster et al., *supra* note 20; *see also supra* Table 1. It is important to distinguish between tropospheric (or ground-level ozone) and ozone that occurs high in the stratosphere. Stratospheric ozone actually cools the lower atmosphere because it blocks high energy, UV solar radiation. By contrast, ground-level ozone acts to scatter light at ground level and so warms the lower atmosphere. *See What is Ozone?*, EPA, https://www3.epa.gov/apti/ozonehealth/what.html [https://perma.cc/F8T6-7XTF] (last updated Feb. 22, 2016).

162. Ramanathan & Xu, *supra* note 37, at 8058; Mario Molina et al., *Reducing Abrupt Climate Change Risk Using the Montreal Protocol and Other Regulatory Actions to Complement Cuts in CO_2 Emissions*, 106 PROC. NAT'L ACAD. SCI. 20,616 (2009).

Finally, another group of scientists realized that a new SLCP was increasing in importance because of its use as a substitute for compounds, especially chlorofluorocarbons, phased out under the Montreal Protocol. Hydrofluorocarbons ("HFCs"), replacement compounds for chlorofluorocarbons that have no impact on ozone but have a strong influence on climate, were set to have a big impact by mid-century if replacements were not found.[163] Estimates indicated that, by 2050, HFC emissions alone would contribute from 0.25 to 0.40 Wm^{-2} to global radiative forcing—equivalent to approximately a decade of current CO_2 emissions or one quarter of the warming caused by CO_2 from the industrial revolution to the present.[164]

Thus while the science constraining the connection between CO_2 and global warming has remained relatively stable from the first intergovernmental assessments to the present, scientific understanding of short-term climate pollutants has advanced rapidly. The last two decades, since the legal framework governing the Climate Regime was agreed upon and during which it has ossified, have seen dramatic improvements in scientific understanding of a variety of pollutants that cause climate change.[165] Black carbon and tropospheric ozone have emerged as important influences on climate, second only to carbon dioxide in importance. At the same time, methane and HFCs impacts have grown in importance even as these gases remain an, at best, secondary component of ongoing multilateral negotiations. Before turning to a proposal to place these gases at the center of the Climate Regime by broadening the legal framework at its heart, it is worth briefly examining what the prospects for international agreement and progress might be for these four pollutants.

IV. THE POLITICAL ECONOMY OF SHORT-LIVED CLIMATE POLLUTANTS

A shift in focus from the Kyoto Protocol six-gas framework to a focused effort aimed at agreements to reduce emissions of short-lived climate pollutants, were it to occur, is likely to be a more productive path forward for the international Climate Regime. An

163. Guus J. M. Velders et al., *The Large Contribution of Projected HFC Emissions to Future Climate Forcing*, 106 PROC. NAT'L ACAD. SCI. 10,949 (2009).

164. *Id.*

165. *See generally* CLIMATE CHANGE 2007, *supra* note 20 (discussing the different kinds of gases that impact climate change).

important precondition for such a move is supportive domestic politics within nation states for SLCP mitigation. Agreements to limit greenhouse gases are not self-enforcing and so implementation depends to a significant degree on enactment of domestic laws and their enforcement. In this Part, I argue that such a supportive, or at least more supportive, environment does in fact exist, for at least three reasons. First, developed and developing countries have much more experience in abatement of SLCPs than for carbon dioxide. Abatement capacity and abatement costs are well understood, thus reducing uncertainty in negotiations. In addition, these reductions have been accomplished without creating politically unacceptable impacts to economic growth. Second, the benefits of reducing short-lived climate pollutants are very often local as well as global. Thus, countries taking action to cut emissions will enjoy a far greater share of the benefits than they would for cuts in CO_2. This shifts the balance of costs and benefits in a favorable direction for countries considering making commitments under international law. Third, the local benefits accrue at the same time as the local costs are borne while climate benefits accrue on a shorter timescale than for CO_2. This avoids the political challenge of paying today for benefits entirely received in the far distant future, as is the case for reducing CO_2 emissions. Instead, costs incurred today produce a mixture of immediate air pollution benefits and relatively short-term climate benefits. In other words, political capital invested in SLCP mitigation is likely to pay dividends on a relevant timescale to actors that support it. Avoided near-term damages—especially reduced morbidity and mortality—help to offset reduction costs and improve political acceptance of commitments.

Nevertheless, domestic political obstacles to implementing these policies remain and are significant, particularly in low-income countries. Sooty, unhealthy air is a familiar feature of the developing world's cities. Theory and practice suggest that international agreement and financial assistance from international bodies can be helpful in overcoming these implementation barriers. A series of known regulatory and technological steps can be taken to reduce emissions of SLCPs. These changes have and will produce opposition from constituencies who will pay the costs of regulation. On the other hand, as addressed in Part V, these costs can be reduced by the Climate Regime. This contrasts with the magnitude of political obstacles that stand in the way of reducing energy-related CO_2 emissions. Overall, the balance of costs and benefits for implementation of cuts in SLCPs, while perhaps not tilted strongly enough to cause these cuts to occur absent cooperative international outcomes, is more likely to be susceptible to the relatively weak influence that international climate agreements can bring to bear. And, as Part V will address, the influence and resources of the Climate Regime can help to overwhelm local constituencies opposed to cuts in SLCP emissions.

A. Technologies and Abatement Costs Are Known

One major challenge for crafting both domestic and international climate policy is that there is tremendous uncertainty about how to produce economic growth without growth in fossil fuel energy sources. Europe and the United States became wealthy by exploiting domestic and ultimately international stocks of fossil fuels to increase the productivity of their economies. Developing countries rightly see access to low-cost, reliable energy services as a necessary component of any development agenda. Yet, there is no real-world example of a truly low-carbon developed economy. When a developed country such as the United States asks that a developing country such as China or India limit its carbon emissions, this request is viewed with tremendous skepticism.[166] Developing countries look to the developed world's behavior over the past 150 years and reasonably conclude that the prudent strategy is to do what rich countries have done, not what they say, with respect to energy and CO_2 emissions.[167]

This "do as I say, not as I do" negotiating dynamic need not arise in the context of short-lived climate pollutants because the first and most cost-effective steps to limit emissions of these pollutants have already been taken in many developed countries that still rely

166. *See* Coral Davenport, *Deal on Carbon Emissions by Obama and Xi Jinping Raises Hopes for Upcoming Paris Climate Talks*, N.Y. TIMES (Nov. 12, 2014), http://www.nytimes.com/2014/11/13/world/asia/deal-on-carbon-emissions-by-obama-and-xi-jinping-raises-hopes-for-upcoming-paris-climate-talks.html?_r=0 [https://perma.cc/WDJ5-36EG] ("Many other governments also refused to cut emissions, arguing that if the world's top two polluters [China and the United States] were not acting, they shouldn't have to either.")

167. *See, e.g.*, U.N. FRAMEWORK ON CLIMATE CHANGE, CLIMATE CHANGE: IMPACT, VULNERABILITIES, AND ADAPTATION IN DEVELOPING COUNTRIES 30 (2007) ("The effectiveness of a practice tends to depend on location and socio-economic situation, but that does not prevent practices from being shared, replicated and improved.").

heavily on fossil fuels for energy.[168] Black carbon emissions occur due to combustion of coal, diesel fuel, and biofuel, and biomass burning. The first two categories of emissions have been the subject of emission controls of increasing stringency in the United States and EU since the 1970s.[169] The result is that today's coal combustion at power plants and gasoline and diesel combustion in automobile engines emit far lower levels of particulate matter, a significant percentage of which is black carbon, than they would without pollution controls.[170] As a result of increased utilization of various types of particulate traps and scrubbers on power plants and engines, black carbon emissions from developed country use of fossil fuels have fallen significantly,[171] despite large increases in fuel consumption.[172] In other words, countries need not choose between reducing emissions of this SLCP and abundant use of fossil fuels.

Just as for black carbon, there is a wealth of experience acquired in reduction of methane emissions in developed countries over the past several decades.[173] Methane emissions, in addition to causing

168. *See* John M. Broder, *U.S. Pushes to Cut Emissions of Some Pollutants That Hasten Climate Change*, N.Y. TIMES (Feb. 15, 2012), http://www.nytimes.com/2012/02/16/science/earth/us-pushes-to-cut-emissions-that-speed-climate-change.html [https://perma.cc/E4BB-YJP9].

169. Black carbon is the most strongly light-absorbing component of particulate matter. In the United States, emissions of black carbon have been reduced via particulate controls on large stationary sources like coal-fired power plants and via catalytic converters and particulate traps on mobile sources as well as through a variety of programs implemented via State Implementation Plans under the Clean Air Act. Similar programs have accomplished similar outcomes in the EU. *See generally Black Carbon: Basic Information*, EPA, http://www.epa.gov/blackcarbon/basic.html [https://perma.cc/GQJ8-PVCE] (last visited Feb. 4, 2016); *see also Emissions of Primary PM2.5 and PM10 Particulate Matter*, EUR. ENV'T AGENCY, http://www.eea.europa.eu/data-and-maps/indicators/emissions-of-primary-particles-and-5/assessment-2 [https://perma.cc/KB5N-ZSD8] (last modified Sept. 4, 2015) (describing progress in the EU); *National Trends in Particulate Matter Levels*, EPA, http://www.epa.gov/airtrends/pm.html#pmnat [https://perma.cc/6TXQ-J8CR] (last visited Feb. 4, 2016) (describing progress on reducing particulate matter emissions in the United States).

170. *Black Carbon: Basic Information*, *supra* note 169.

171. *Mitigating Black Carbon*, EPA, https://www3.epa.gov/blackcarbon/mitigation.html [https://perma.cc/VAZ7-RBKB] (last updated Feb. 23, 2016) (describing the decrease of black carbon emissions due to the use of control technologies and strategies).

172. BP, BP STATISTICAL REVIEW OF WORLD ENERGY 9, 23 (2015), https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf [https://perma.cc/5J69-7UFU] (listing the growth of oil and gas consumption in 2014).

173. *See, e.g.*, *Fact Sheet: EPA's Strategy for Reducing Methane and Ozone-Forming Pollution from the Oil and Natural Gas Industry*, EPA (Jan. 14, 2015), https://yosemite.epa.gov/opa/admpress.nsf/0/BA7961BF631C87BF85257DCD00526FF7 [https://perma.cc/QL4U-2PQK] (noting methane emissions had decreased sixteen percent since 1990).

climate change, are a potential safety hazard, are important ozone precursors, and often co-occur with emissions of other hazardous volatile organic carbon compounds.[174] Major sources of methane include oil and gas operations, landfills, sewage treatment plants, rice farming, livestock operations, and coal mining.[175] Over the past several decades, in order to abate local air and water pollution caused by co-emitted volatile compounds, many of these facilities have shifted towards practices that dramatically lower their methane emissions.[176] In particular, where methane emissions are concentrated—and so are more of an explosion risk, air quality risk, and are easier to control than diffuse sources—significant reductions have occurred in developed countries.[177] Techniques for reducing emissions from landfills, the third largest source after agriculture and oil and gas extraction and processing, have been successfully implemented in the United States and the EU.[178] Using relatively inexpensive controls, such as lining landfills and installing systems of pipes and wells to vent and flare gases produced during anaerobic decomposition of organic material, significant reductions in emissions have been achieved at low cost.[179] Costs are further reduced by the fact that emissions of methane from significant sources such as landfills can often be processed for sale as natural gas.[180] These controls have led to a decline by almost one-third in U.S. landfill gas emissions over the

174. Ramanathan & Xu, *supra* note 37, at 8058.

175. *Overview of Greenhouse Gases: Methane Emissions*, EPA, https://www3.epa.gov/climatechange/ghgemissions/gases/ch4.html [https://perma.cc/3EGF-WCCY] (last visited Apr. 15, 2016) (describing the situations and substances that emit methane).

176. *See, e.g.*, *id.* (listing the methods to reduce methane).

177. *See, e.g.*, Suzanne Goldenberg, *US and Canada Continue Climate Alliance with Move to Curb Methane Emissions*, GUARDIAN (Apr. 6, 2016), http://www.theguardian.com/environment/2016/apr/06/us-canada-obama-trudeau-climate-change-methane-emissions [https://perma.cc/5V9N-CESC] (reporting that Canada committed to cutting down methane emissions by over forty-five percent late last year).

178. *See* Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills, 61 Fed. Reg. 9905 (1996) (codified at 40 C.F.R. pts. 51, 52 & 60; Council Directive 1999/31, 1999 O.J. (L 182) 1 (EC).

179. *See, e.g.*, John Schwartz, *Study Finds Low Cost in Reducing Methane Emissions*, N.Y. TIMES (Apr. 21, 2015), http://www.nytimes.com/2015/04/22/world/ americas/study-finds-low-cost-in-reducing-methane-emissions.html [https://perma.cc/6ZLW-WUD7] (describing low-cost methane emissions as feasible).

180. As of July 2013, 621 out of 1071 (58%) of the potential landfill methane capture projects in the United States utilized the captured methane rather than flaring it. *See Landfill Methane Outreach Program, Energy Projects and Candidate Landfills*, EPA, http://www.epa.gov/outreach/lmop/projects-candidates/index.html [https://perma.cc/J6MH-KL2G] (last visited Feb. 4, 2016).

past two decades, even as total disposal rates have increased.[181] Similar options are available and increasingly utilized for sewage treatment, coal mines, and oil and gas operations.[182] Reductions of emissions have been accomplished despite large increases in all of these activities.[183]

Tropospheric ozone, also called ground-level ozone, has likewise been a target of air quality regulations since their advent in the United States and EU. Regulations in these developed countries have successfully controlled many sources of ground-level ozone even while growth in the regulated sectors has continued.[184] Tropospheric ozone, because it is the product of complex chemical reactions that occur in the presence of sunlight, requires regulators to cut emissions of reactants or so-called precursor compounds. The major precursor compounds of ground-level ozone are volatile organic carbon compounds ("VOCs") including but not limited to methane, carbon monoxide, and nitrogen oxides ("NOx"). Control of these compounds serves to both reduce background levels and to avoid local spikes in ozone levels that lead to adverse health consequences.[185] As with black carbon and methane, there is enormous technological and regulatory experience developed over several decades in developed countries on techniques for reducing or eliminating ozone precursor emissions.[186] While some ozone precursor emissions, especially of NOx from fossil fuel combustion, are very difficult to eliminate entirely, significant

181. EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2011, at 8-2 (2013), http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf [https://perma.cc/7KGG-KV83].

182. ICF INT'L, ECONOMIC ANALYSIS OF METHANE EMISSION REDUCTION OPPORTUNITIES IN THE U.S. ONSHORE OIL AND NATURAL GAS INDUSTRIES 1-2 (2014), https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf [https://perma.cc/42L2-TRD7] (depicting a graph of inexpensive methods to reduce the emission of methane from many industries, including the oil and gas industry).

183. *Id.* at 1-1, 2-1 (projecting methane emission growth from oil and gas to be 4.5%, while also noting certain companies in the oil and gas markets that have made significant voluntary reductions in their methane emissions).

184. *See* Brad Knickerbocker, S*mog Check: EPA Proposes Tougher Regs for Ground-level Ozone Pollution*, CHRIS. SCI. MON. (Nov. 26, 2014), http://www.csmonitor.com/Environment/2014/1126/Smog-check-EPA-proposes-tougher-regs-for-ground-level-ozone-pollution-video [https://perma.cc/CT8L-8349].

185. Arlene M. Fiore et al., *Linking Ozone Pollution and Climate Change: The Case for Controlling Methane*, 29 GEOPHYSICAL RES. LETTERS 1919 (2002).

186. *See, e.g.*, *Nitrogen Oxides (NOx) Control Regulations*, EPA, https://www3.epa.gov/region1/airquality/nox.html [https://perma.cc/E9B9-J3HE] (last visited Apr. 15, 2016) (detailing several NOx programs in place in New England area of the United States).

reductions are possible.[187] U.S. ozone concentrations have fallen by twenty-five percent over three decades even as underlying economic activity, fossil fuel combustion, and background ozone levels have increased substantially.[188] Strengthening ozone requirements is not without controversy.[189] Again, when it comes to tropospheric ozone, there is deep experience in regulating that could be used to inform both developed and developing country negotiators. Furthermore, this experience in reducing emissions has occurred in a broader context of economic growth predicated on abundant energy supplies.

One pollutant for which such experience does not exist to the same degree as for other SLCPs is hydrofluorocarbon emissions. HFCs are new compounds, having only been widely produced since CFCs and hydrochlorofluorocarbons ("HCFCs") were regulated and ultimately phased out under the Montreal Protocol.[190] Also, HFCs are unlike other short-lived climate pollutants in that they do not cause localized harms. They are, however, similar to the other SLCPs in that they cause disproportionate short-term harm to the climate and are projected to have large impacts on the climate of the next several decades.[191] Finally, rapid experience is currently being gained in reducing HFC emissions in developed countries.[192] Also, substantial work has been done to assess the possibility of reducing their use by both Montreal Protocol and UNFCCC

187. *See, e.g.*, *id.* (noting NOx emissions from utilities in New England have decreased fifty-seven percent from 1990 to 1996 as a result of an emission control program).

188. The average recorded maximum eight-hour ground-level ozone concentration in the United States fell from 0.101 to 0.076 parts per million in the period from 1980 to 2012. *National Trends in Ozone Levels: 1990–2012*, EPA, http://www.epa.gov/ airtrends/ozone.html [https://perma.cc/7QDX-KA4F] (last visited Feb. 19, 2016).

189. For example, the most recent attempt on the part of EPA to lower ambient air quality standards for ozone was rejected by the Office of Management and Budget. *See* Letter from Cass Sunstein, Adm'r, Office of Info. & Reg. Affairs, to Lisa Jackson, Adm'r, EPA (Sept. 2, 2011), http://www.whitehouse.gov/sites/default/files/ozone_national_ambient_air_quality_standards_letter.pdf [https://perma.cc/MA3G-VSZT].

190. Velders et al., *supra* note 63, at 4814.

191. Guus J.M. Velders et al., *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, 335 SCIENCE 922, 922 (2012) (describing the future potential of HFCs if their use continues to increase).

192. Notably, HFC-134 is being eliminated from use in mobile air conditioners in the EU under the Mobile Air Conditioning Directive. While this change is not without controversy, most automobile manufacturers have accepted and are implementing cost-effective compliance strategies. *See* Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 Relating to Emissions from Air-Conditioning Systems in Motor Vehicles and Amending Council Directive 70/156/EC, 2006 O.J. (L 161) 12.

technical bodies.[193] Further work is under way this year[194] in support of proposals to amend the Montreal Protocol to place limits on these compounds.

Thus for all of the most important SLCPs, there exists significant technological, regulatory, and economic information about steps that can be taken today to significantly reduce emissions far below current levels without causing major disruptions to economic activity. This is a stark contrast with energy-related CO_2 emissions where options to reduce emissions, if known, are substantially more expensive than their more polluting alternatives. Examples exist in many countries of policies that can lead to substantial reductions in SLCPs. These policies have been implemented without noticeable decrease in either wealth or growth rates.

B. Reductions Produce both Local and Global Benefits

One of the greatest challenges with securing agreement to reduce energy-related carbon dioxide emissions is that the costs of reductions are borne by the country that makes them but benefits are of necessity shared by all nations. The benefit of reductions in greenhouse gas emissions is a non-rivalrous and non-excludable good.[195] It is non-rivalrous in that one nation's benefiting from a stable and equable climate does not reduce the extent of other countries' benefits. It is non-excludable in that no nation, when it incurs a cost to reduce its greenhouse gas emissions, can prevent another from enjoying the climate benefits thereby created. As has been frequently noted,[196] this creates a serious incentive problem for nations attempting to negotiate agreements to reduce greenhouse gases. Costs are borne entirely by the country that reduces emissions while benefits are enjoyed by all nations. In this situation, the temptation to free-ride on other's efforts is strong

193. *See* IPCC & TECH. & ECON. ASSESSMENT PANEL, SAFEGUARDING THE OZONE LAYER AND THE GLOBAL CLIMATE SYSTEM: ISSUES RELATED TO HYDROFLUOROCARBONS AND PERFLUOROCARBONS 12 (2005), http://www.ipcc.ch/pdf/special-reports/sroc/ sroc_full.pdf [https://perma.cc/WE4X-THY9].

194. U.N. Environment Programme, *Response to the Report by the Technology and Economic Assessment Panel on Information on Alternatives to Ozone-Depleting Substances (Decision XXIV/7, Paragraph 1)*, U.N. Doc. UNEP/OzL.Pro.25/9, Dec. XXV/5 (Nov. 13, 2013).

195. Pollution control and prevention is a public good as defined by the traditional meanings of non-rivalrous and non-excludable goods. *See, e.g.*, Tyler Cowen, *Public Goods Definitions and Their Institutional Context: A Critique of Public Goods Theory*, 43 REV. SOC. ECON. 53, 54 (1985) (critiquing but defining non-excludable and non-rivalrous goods).

196. SCOTT BARRETT, ENVIRONMENT AND STATECRAFT: THE STRATEGY OF ENVIRONMENTAL TREATY MAKING (2003).

while the return on investment for one's own efforts is, of necessity, small. This is one of the key aspects of what makes climate change a "super wicked" problem.[197]

Some have even argued that the countries that must cut these emissions to avoid climate change might even enjoy some benefits under modest warming scenarios.[198] This points to a related challenge presented by the distribution of payoffs for cuts in energy-related CO_2 emissions—there is a relatively small set of nations that must cut emissions and so bear costs, but the benefits will be shared by a large set of countries that do not contribute to the problem and so need not pay a cost to resolve it.

Both from a free-rider and a participation perspective, SLCPs present a different set of incentives because cuts in these emissions produce substantial local benefits. Black carbon is one of the major components of particulate matter. Cuts in black carbon emissions produce the side effect of cuts in airborne particulates that are a leading cause of asthma and premature death in many countries.[199] Cuts in ozone reduce lung cancer rates and respiratory distress amongst vulnerable populations.[200] In addition, significant benefits accrue to agriculture and forestry from ground-level ozone reductions.[201] Reduction in methane emissions will lead to a fall in many co-emitted species of volatile organic carbon as well as decreased background concentrations of tropospheric ozone.[202] Indeed, past efforts to cut SLCPs and knowledge of SLCP

197. Lazarus, *supra* note 8, at 1183.

198. Posner & Sunstein, *supra* note 5, at 1568.

199. *See* EARTHJUSTICE, REDUCING BLACK CARBON EMISSIONS 2 http://earthjustice.org/sites/default/files/library/factsheets/ej_blackcarbon_factsheet.pdf [https://perma.cc/4CKU-2JE8].

200. *See* WORLD HEALTH ORG., THE WORLD HEALTH REPORT 2002: REDUCING RISKS, PROMOTING HEALTHY LIFE 68–69 (2002), http://www.who.int/whr/2002/en/whr02_en.pdf [https://perma.cc/T8WP-J7F7]; *Health Effects of Ozone in the General Population*, EPA, https://www3.epa.gov/apti/ozonehealth/population.html [https://perma.cc/U65V-H9PA] (last updated Feb. 23, 2016) (describing the negative impacts ground-level ozone can have on human health).

201. *See, e.g.*, *Effects of Ozone Air Pollution on Plants*, USDA, http://www.ars.usda.gov/Main/docs.htm?docid=12462 [https://perma.cc/9JFA-DQ6R] (last modified Mar. 17, 2012) (detailing the negative impact ozone can have on agriculture and the decreased yields that can result).

202. WHITE HOUSE, CLIMATE ACTION PLAN: STRATEGY TO REDUCE METHANE EMISSIONS 1–2 (2014), https://www.whitehouse.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf [https://perma.cc/7M9Q-V6W8] ("Methane is a contributor to ground level ozone, so cutting methane emissions reduces smog . . . . Moreover, methane is often co-emitted with volatile organic compounds, some of which are hazardous air pollutants, and many measures can cost-effectively reduce both pollutants.").

pollution reduction options are due to these public health benefits, not climate change.

Increasing the localized, hence excludable, benefits of any agreement is likely to increase participation rates or to reduce the side-payments that must be made in order to induce participation. Furthermore, it will tend to create important local constituencies that support implementation of the policy because they benefit disproportionately from these local benefits. Thus we might expect that short-lived climate pollutant agreements would be easier to negotiate and implement than agreements within the existing six-gas 100-year GWP framework. In contrast to the need to generate political support for bearing real local and present day costs to provide benefits to mostly people living elsewhere—assuming these others cooperate and do not renege on their commitments—parties can be sure that cuts in SLCPs will produce local environmental benefits. When placed into an international framework that accelerates these cuts, they may also insure that near-term climate change is less intense than would otherwise be the case.

C. Timing of Costs and Benefits of SLCP Reductions

In addition to the location of benefits produced by cuts in SLCPs, the timing of benefits will likely serve to increase the odds of meaningful international agreement, relative to cuts in energy-related CO_2. This is for two reasons. First, local air pollution benefits are produced at the same time as abatement costs are incurred. Second, climate benefits occur more quickly than is the case for energy-related CO_2. These factors combine to improve the political economy of SLCP abatement because costs and benefits are not separated in time to the degree that they are for CO_2.

Just as cuts in SLCPs produce air pollution benefits in the same jurisdiction as they occur, they also produce local air pollution benefits at the same time as the cuts are made. Cuts in black carbon, tropospheric ozone, and methane produce immediate air quality benefits. Over slightly longer timescales, cuts in methane emissions will also produce noticeable air quality impacts by lowering background concentrations of tropospheric ozone. This is in stark contrast to cuts in energy-related CO_2 emissions that must be motivated primarily by concerns about impacts of climate change on future generations.

The SLCPs are all extremely potent greenhouse gases, when compared to CO_2. This means that on a per ton basis, they cause much greater warming than does CO_2, and because of their shorter atmospheric lifetimes, the difference is greater the shorter the time span of interest.[203] For some SLCPs, like black carbon and tropospheric ozone, climate benefits accrue on the timescale of days to weeks.[204] For others, like methane and HFCs, reductions would produce benefits on the timescale of a decade.[205] Benefits appear quickly both because of the strong radiative forcing of SLCPs and also because they are removed from the atmosphere relatively quickly. This means that once emissions fall, concentrations in the atmosphere will begin to adjust to lower levels relatively quickly. By contrast, even if we stopped emitting CO_2 entirely, the CO_2 we have already added to the atmosphere will remain there for centuries.[206] Under such a scenario, there would not be a noticeable reduction in either atmospheric concentration or in global warming for a similar time span.

Thus, unless one discounts future benefits only slightly or not at all, agreements to cut SLCPs are more likely to produce net benefits than agreements to cut energy-related CO_2. Domestic politicians tend to have very high discount rates because of election cycles, thus SLCPs reductions may appeal more strongly to them. In the international Climate Regime, given that parties appear to lack sufficient trust for meaningful agreement to cut CO_2 emissions, this contraction of time horizons may help to facilitate greater and more effective cooperation.

D. Domestic Obstacles to Abatement

Increasing the stringency of domestic air pollution law—the basic mechanism for implementing cuts in short-lived climate pollutants—is rarely if ever straightforward or easy. Tough regulations always create resistance from stakeholders in the political process who benefit from the status quo and will bear increased costs under a more environmentally protective regime. These stakeholders may be inside or outside of government.[207]

203. *See* CLIMATE CHANGE 2007, *supra* note 20, at 77.

204. *See id.* at 23–24.

205. *See id.*

206. *See id.* at 77.

207. An important current example of this process of stakeholder resistance for an SLCP is the state-owned oil company resistance to implementation of low-sulfur gasoline standards

Nevertheless, at least some evidence suggests that there is a predictable path towards greater local air pollution regulation as wealth increases.[208]

Inclusion of SLCPs within the Climate Regime via a revision to its legal framework has the potential to improve the domestic political economy of regulation for these pollutants in several ways. It would tend to push for inclusion of the climate benefits in cost-benefit calculations on whether and how stringently to regulate. Even in jurisdictions with vigorous support for climate change policy, regulation of SLCPs is not seen as related to local air pollution because of the limitations of the six-gas 100-year GWP legal framework. For example, California does not include its numerous actions to cut SLCPs in its assessment of its climate activities.[209]

Were nations engaged at the international level to cut SLCPs, national governments might be more willing to take action than they are today because they would face pressure to do so from both those focused on local air quality and those focused on climate change. Further, for governments interested in taking such action but wary of political fallout, collaboration in the international Climate Regime might provide convenient political cover for action.[210]

Finally, participation in SLCP agreements under the Climate Regime would likely come with significant benefits for developing countries. In particular, developed nations have committed to and are already contributing substantial sums towards international climate finance.[211] SLCP agreements with binding targets for reductions would provide a convenient destination for such international assistance as it is available. Thus to some degree, governments may be able to externalize some of the costs for cuts

in China. *See* Edward Wong, *As Pollution Worsens in China, Solutions Succumb to Infighting*, N.Y. TIMES (Mar. 21, 2013), http://www.nytimes.com/2013/03/22/world/asia/as-chinas-environmental-woes-worsen-infighting-emerges-as-biggest-obstacle.html [https://perma.cc/7E5M-WVQR].

208. *See* Gene M. Grossman & Alan B. Krueger, *Economic Growth and the Environment* 18–19 (Nat'l Bureau of Econ. Research, Working Paper No. 4634, 1994) (finding that environmental quality falls with economic growth up to about $8000 per capita income after which it increases for a broad set of measures).

209. *See* CAL. AIR RES. BD., CLIMATE CHANGE SCOPING PLAN: A FRAMEWORK FOR CHANGE (2008), http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf [https://perma.cc/CKK5-6BGG].

210. *See* KEOHANE, *supra* note 18.

211. *Pledge Tracker*, GREEN CLIMATE FUND, http://www.greenclimate.fund/contributions/pledge-tracker [https://perma.cc/8YPX-RRXK] (last visited June 5, 2016).

to SLCPs. Commitments of international assistance on SLCP agreements would also likely be more credible than for CO_2 because the costs would be smaller and the actions necessary to accomplish them better understood.[212]

Moreover, finance for SLCP-related activities may be more likely to be forthcoming from developed countries for some of the same reasons that doing the cuts in developing countries is more likely. It is quite possible that some developed countries would receive near-term air pollution benefits from reductions in developing-country air pollution. Japan might be happy to help its upwind neighbor China to reduce SLCPs if, as a side effect, it received a lower particulate and tropospheric ozone burden.[213]

Overall, it appears that agreements to cut short-lived climate pollutants have a superior chance of adoption than does an agreement to cut energy-related carbon dioxide emissions. A series of SLCP agreements would ask nations to take well-understood actions of known cost. They would produce both local as well as global benefits. These benefits would accrue either at the same time as costs are expended or shortly thereafter. And international engagement in the process of SLCP reductions potentially allows for increased domestic political pressure and international cost-sharing to further improve the cost-benefit calculus for parties to an agreement. Along all of these dimensions, SLCP agreements have a more favorable political economy than does an agreement to cut energy-related carbon dioxide emissions within the Climate Regime's current legal framework.

For all of these reasons, it is perhaps not surprising that the international community has embarked on several efforts to cut SLCP emissions. The earliest are proposals by Canada, Mexico, and the United States to freeze and then phase down emissions of HFCs using the Montreal Protocol.[214] This effort has gradually been gaining support from more parties to the Ozone Regime, and was given a major boost last year by an agreement between

212. *See supra* Section IV.A.

213. *See* Kate Galbraith, *Worries in the Path of China's Air*, N.Y. TIMES (Dec. 25, 2013), http://www.nytimes.com/2013/12/26/business/energy-environment/worries-in-the-path-of-chinas-air.html?_r=0 [https://perma.cc/5VNL-UN9L] (finding that air pollutants from China cause forty to sixty percent of the annual fine-particle pollution and ten to twenty percent of springtime ozone pollution in Japan).

214. *See Recent International Developments Under the Montreal Protocol*, EPA, https://www.epa.gov/ozone-layer-protection/recent-international-developments-under-montreal-protocol [https://perma.cc/JJ9R-J8AT] (last updated Mar. 21, 2016).

Presidents Obama and Xi to work together to negotiate within the Ozone Regime for cuts in HFC emissions.[215]

One effort, known as the Climate and Clean Air Coalition, currently involves thirty-six countries and has targeted voluntary reductions of all four of the SLCPs discussed in this Article.[216] Since its founding in 2012, the Climate and Clean Air Coalition has targeted eleven initiatives aimed at cutting SLCPs and has raised $50 million from member governments.[217]

The key question that these efforts raise both with respect to SLCP reductions and, more importantly, the broader strategy to cut greenhouse gas emissions, including CO_2, is whether smaller, fragmented efforts to cut emissions are more likely to be effective than efforts within the Climate Regime. The next Part argues that this fragmentation of effort may in fact be a mistake, and that nations most concerned with reducing GHG emissions should instead attempt to take the international climate institution they have—the UNFCCC—and use the SLCPs as a set of issues to modify, build, and strengthen the regime so that it may one day be up to the challenge of cooperation on energy-related CO_2 emissions.

V. SHORT-LIVED CLIMATE POLLUTANTS AS FIRST STEPS ON THE ROAD TO INTERNATIONAL COOPERATION ON GLOBAL WARMING

In this Part, I describe a new approach to near-term cuts in short-lived climate pollutants such as black carbon, methane, tropospheric ozone, and HFCs. First, I explain how this approach might fit within the existing Climate Regime. Next, I describe how such an approach would offer potential new opportunities within that framework. Then, I explain how multilateral deals to cut SLCPs are superior to plurilateral or bilateral agreements to reduce emissions of these pollutants along two dimensions. Successful

215. *See* Press Release, White House, Office of the Press Secretary, United States and China Agree to Work Together on Phase Down of HFCs (June 8, 2013), https://www.whitehouse.gov/the-press-office/2013/06/08/united-states-and-china-agree-work-together-phase-down-hfcs [https://perma.cc/8L9U-7CQL].

216. *See* CLIMATE & CLEAN AIR COAL., CLIMATE AND CLEAN AIR COALITION MARKS TWO YEARS OF RAPID GROWTH IN ACTION ON SHORT-LIVED CLIMATE POLLUTANTS (2014), http://www.unep.org/ccac/Portals/50162/docs/ccac/two_years_and_rapid_growth.pdf [https://perma.cc/24MJ-2PQ6].

217. *Initiatives*, CLIMATE & CLEAN AIR COALITION, http://www.ccacoalition.org/en/initiatives [https://perma.cc/MWW8-9ELH] (last visited Apr. 7, 2016) (listing the eleven initiatives being undertaken to reduce SLCPs).

multilateral agreements covering these four pollutants would improve outcomes for short-lived climate forcers relative to pluri- or bilateral approaches because of the legitimacy, capacity, and resources that the Climate Regime possesses. Also, a succession of agreements to reduce these pollutants would begin to create the sort of robust institutions, confidence, and process that will be necessary to craft much more difficult cooperation on deep cuts in energy-related CO_2 emissions.

Agreement to substantial cuts to energy-related carbon dioxide emissions, if it occurs, will require unprecedented levels of trust and cooperation on the part of large numbers of countries with diverse interests. Theory as well as experience from other regimes teaches that the development of cooperation is a dynamic process rather than a single outcome. Multilateral agreements to cut short-lived climate pollutants can serve as initial confidence building steps down a path toward more challenging agreements in ways that pluri- or bilateral commitments outside the Climate Regime cannot. This Part concludes on a cautionary note, with consideration of how and why a multilateral deal to cut short-lived climate pollutants might still fail to produce deepening of cooperation on energy-related carbon emissions.

A. A Multilateral Pathway for Short-Lived Greenhouse Pollutants

If, rather than being handled outside of the Climate Regime, SLCPs were to be brought within it, they would need to be fit into the recently concluded Paris Agreement.[218] The Paris Agreement will define the contours of the Climate Regime negotiations for at least the next decade.[219] For an agreement, let alone agreements, on short-lived climate pollutants to have any chance of getting on the agenda in the near term, they must fit into the broader Paris Agreement agenda that emerged from the most recent Conference of the Parties to the UNFCCC.[220] The Paris Agreement is an

218. *See generally* UNFCCC, *Paris Agreement*, *supra* note 72 (establishing a platform that will allow countries to work together to fight climate change, but without addressing SLCPs).

219. The initial compliance deadline for commitments made under the Paris Agreement is 2025, but activities to assess progress towards compliance will occur prior to this date. *Id.* at arts. 13, 14.

220. Although there have been promising non-UNFCCC negotiating initiatives on climate, none have managed to sustain themselves beyond early enthusiasm. Nations must already commit substantial diplomatic capacity to fully participating in the UNFCCC negotiations. Few appear willing or able to commit resources to additional climate related efforts. Also, all such initiatives have struggled to overcome the perception that they are

agreement by parties to the UNFCCC to, among other things,[221] make "nationally determined contributions" to reducing their GHG emissions[222] that are subject to expert technical review.[223] In addition, there are regularly scheduled "stock take" processes by which the efforts volunteered to date are compared with the stated goal of avoiding more than 2°C of warming.[224] The Nationally Determined Contributions volunteered as initial commitments under this new framework fall far short of what is needed to achieve the desired outcome.[225] Nationally Determined Contributions can be revised at any time without approval of other parties[226] and are not limited, either for developed or developing countries, to emissions targets expressed in terms of the six-gas 100-year GWP framework of the Kyoto Protocol and Copenhagen Accord[227] although this is expressed as an aspirational goal towards which developing countries should aim.[228] The stated intention is for these pledges to be updated on a five-year rolling basis.[229] Thus in 2020, parties would make pledges for 2030, and so on. Notably, a pledge by a party can be strengthened at any time without a vote of the parties to the Paris Agreement.[230]

The commitments submitted by parties represent a further step towards focusing on both the policy inputs to achieving emissions reductions as well as the outputs of those policies in terms of GHG emissions reductions. At Kyoto, commitments were expressed as a

simply an attempt by developed countries, especially the United States, to avoid serious commitments within the UNFCCC. *See, e.g.*, *Asia-Pacific Partnership and the Kyoto Protocols: In Conflict or Cooperation?*, SCIENCEDAILY (Jan. 11, 2010), http://www.sciencedaily.com/releases/2010/01/100111102529.htm [https://perma.cc/XGW8-YJ29].

221. Also included in the agreement are provisions covering climate finance, adaptation to climate change, compensation for loss and damage due to climate change, REDD, and transfer of climate friendly technologies. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at arts. 5, 7, 8, 9, 10.

222. *Id.* at art. 4.

223. *Id.* at art. 13, § 7(b).

224. *Id.* at arts. 2, 14.

225. *See* U.N. Framework Convention on Climate Change, *Synthesis Report on the Aggregate Effect of the Intended Nationally Determined Contributions*, at 10–11, U.N. Doc. FCCC/CP/2015/7 (Oct. 30, 2015) [hereinafter UNFCCC, *Synthesis Report*].

226. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4, § 11.

227. The Nationally Determined Contributions are described as measures aimed at reducing "greenhouse gas emissions" a term that is defined in article 1 of the UNFCCC as "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation." *Id.* at arts. 1, 4, § 1; UNFCCC, *supra* note 23, at art. 1, § 5.

228. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4, § 4.

229. *Id.* at art. 4, § 9.

230. *Id.* at art. 4, § 11.

single number in an annex to the agreement.[231] For the Copenhagen Accord, developed country parties made commitments in a standardized tabular form that allowed for a very modest explanation of how targets would be achieved.[232] By contrast, for the Paris Agreement, Nationally Determined Contributions took the form of detailed explanations of policies and measures that together will serve to accomplish the quantitative reductions targets, if these are provided at all.[233] Most notable of all, all countries' commitments are made, irrespective of development status or past responsibility for greenhouse gas emissions, in the same form, but with allowances given for differentiation. This marks a break from prior precedents under the UNFCCC and was strongly opposed by most developing nations prior to the Paris COP.[234] In the end, these procedural and structural changes to the Climate Regime, much more than the unilateral pledges to limit emissions recorded in the Paris Agreement, which the COP has acknowledged are inadequate to solve the problem of global warming,[235] may lay the seeds for an effective agreement to reduce emissions of energy-related CO_2 emissions. The Paris Agreement's language on mitigation and verification is forthright in emphasizing that commitments need to be much more transparent than they have been in past agreements[236] and that there needs to be much more independent review of both the initial steps towards fulfilling commitments[237] and the ultimate delivery on those promises.[238]

The objective of all of these procedural innovations in the Paris Agreement is to spur additional actions beyond those already contained in the Nationally Determined Contributions with a view towards ensuring the highest possible mitigation efforts by all parties. The so-called "ambition gap" is the gap between what

231. *See* Kyoto Protocol, *supra* note 24, at annex B.

232. *See* UNFCCC, *Copenhagen Accord*, *supra* note 101, at app. II.

233. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at paras. 12–21.

234. *See* Matthias Williams, *India Will Reject Greenhouse Gas Emission Targets*, REUTERS (June 30, 2009), http://www.reuters.com/article/2009/06/30/us-india-climate-idUSTRE55T65N20090630 [https://perma.cc/U964-MCSD].

235. UNFCCC, *Synthesis Report*, *supra* note 225, at 45 ("Thus, it can be concluded that greater reductions in the aggregate global emissions than those presented in the INDCs will be required for the period after 2025 and 2030 to hold the temperature rise below 2°C above pre-industrial levels.").

236. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4, § 8.

237. *Id.* at art. 13, §§ 5, 7, 11–12.

238. *Id.* at art. 15.

parties are prepared to commit to so far and the level of emissions reductions necessary to have a chance of avoiding a 1.5 to 2°C increase in global temperature.[239] How might parties increase reductions in ways that both drive reductions and build the trust and confidence, both in negotiating partners and in the Climate Regime itself, that will ultimately be necessary to facilitate the needed cuts in energy-related carbon dioxide emissions? One approach is by negotiating deep cuts in short-lived climate forcers that are independent of or supplementary to that framework.

There are two ways that such a process might unfold. One, proposed by the European Union, Japan, and Australia in the lead-up to the Doha Conference of the Parties in late 2012, would be to create a mechanism by which the UNFCCC can recognize international initiatives agreed to outside its auspices as contributions towards closing the ambition gap.[240] Such a process would greatly simplify negotiation of new agreements between willing partners by reducing the number and diversity of interests that must be aligned in order to achieve agreement. For example, it might be far easier to craft an agreement by which the EU, the United States, and China would commit to and collaborate on further cuts in black carbon emissions than to get a fully multilateral consensus based agreement on similar issues.[241]

While such flexibility would no doubt simplify the negotiation process, it is not clear that key stakeholders within the UNFCCC, most notably China and India, are open to concluding deals to limit emissions outside of the Climate Regime. Both nations have

239. *Id.* at arts. 2, 4, § 1.

240. *See, e.g.*, AUSTRALIA, SUBMISSION UNDER THE DURBAN PLATFORM FOR ENHANCED ACTION, NOVEMBER 2012: RESPONSE TO THE JOINT MESSAGE FROM THE CO-CHAIRS OF THE ADP DATED 24 SEPTEMBER 2012 (2012), http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_australia_workstream1and2_13112012.pdf [https://perma.cc/WF6Z-D9UT]; EUROPEAN UNION, RESPONSE TO JOINT MESSAGE: WORKSTREAM ON ENHANCING PRE 2020 MITIGATION AMBITION, http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_eu_workstream2_17102012.pdf [https://perma.cc/N6EY-F8YX]; JAPAN, RESPONSE TO THE JOINT MESSAGE FROM THE CO-CHAIRS OF THE AD HOC WORKING GROUP ON THE DURBAN PLATFORM FOR ENHANCED ACTION (ADP) (2012), http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_japan_workstream1and2_29102012.pdf [https://perma.cc/Y425-9ELG].

241. The UNFCCC has never adopted rules of procedures and so by default requires consensus of all 192 participating parties in order to act. *See* U.N. Framework Convention on Climate Change, *Report of the Conference of the Parties on its Thirteenth Session*, U.N. Doc. FCCC/CP/2007/6, at 7 (Mar. 14, 2008) (noting that no consensus regarding the draft rules of procedure had been reached, and continuing to apply the draft rules of procedure contained in document FCCC/CP/1996/2).

refused to join the Climate and Clean Air Coalition,[242] a group of countries whose goal is encouraging reductions of emissions of short-lived climate pollutants outside of the UNFCCC framework.[243] Further, both countries have, until recently, blocked proposals to limit emissions of HFCs within the Montreal Protocol framework, saying the appropriate location for such a discussion is within the UNFCCC.[244] Over the last two years, however, first China[245] and then India[246] have agreed to discuss HFC limits under a Montreal Protocol amendment. India is still resistant, particularly on the issue of compensation for developing country compliance costs, but has agreed to study the issue within the Montreal Protocol.[247] Since China and India produce a significant fraction of current and future emissions of HFCs, black carbon, tropospheric ozone, and methane, their resistance to efforts to reduce short-lived greenhouse pollutants outside of the Climate Regime is a significant problem for a plurilateral approach.

On the other hand, the more flexible process at the heart of the Paris Agreement, whereby commitments in the form of amendments to Nationally Determined Contributions can be incorporated by any party at any time, potentially allows for agreements made outside the UNFCCC process between a subset of parties to be brought inside it and subjected to its transparency and

242. *See Country Partners*, CLIMATE & CLEAN AIR COALITION, http://www.ccacoalition.org/en/partners [https://perma.cc/QR75-UZ9G] (last visited Feb. 1, 2016).

243. *See About*, CLIMATE & CLEAN AIR COALITION, http://www.ccacoalition.org/en/content/about-us [https://perma.cc/PP22-UUVL] (last visited Feb. 1, 2016).

244. Although the Montreal Protocol is intended to limit emissions of ozone depleting substances, arguments have been advanced by the United States, Mexico, and Canada, and endorsed by over 100 countries, that HFCs should be subject to its regulation because their emissions and the consequent impacts on climate are an unintended consequence of phase outs of chemicals under the treaty. *See, e.g.*, U.N. Environment Programme, *Proposed Amendment to the Montreal Protocol Submitted by European Union and Its Member States,* U.N. Doc. UNEP/OzL.Pro.WG.1/36/5 (Apr. 30, 2015) (requesting to amend Montreal Protocol to include phase-down of HFCs).

245. While China is open to discussing the issue of regulating HFCs within the Montreal Protocol, it opposed creation of a contact group to discuss such a proposal at the most recent Meeting of the Parties. *See Summary of the Twenty-Fifth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer*, EARTH NEGOTS. BULL., 28 October 2013, at 1, http://www.iisd.ca/download/pdf/enb19100e.pdf [https://perma.cc/9SW8-PRUH].

246. In November of 2015, India changed its position and supported the adoption of the most recent decision by the parties to the Montreal Protocol, known as the Dubai Pathway on Hydrofluorocarbons, for a process to negotiate an amendment to the Montreal Protocol aimed at limiting production and consumption of HFCs. *See* U.N. Environment Programme, *Dubai Pathway on Hydrofluorocarbons*, U.N. Doc. UNEP/OzL.Pro.27/13, Dec. XXVII/1 (Nov. 30, 2015).

247. *See id.*

expert review-based monitoring regime, once that is more fully developed.

Even if agreements to enhance mitigation must occur within the ongoing Paris Agreement process, with all of the complications and costs this implies, reaching such agreements need not be as difficult as securing commitments to limit energy-related carbon dioxide emissions would be. This is true for two reasons: first, at least as far as it concerns developing countries, control of short-lived climate pollutants is entirely consistent with development. Second, by committing to mitigate these emissions, developing countries are committing to implement well understood technologies that have been successfully deployed at known costs in the developed economies.

While carbon dioxide emissions are, as of yet, strongly correlated with development,[248] emissions of the short-lived climate pollutants are either uncorrelated or are anti-correlated with development.[249] As countries grow richer, they almost always address emissions of the short-lived climate pollutants in order to improve local air quality.[250] Controlling these emissions is actually part of the normal development pathway for many countries.[251] Thus an agreement to control these emissions amounts to accelerating and prioritizing something that the countries involved want to do and likely would do eventually on their own. An international agreement to limit SLCPs amounts to a cooperative agreement to

248. Luis Costa, Diego Rybski & Jürgen P. Kropp, *A Human Development Framework for CO_2 Reductions*, PLOS ONE, Dec. 2011, at 1, 1–2, http://www.plosone.org/article/fetchObject.action?uri=info:doi/10.1371/journal.pone.0029262&representation=PDF [https://perma.cc/9FV8-D2S5].

249. While GDP has steadily increased since 1940 in the United States, the presence of SLCPs has not followed a similar trajectory. *Compare Particulate Matter*, EPA, http://www.epa.gov/airtrends/pm.html [https://perma.cc/QY2V-EWHQ] (last visited Feb. 1, 2016), *and Ozone*, EPA, http://www.epa.gov/airtrends/ozone.html [https://perma.cc/9DZ4-V4YK] (last visited Feb. 1, 2016), *with* OFFICE OF MGMT. & BUDGET, HISTORICAL TABLES § 10 tbl.10.1, https://www.whitehouse.gov/sites/default/files/omb/budget/fy2017/assets/hist.pdf [https://perma.cc/795T-2KP4].

250. Indeed, China is facing increasing domestic political pressure to address these pollutants because of severe local air pollution problems. *See* Edward Wong, *China Lets Media Report on Air Pollution Crisis*, N.Y. TIMES (Jan. 14, 2013), http://www.nytimes.com/2013/01/15/world/asia/china-allows-media-to-report-alarming-air-pollution-crisis.html [https://perma.cc/EBF3-MTU8].

251. INT'L BANK FOR RECONSTRUCTION & DEV., WORLD BANK, WORLD DEVELOPMENT REPORT 1992: DEVELOPMENT AND THE ENVIRONMENT 38–40 (1992) (containing an early statement of the Environmental Kuznets Curve hypothesis). *But see* David I. Stern, *The Rise and Fall of the Environmental Kuznets Curve*, 32 WORLD DEV. 1419 (2004) (arguing that the Environmental Kuznets Curve hypothesis is unsupported by empirical evidence).

accelerate reductions in these pollutants rather than a decision that would not have been taken without international action.

Phasing out the use of carbon dioxide producing energy technologies faces formidable technological and economic hurdles, especially for developing countries that may be more dependent on energy-intensive manufacturing for economic growth. These nations face significant challenges just meeting their growing needs for energy, let alone devising, testing, and deploying new methods for satisfying these demands.[252] At the same time, developed nations remain highly dependent on fossil fuels for energy production in the power sector, heavy industry, and in transport.[253] The EU and California have proposed ambitious goals involving a shift to low or zero carbon energy sources.[254] But none has yet actually made the transition to a low carbon economy. Partly as a result, the methods for doing so and the costs of achieving these objectives remain contested and uncertain.[255]

By contrast, numerous countries have implemented regulations that either directly or indirectly target the short-lived climate pollutants. As described in greater detail in Part IV, in the United States and EU, black carbon emissions have fallen due to regulation of particulate emissions from diesel engines.[256] In the

252. Richard L. Ottinger, *Energy and Environmental Challenges for Developed and Developing Countries*, 9 PACE ENVTL. L. REV. 55, 56 (1991) (discussing the issues developing nations face as energy demands increase).

253. *See Fossil Fuel Energy Consumption (% Total)*, WORLD BANK, http://data.worldbank.org /indicator/EG.USE.COMM.FO.ZS/countries/1W-XP?display=graph [https://perma.cc/ T2ZT-YQ72] (last visited Apr. 16, 2016) (displaying a graph showing that over eighty percent of energy consumption is from fossil fuels for middle income countries).

254. The EU has pledged to cut its greenhouse gas emission level to twenty percent below 1990 level by 2020 and eighty percent below 1990 level by 2050. *See Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*, COM (2011) 112 final (Mar. 8, 2011). California has as its stated aim to return to its 1990 emission level by 2020, a cut of about thirty percent, and to reduce emissions to eighty percent below 1990 level by 2050. *See* Cal. Exec. Order No. S-3-05 (June 5, 2005), https://www.gov.ca.gov/news.php?id=1861 [https://perma.cc/KN6U-2NX4]; *Climate Change Programs*, CAL. AIR RES. BD., http://www.arb.ca.gov/cc/cc.htm [https://perma.cc/9E5A-MJXF] (last updated Dec. 2, 2015).

255. There was enormous debate and disagreement regarding the likely costs of implementing the Kyoto Protocol in the United States, where compliance would have required substantial investments in zero- or low-emission energy technologies. *See* U.S. ENERGY INFO. ADMIN., IMPACTS OF THE KYOTO PROTOCOL ON U.S. ENERGY MARKETS AND ECONOMIC ACTIVITY 137–51 (1998), http://www.eia.gov/oiaf/kyoto/pdf/ sroiaf9803.pdf [https://perma.cc/K2HD-4UQP].

256. *See supra* note 169 and accompanying text.

EU, HFC emissions have been controlled since 2006.[257] In the United States, reduction of ozone precursors is an extensive and well-understood sub-discipline of air pollution regulation.[258] In the United States, methane emissions from large landfills have long been regulated as part of efforts to control air and water pollution impacts from these sites.[259] Thus there is experience in the development and deployment of technologies aimed at combating SLCPs that could be deployed in service of global cooperation to cut their emissions.

This past experience in cutting SLCP emissions fundamentally alters the dynamic in developing future cooperation on SLCP emissions. Presuming that some or all parties were to commit to reductions in SLCPs below current levels, a different allocation of burdens and risk emerges. For developing countries, committing to cuts amounts to committing to implement a known set of technologies and policies, potentially with appropriate adaptation to individual country contexts. For developed countries, committing to cuts amounts to continued efforts and innovation to reduce emissions of already regulated pollutants. This structure is fundamentally different than that for CO_2 cuts because it allocates technological and economic risks away from developing and towards the developed nations. That is, developing countries, in agreeing to cut SLCPs by some fraction, are agreeing to implement a set of strategies that are well tested in developed countries. By contrast, developed countries face the risk that further cuts in emissions will prove either technically or economically more

257. *See* Regulation (EC) No. 842/2006 of the European Parliament and of the Council of 17 May 2006 on Certain Fluorinated Greenhouse Gases, 2006 O.J. (L 161) 1; Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 Relating to Emissions From Air-Conditioning Systems in Motor Vehicles and Amending Council Directive 70/156/EEC, 2006 O.J. (L 161) 12.

258. Ozone was first regulated under the Clean Air Act in 1971. *See* National Primary and Secondary Ambient Air Quality Standards, 36 Fed. Reg. 8186 (Apr. 30, 1971). National Ambient Air Quality Standards for ozone were last updated in 2015. *See* National Ambient Air Quality Standards for Ozone, 80 Fed. Reg. 65,292 (Oct. 26, 2015).

259. Emissions of volatile organic carbon compounds from new and existing large municipal solid waste landfills are regulated under the New Source Performance Standards program of the Clean Air Act. Methane is not currently regulated but the technology used to capture non-methane volatile organic carbon compounds, flaring, also captures and destroys methane. *See* Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills, 61 Fed. Reg. 9905 (Mar. 12, 1996).

challenging than anticipated.[260] The reverse appears to be true for CO_2 because of the differences in economic growth rates between developed and developing countries and the continued connection between growth and energy consumption, especially in export-driven economies.[261] It is far easier to cut CO_2 emissions when total energy demand is flat or falling, as it has been recently in the United States,[262] than when it is growing at approximately ten percent per year, as it did for much of the last decade in China.[263]

B. New Options Within a Short-Lived Climate Pollutant Approach

Here, I briefly outline three possible advantages that a focus on SLCPs might bring to the implementation of the Paris Agreement. First, deals to cut SLCPs allow for simple targeted reductions, rather than necessitating complex emissions trading markets and regulatory regimes, because we have substantial evidence about how to reduce them. Second, new SLCP agreements within the Paris Agreement allow for new approaches to the issue of common but differentiated responsibilities. Third, SLCPs allow for a faster pace of the agreement cycle than do deals to deepen commitments on energy-related carbon dioxide emissions.

260. A similar geometry facilitated initial agreement on action to reduce ozone depleting substances under the Montreal Protocol. All parties to the Montreal Protocol agreed to fifty percent reductions. But because the United States, which was the leading advocate for the agreement, had already implemented a fifty percent reduction unilaterally, it faced much greater technological and economic risks than did Japan or the EU, which merely had to implement the policies already proven to work in the United States. *See* PARSON, *supra* note 84.

261. One piece of evidence for this connection is the Li Keqiang Index. The index uses measures of railway cargo (mostly coal), electricity consumption, and loans disbursed by banks to estimate economic growth and was considered a more reliable indicator than China's official statistics. *See Keqiang Ker-Ching: How China's Next Prime Minister Keeps Tabs on its Economy*, ECONOMIST (Dec. 9, 2010), http://www.economist.com/node/17681868?story_id=17681868 [https://perma.cc/DR3B-JFTN].

262. *See* U.S. ENERGY INFO. ADMIN., APRIL 2014 MONTHLY ENERGY REVIEW 7 (2014), http://www.eia.gov/totalenergy/data/monthly/archive/00351404.pdf [https://perma.cc/UA73-QZKM].

263. *See International Energy Statistics: Total Primary Energy Consumption, China*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=44&aid=2&cid=CH,&syid=2002&eyid=2012&unit=QBTU [https://perma.cc/Q7AS-2R8M] (showing that China's total primary energy consumption grew at an average annual rate of 9.38% between 2002 and 2012).

1. Emissions Trading Versus Targeted Reductions

The rationale for the inclusion of market-based approaches, including the accounting of emissions of different greenhouse gases via 100-year GWP, was cost reduction. Cuts in energy-related carbon dioxide emissions were likely to be expensive, particularly if they were forced upon nations and industries in a relatively inflexible fashion. Allowing substitution of other types of pollution cuts in lieu of changes to energy production was thought, and has turned out to be in practice, a cheaper means of reducing greenhouse gases.[264] In theory, a regulator with perfect information could simply specify the reduction measures that a firm or facility might take, thus achieving a market-like outcome.[265] The reality is that the informational demands of such an approach are enormous in the energy sector, thus making emissions pricing approaches relatively more attractive.[266] However, it is far less clear that similar arguments apply in the sectors most important to short-lived climate pollutant reductions. For example, mandating production of low-sulfur gasoline and diesel fuels in order to facilitate the effective use of three-way catalytic converters on mobile sources requires centralized standard setting rather than individualized interventions at polluting facilities.[267] Similarly, it is unclear that markets are required to drive highly cost-effective reductions in methane emissions at large municipal landfills or sewage treatment facilities where evidence suggests that standardized interventions can be cheap and effective.

2. A New Approach to Common but Differentiated Responsibilities

The Paris Agreement takes a dramatic step away from the rigid differentiation between developed and developing countries of past climate agreements. It does this by committing both to the same mitigation obligations while qualifying the developing country

264. *See* Michael Wara, *Is the Global Carbon Market Working?*, 445 NATURE 595, 595 (2007).

265. I have suggested in previous work that where information about low-cost reductions is available, non-market-based approaches may be more cost-effective. *Id.*

266. For example, the reporting program for major sources of greenhouse gases within the United States covers more than 8000 sources. *See Greenhouse Gas Reporting Program 2014: Reported Data*, EPA, http://www.epa.gov/ghgreporting/ghgrp-2014-reported-data [https://perma.cc/5JU7-HEGX] (last updated Oct. 13, 2015).

267. *See supra* note 169 and accompanying text; *infra* note 273 (discussing the low cost of the implementation of the Tier-2 Low-Sulfur Gasoline rule, an important step in the United States for reducing black carbon and ozone pollution).

commitments in various ways. For example, developing country commitments may be influenced by provision of financial support, and review of implementation of these commitments will take their capacity into account.[268] Fully unpacking the concept of common but differentiated responsibilities is beyond the scope of this Article.[269] Its traditional interpretation within the legal framework of the Climate Regime has been that developing countries need not place binding caps on their emissions because to do so would limit their development[270] and they need not take actions to reduce emissions unless these are financed by developed countries. Because of the very high costs of most energy-related abatement options, little abatement has occurred, except via emissions trading, in developing countries under the UNFCCC.[271]

As described above, short-lived climate pollutants are different from carbon dioxide in that they are both cheaper to abate and their abatement is consistent with developing country economic growth and public health priorities. Furthermore, because of the lower costs of making these cuts, much more meaningful financial assistance might be available from developed countries to assist developing countries in their efforts.

It is at least worth considering, as in the Montreal Protocol, that agreements to limit short-lived climate pollutants might be negotiated that exchanged amendments to Nationally Determined Contributions for developing countries with enhanced financing by developed countries.[272] Given that the costs of implementing many of the reductions considered here might be relatively small as

268. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4, § 5; *id.* at art. 13, § 2.

269. For a comprehensive history, see Christopher D. Stone, *Common but Differentiated Responsibilities in International Law*, 98 AM. J. INT'L L. 276 (2004).

270. *See, e.g.*, Michael Wara, *Measuring the Clean Development Mechanism's Performance and Potential*, 55 UCLA L. REV. 1759, 1768 (noting that Kyoto Protocol was criticized for not requiring binding caps on emissions for developing countries China and India); *see also* James P. Barret & Dean Baker, *Cleaning up the Kyoto Protocol*, ECON. POL'Y INST. (May 1, 1999), http://www.epi.org/publication/issuebriefs_ib131/ [https://perma.cc/F5F5-KRKH] (noting that developing countries are not subject to binding caps on their emissions).

271. *See* Wara, *supra* note 270, at 1759.

272. This model of common but differentiated responsibilities has been implemented with great success under the Montreal Protocol. There, developing countries adopt targets to reduce emissions of ozone depleting substances while developed countries commit to pay the agreed incremental costs of developing country compliance. The system has functioned effectively for over twenty-five years. *See generally* CTR. FOR INT'L SUSTAINABLE DEV. LAW, THE PRINCIPLE OF COMMON BUT DIFFERENTIATED RESPONSIBILITIES: ORIGINS AND SCOPE (2002), http://cisdl.org/public/docs/news/brief_common.pdf [https://perma.cc/H3BJ-TZEE] (highlighting the Montreal Protocol as a key example of using international funding to implement differentiated responsibility).

compared to contemplated climate financing, this is likely a workable exchange.[273]

This change might be made more feasible by recognizing that neither developed nor developing countries would have incentives to attempt to extend the precedent. Developed countries believe that they cannot afford, and in any case appear unwilling, to fully finance energy-related emissions reductions to any great extent. To commit to doing so would be to effectively finance the industrial development of their most potent economic competitors.[274] Likewise, those nations that are developing most rapidly are the least willing to accept limits on their energy-related CO_2 given the suite of currently available technologies and the lack of demonstrated success, not to mention costs, in reducing emissions by developed countries.[275]

In any case, there exists the possibility that, as the Paris Agreement is further articulated in future decisions of the parties to the UNFCCC and by amendments to individual parties' Nationally Determined Contributions, a break with the past legal framework of the Climate Regime would be possible. Further, these agreements might contain, because of their smaller scale, new arrangements between developed and developing countries involving stronger commitments from developing countries in exchange for greater assistance in meeting these commitments from developed countries.

273. Developed to developing country climate financing over the past three years totaled over $33 billion. *See* Taryn Fransen & Smita Nakhooda, *5 Insights from Developed Countries' Fast Start Finance Contributions*, WORLD RESOURCES INST.: INSIGHTS (June 11, 2013), http://www.wri.org/blog/5-insights-developed-countries-fast-start-finance-contributions [https://perma.cc/5QC4-ZVUS]. Developed countries committed under the Copenhagen Accord to provide $100 billion by 2020. *See* UNFCCC, *Copenhagen Accord*, *supra* note 101, at para. 8. By contrast, phasing in the Tier-2 Low-Sulfur Gasoline rule, an important step in the United States for reducing black carbon and ozone pollution, was estimated by EPA to cost less than $3 billion per year. *See* EPA, EPA420-R-99-023, REGULATORY IMPACT ANALYSIS—CONTROL OF AIR POLLUTION FROM NEW MOTOR VEHICLES: TIER 2 MOTOR VEHICLE EMISSIONS STANDARDS AND GASOLINE SULFUR CONTROL REQUIREMENTS, at V-60–62 (1999), http://www.epa.gov/tier2/documents/r99023.pdf [https://perma.cc/4ZPE-YUR5].

274. Shannon Tiezzi, *The US and China Play Chicken over Climate Change*, DIPLOMAT (Nov. 26, 2013), http://thediplomat.com/2013/11/the-us-and-china-play-chicken-over-climate-change/ [https://perma.cc/G66H-9CYV] ("The United States has always been reluctant to accept drastic emissions cuts. . . . U.S. politicians are unwilling to commit to emissions cuts that would not apply equally to China, fearing that would put the United States at a disadvantage economically.").

275. *See id.* (discussing China's reluctance to agree to a level of emissions reduction that would "deprive Chinese citizens of the benefits of development already enjoyed by Western nations").

3. Increasing the Pace of Cooperation

Approaches to limiting emissions of short-lived climate pollutants may be faster to implement than those aimed at limiting energy-related carbon emissions. Reducing emissions of carbon dioxide from energy produced using fossil fuels either requires a switch to lower carbon energy sources or application of technologies known as carbon capture and storage.[276] Both require replacement of existing long-lived capital assets—e.g. power plants—with alternative technologies. On the other hand, abatement of short-lived climate pollutants requires either well-understood end of pipe pollution controls or improvements to gasoline and diesel fuel quality.[277] The exception, cuts in HFC emissions, mostly requires substitution of new refrigerant gases in refrigeration and air conditioning systems that are of much lower cost than cuts in emissions from fossil fuels.[278]

Cost and a slow rate of turnover in the capital stock[279] are important reasons that compliance timelines for the Kyoto Protocol, the Copenhagen Accord, and the Paris Agreement are long. The Kyoto Protocol was agreed to in late 1997 and created obligations that ran from 2008 to 2012.[280] The Copenhagen Accord was agreed to in late 2009 and created compliance obligations that do not occur until 2020.[281] The Paris Agreement, negotiated late in 2015, created obligations that will not occur until 2025.[282] The cuts mandated by these agreements are relatively modest and are in any case inadequate if the world is to achieve the UNFCCC objective of "prevent[ing] dangerous anthropogenic interference with the climate system."[283] Thus, nations have so far

276. *See What Is Carbon Dioxide Capture and Sequestration*, EPA, https://www3.epa.gov/climatechange/ccs/ [https://perma.cc/9KQK-TW2T] (last updated Feb. 23, 2016) (describing the physical capture of carbon from factory or industrial process emissions).

277. *See, e.g.*, CAL. AIR RES. BD., SHORT-LIVED CLIMATE POLLUTANT REDUCTION STRATEGY (2015), http://www.arb.ca.gov/cc/shortlived/concept_paper.pdf [https://perma.cc/Y6FH-VNGD] (discussing current and proposed methods for reducing SLCP emissions in California).

278. *See* IPCC & TECH. & ECON. ASSESSMENT PANEL, *supra* note 193, at 13–15.

279. The United States has many operating power plants that date from the 1950s and 60s. *See Age of Electric Power Generators Varies Widely*, U.S. ENERGY INFO. ADMIN.: TODAY IN ENERGY (June 16, 2011), http://www.eia.gov/todayinenergy/detail.cfm?id=1830# [https://perma.cc/4GCN-B78A].

280. Kyoto Protocol, *supra* note 24, at art. 3.

281. UNFCCC, *Copenhagen Accord*, *supra* note 101, at paras. 4, 8.

282. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at para. 17.

283. UNFCCC, *supra* note 23, at art. 2; *see also* UNFCCC, *Paris Agreement*, *supra* note 72, at art. 2.

shown a willingness to agree to modest reductions in greenhouse gases a decade hence. By contrast, the Montreal Protocol called for deep cuts (fifty percent) in chlorofluorocarbon emissions in just five years.[284] Further, as countries experimented with compliance measures under the Montreal Protocol, they felt enough confidence to increase the required cuts and to accelerate their implementation.[285] In contrast to past agreements within the Climate Regime, the Paris Agreement potentially allows for such rapid cuts via the Nationally Determined Contribution amendment process.[286]

It seems likely that a more rapid pace of implementation and compliance may be possible for the short-lived climate pollutants than has previously been the norm within the UNFCCC. The reasons for this have to do with the far simpler, better understood, and cheaper compliance strategies available to governments. While there will no doubt be challenges to phasing in gasoline content regulations in key developing countries, or to implementing requirements for catalytic converters and particle traps on mobile sources, these challenges are likely to be surmountable, particularly with expert technological and financial assistance from developed countries.

If the cycle of agreement, implementation, and compliance can be accelerated, there is the possibility of creating a dynamic within the Climate Regime whereby a succession of commitments of modest scale and scope are agreed to, complied with, and verified by the international community. This process of adjustment and deepening is important in a number of respects. First, it will help to build trust between parties. This is important not just for repeated commitments to cut the short-lived pollutants but also in terms of inspiring confidence in meaningful long-lived climate pollutant reductions. Both theory[287] and practice[288] suggest that

284. PARSON, *supra* note 84, at 137, 146.

285. *Id.* at 156.

286. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 4, § 11.

287. Game theory suggests that global commons problems that can be modeled as a prisoner's dilemma may be resolved under conditions of repeat play where there is no final round of play. *See* ROBERT AXELROD, THE EVOLUTION OF COOPERATION (1984).

288. For example, successive rounds of negotiations built trust in the commitments made by parties in the international trade regime. *See* RUTH GREENSPAN BELL ET AL., BUILDING INTERNATIONAL CLIMATE COOPERATION: LESSONS FROM THE WEAPONS AND TRADE REGIMES FOR ACHIEVING INTERNATIONAL CLIMATE GOALS (2012), http://www.wri.org/sites/default/files/pdf/building_international_climate_cooperation.pdf [https://perma.cc/J6YQ-XDYT]

countries that have made and kept one set of climate pollution commitments are more likely to be worthwhile partners in subsequent commitments. Trustworthy partners increase a country's willingness to strike costly but mutually beneficial bargains.[289] Likewise, commitments can only be credible when made by a nation with a strong reputation for keeping its promises.[290] This sort of observed trust is especially important for the countries where government leadership and decision making is opaque or where governance capacity may be lacking. Outsiders seeking to make bargains with such partners may have trouble discerning both the intent to keep a promise and whether, even with good intentions, a nation is capable of implementing the domestic policy necessary to comply with its international commitment.[291]

Second, repeated cycles of compliance and agreement are likely to increase the capacity of the UNFCCC compliance regime to monitor and verify compliance with commitments. Currently, this regime is, like most multilateral environmental agreements, relatively weak in that it depends on self-reporting,[292] has, until recently, lacked the ability to question the substantive claims of parties,[293] and is inexperienced in that it has not yet verified treaty obligations on the part of any party or dealt with substantive non-compliance issues.[294] Although the language of the Paris

(examining the considerable experience gained in devising agreements and institutions in control of weapons of mass destruction and multinational economic arrangements).

289. *See id.* at 3–4 (discussing how countries that develop trust are often more willing to accept systems of accountability and make greater concessions that "previously seemed unthinkable").

290. *See, e.g.*, *id.* at 12–24 (observing that verification systems through regimes such as UNFCCC can build trust and accountability, which may lead countries to agree to greater intrusions on sovereignty and other concessions that would not have been possible without first establishing trust).

291. *See* KEOHANE, *supra* note 18, 92–95.

292. UNFCCC, *supra* note 23, at art. 4, § 1(a).

293. *See id.* at art. 12. It remains to be seen how review of so-called Biennial Reports, the first of which were due from developed countries on January 1, 2014 will fare under the newly adopted international assessment and review process. This process holds promise in that it significantly strengthens the ability of the UNFCCC to review submissions by developed and developing countries regarding their commitments as parties to the Copenhagen Accord. *See* U.N. Framework Convention on Climate Change, *Outcome of the Work of the Ad Hoc Working Group on Long-term Cooperative Action Under the Convention*, U.N. Doc. FCCC/CP/2011/9/Add.1, Dec. 2/CP.17 (Mar. 15, 2012).

294. The Kyoto Protocol does have a compliance mechanism but the system has, in practice, focused on managing compliance of implementation mechanisms rather than on monitoring and verifying the performance of parties to the agreement. In addition, the

Agreement suggests a shift towards a more intrusive—though still managerial—style of compliance review, the specifics have yet to be articulated, let alone tested in practice.[295] Empirical study of other environmental treaty compliance regimes[296] as well as the compliance regime in the arms control regime[297] indicates that compliance procedures develop in terms of their depth, their methods for dealing with non-compliance, and their intrusiveness only over time and in response to instances of alleged or real non-compliance.

Exactly how commitments to cut energy-related CO_2 emissions should be monitored has been the subject of lengthy negotiation within the Climate Regime. Establishing rules for external monitoring of developing country commitments has been particularly contentious. The United States has at times demanded relatively intrusive external monitoring while China has resisted such infringements on its sovereignty.[298] Were agreements to curb short-lived climate pollutants to become an established part of the Paris Agreement, these monitoring and transparency issues could be worked out based on practical experience and through successive agreements relatively quickly, rather than in theory or in the midst of infrequent high-stakes diplomatic negotiations.

In sum, because agreements to cut short-lived climate pollutants have the potential to be agreed to, implemented, and periodically strengthened at a more rapid pace than agreements to cut energy-related carbon dioxide emissions, they offer the opportunity to both strengthen trust between partners and develop governance capacity on the part of the Climate Regime—key goals of the Paris Agreement.

compliance mechanism does not enable parties to independently monitor or audit submissions. *See* U.N. Framework Convention on Climate Change, *Procedures and Mechanisms Relating to Compliance Under the Kyoto Protocol*, U.N. Doc. FCCC/CP/2001/13/Add.3, Dec. 24/CP.7 (Jan. 21, 2002).

295. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 13.

296. For a discussion of other international treaty regimes, see Owen Greene, *The System for Implementation Review in the Ozone Regime*, *in* THE IMPLEMENTATION AND EFFECTIVENESS OF INTERNATIONAL ENVIRONMENTAL COMMITMENTS: THEORY AND PRACTICE 89, 118–24 (David G. Victor et al. eds., 1998); David G. Victor, *The Operation and Effectiveness of the Montreal Protocol's Non-Compliance Procedure*, *in* THE IMPLEMENTATION AND EFFECTIVENESS OF INTERNATIONAL ENVIRONMENTAL COMMITMENTS: THEORY AND PRACTICE, *supra*, at 137, 137–140.

297. *See* BELL ET AL., *supra* note 288, at 22.

298. *See* Paul G. Harris, *Diplomacy, Responsibility and China's Climate Change Policy*, *in* CHINA'S RESPONSIBILITY FOR CLIMATE CHANGE, ETHICS FAIRNESS AND ENVIRONMENTAL POLICY 1, 11 (Paul G. Harris ed., 2011).

C. The Rationale for a Multilateral Approach

Reaching successful outcomes within the UNFCCC is extremely challenging and resource intensive. Thus, some have argued that the solution to the lack of progress in the UNFCCC may lie in other negotiating fora, such as the Montreal Protocol or bilateral negotiations.[299] However, there are two self-reinforcing reasons to stay within the UNFCCC process for negotiations on short-lived climate pollutants. First, only the multilateral Climate Regime is likely to provide the legitimacy, the financial resources, and the institutional capacity necessary for deep and effective cuts. Second, near-term international success with short-lived pollutants can generate a cooperative multilateral dynamic within the broader negotiation that increases the odds of a meaningful agreement on energy-related carbon dioxide.

The process of repeated success and deepening of cooperation as well as the robust institutions that result from successful implementation of effective agreements are a necessary, but currently lacking, condition for any global agreement to meaningfully limit CO_2 emissions. Indeed, much of the Paris Agreement is oriented at generating just such a dynamic within the Climate Regime.[300] In the long run, an agreement limiting energy-related carbon emissions is essential to avoiding the worst impacts of climate change. Nevertheless, even if agreements are ultimately formalized and legally situated within the UNFCCC, experience suggests that progress made within other bilateral or plurilateral forums may not transfer easily to the UNFCCC. In particular, despite the enormous success of the Montreal Protocol in controlling emissions of gases that both destroy the ozone layer and warm the climate, there has been little transfer of legitimacy or credibility between the Ozone and Climate Regimes. This is best reflected by the choice of Canada, Mexico, and the United States to push for amendments to the Montreal Protocol as a first step to

299. *See* David G. Victor, *Climate Accession Deals: New Strategies for Taming Growth of Greenhouse Gases in Developing Countries* (Harvard Project on Int'l Climate Agreements, Discussion Paper 2008-18, 2008), http://pages.ucsd.edu/~dgvictor/publications/Victor_Chapter_2009_Climate%20Acession%20Deals.pdf [https://perma.cc/FT23-6SR7].

300. *See, e.g.*, UNFCCC, *Paris Agreement*, *supra* note 72, at paras. 12–21 (allowing countries to create their own emission goals with respect to the UNFCCC, thereby initiating cooperation of the parties on the terms of each country).

dealing with HFCs rather than pursuing this agenda within the Climate Regime.[301]

1. The Climate Regime Offers Legitimacy, Finance, and Capacity

Various authors have suggested that agreements to reduce short-lived climate pollutants should be negotiated outside of the multilateral climate negotiations process.[302] This argument, while it focuses on the challenges and high costs of working within a 192-party process which requires consensus to act,[303] underestimates the value that such a process brings in terms of legitimacy, finance, and access to transparent and accepted monitoring, reporting, and verification, particularly given the level of transparency and monitoring agreed to in the Paris Agreement. I argue that this value more than makes up for potential increases in negotiating costs that inclusion within the UNFCCC process creates.

Concluding agreements to cut SLCPs within the Paris Agreement framework would provide an important imprimatur of legitimacy to any deals to limit these emissions. The reason is that such a deal would have to occur within a broader context of the parties working to limit emissions of CO_2. A separate agreement limiting these compounds runs the risk of creating the appearance of its members attempting to shirk responsibility for the single largest cause of long-term climate change.[304] Thus inclusion within the UNFCCC provides cover and legitimacy that might allow developed and developing nations to take action that they would be unable to agree on otherwise. In other words, agreement within the UNFCCC helps to assure that a balanced approach to climate

301. *See* Press Release, U.S. Dep't of State, United States, Canada, and Mexico Submit North American HFC Phase Down Amendment to the Montreal Protocol (May 9, 2014), http://www.state.gov/r/pa/prs/ps/2014/05/225927.htm [https://perma.cc/7NQC-PK3V].

302. David Victor is perhaps best known for this perspective. *See* Victor, *supra* note 299, at 37–38; David G. Victor et al., *The Climate Threat We Can Beat: What It Is and How to Deal with It*, FOREIGN AFF., May/June 2012, https://www.foreignaffairs.com/articles/2012-04-20/climate-threat-we-can-beat [https://perma.cc/JD9G-GBT5]; *see also* Richard Stewart et al., *A New Strategy for Global Climate Protection*, 120 CLIMATIC CHANGE 1 (2013) (arguing for a "building block" strategy where agreements negotiated in multiple fora that have climate co-benefits are assembled into an effective climate strategy).

303. *See* Victor, *supra* note 299, at 37 (noting the high costs that the current Clean Development Mechanism would require for it to be implemented effectively).

304. On the other hand, to the extent that parties feel that the United States or other countries are not negotiating in good faith with respect to carbon dioxide emissions cuts, they may block proposals to take dramatic cuts in short-term climate pollutants.

change is taken at the international level. Perception of a balance between progress on different objectives in climate agreements have been critical for garnering support from both developed and developing countries.[305]

Unfortunately, and as borne out by the Nationally Determined Contributions,[306] cooperation on cutting energy-related carbon dioxide emissions is unlikely to be especially strong in the near future. Domestic experiments with emissions cuts will likely have to occur first, giving all parties confidence in technological and regulatory pathways for successful compliance. Nevertheless, modest commitments that might be achieved on energy-related carbon dioxide emissions might be paired with much more aggressive cuts in SLCPs. Arguably, such an approach could represent balance given the relative level of effort required for each, or in terms of the understanding of how emissions cuts will be accomplished.

Yet another reason to craft SLCP agreements under the auspices of the Climate Regime is availability of finance. Developed countries have promised developing countries that contributions to the UNFCCC will amount to $100 billion per year in 2020.[307] The Paris Agreement commits developed countries to scaling up beyond $100 billion per year in the post-2020 period.[308] The magnitude of this commitment implies that the multilateral Climate Regime is likely to demand and consume all available finance for climate change over the next decade. Even if not all of the $100 billion per year is delivered as promised, what is available as climate finance is highly likely to be routed through the UNFCCC en route to its eventual objective. Thus, situating agreements to cut short-lived climate pollutants within the Climate Regime helps to assure that they will be eligible to receive at least equal access to whatever funds are available to assist developing

305. For a developed country view on balanced outcomes, see, e.g., Stern, *supra* note 3; for a developing country view on balanced outcomes, see Statement by China on Behalf of Brazil, India, South Africa and China at COP 18, 26 November 2012, Doha Qatar (Nov. 26, 2012), http://unfccc.int/resource/docs/cop18_cmp8_hl_statements/BASIC%20 STATEMENT%20AT%20COP18.pdf [https://perma.cc/5DTK-KQAQ].

306. UNFCCC, *Paris Agreement*, *supra* note 72, at paras. 12–21.

307. The commitment to the $100 billion per year of climate finance was initially made in the Copenhagen Accord negotiations and formalized in the Cancun Agreement. UNFCCC, *Copenhagen Accord*, *supra* note 101, at para. 8; UNFCCC, *Cancun Agreement*, *supra* note 72.

308. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 9, § 3.

countries in implementing their obligations to reduce emissions.[309] Given that an important goal of SLCP agreements is securing reductions from all nations, including developing countries, access to this flow of resources will be critical.

There are already substantial disputes regarding how to define and account for various flows of money that might or might not be characterized as climate finance. Developed countries facing fiscal constraints have an interest in insuring that every dollar devoted to activities that lead to GHG reductions in developing countries is counted toward the $100 billion per year figure. Developing countries have an interest in maximizing the transparency of flows that do occur and of insuring that commitments they take are commensurate with assistance received. Substantial investments in governance of climate finance are currently occurring under the auspices of the Green Climate Fund.[310] It would seem wasteful of resources both within and external to the UNFCCC not to take advantage of this infrastructure to implement SLCP agreements.

Agreements to limit short-lived climate pollutants within the UNFCCC, were they to occur, might also help to induce commitments by developed countries to provide finance that would be clearly additional to other Official Development Assistance ("ODA"). The requirement that climate finance be additional to any other assistance is a key demand of developing countries that is hard to meet for investments in energy infrastructure or climate adaptation that often look very much like ODA.[311] But finance for programs to cut SLCPs is of a very different nature than typical

309. One counter to this argument might be that the many demands present within the Climate Regime will tend to reduce the flows of money to any particular project. On the other hand, developed country governments may be more willing to invest in projects that will generate clear benefits using known technologies. Implementation of programs to reduce diesel soot, HFC emissions, ozone, and methane would appear to meet these criteria.

310. *See* Press Release, Green Climate Fund, Green Climate Fund Approves First 8 Investments (Nov. 6, 2016), http://www.greenclimate.fund/documents/20182/38417/Green_Climate_Fund_approves_first_8_investments.pdf/679227c6-c037-4b50-9636-fec1cd7e8588 [https://perma.cc/65H9-CDMY] (listing the eight new investments of the Green Climate Fund).

311. For example, investments in efficient energy infrastructure or in improved port infrastructure might be characterized as climate mitigation or adaptation investments, respectively. Both are also investments that development banks might choose to finance. *See, e.g.*, Press Release, World Trade Organization, Bangladesh Receives $217 Million from World Bank to Increase Power Generation, Improve Efficiency (Apr. 7, 2016), http://www.worldbank.org/en/news/press-release/2016/ 04/07/bangladesh-receives-217-million-from-world-bank-to-increase-power-generation-improve-efficiency [https://perma.cc/N3KC-AXCX] (describing a financing agreement that the World Bank signed with Bangladesh to upgrade energy infrastructure near Dhaka).

development assistance. Agreements on short-lived climate pollutants would have well defined financing needs that are obviously distinct from other ODA. Installing scrubbers on power plants, retrofit of refineries to improve the quality of transport fuels, and improvement in the capacity of environmental regulators to enforce local pollution controls are quite distinct from typical development assistance. This will aid in defining the scope of assistance, in insuring that the assistance provided is in fact additional to ODA, and in measuring the degree to which assistance is in fact provided as promised. All of these aspects would serve to build trust on climate finance between developed and developing countries by providing clearly defined activities for climate spending.

Thus incorporation of agreements to cut SLCPs within the Paris Agreement process, rather than as standalone agreements, would help to insure the development of the financing mechanisms that are growing within it. The Green Climate Fund will need to develop practical experience in planning and managing financial flows aimed at climate mitigation if it is to have any hope of playing a meaningful role in future agreements to cut energy-related CO_2 emissions. SLCPs offer a near-term, well-defined set of policies to develop these skills. This sort of practical experience will be essential if developed country assistance is expected to scale to the levels promised, and expected, for the post-2020 period.

Finally, working to include agreements to cut short-lived climate pollutants within the Climate Regime and the unfolding Paris Agreement process could take advantage of the increasing capacity within the UNFCCC to monitor, report, and verify emissions reductions. As a result of the Copenhagen Accord and its implementing agreements made at later UNFCCC meetings, new reporting obligations apply both to developed and developing countries.[312] The Paris Agreement envisions expanding and deepening these obligations via the use of expert review of both developed and developing country reporting.[313] These might be modified and utilized to ensure transparent compliance with any agreements that are reached on SLCPs. Development of verification and compliance mechanisms is a time consuming and complex process. Where possible, it is much better to take advantage of existing systems than to develop them from scratch.

312. *See* UNFCCC, *Copenhagen Accord*, *supra* note 101, at para. 5.

313. *See* UNFCCC, *Paris Agreement*, *supra* note 72, at art. 13.

The compliance mechanisms so far implemented or proposed under the UNFCCC are far from perfect. While significant efforts have been devoted to their development, substantial questions remain about how effective they will be at managing compliance with the complex commitments incorporated into the Paris Agreement. On the other hand, an agreement outside of the UNFCCC on SLCPs would require that parties develop an entirely new mechanism to monitor and report emissions.[314] All of the same issues regarding trust, intrusiveness, and costs of monitoring, reporting, and verification would need to be renegotiated. In this context, it is worth noting that these issues have been a key focus of the negotiations since at least the lead up to the Copenhagen Accord, in 2009.[315] Avoiding duplicative negotiation, unless absolutely necessary, avoids incurring a major transaction cost of an agreement.

For these reasons, I argue that the advantages of including agreements to limit short-lived climate pollutants within the multilateral Climate Regime are significant and outweigh the added complexity of engaging with this complex system. Legitimacy, the availability of finance, and the compliance system in development argue for an embrace of the otherwise cumbersome UNFCCC.

2. Agreements Within the UNFCCC Raise the Odds of Meaningful Deals on Carbon Dioxide

The unfortunate reality is that the negotiations within the Climate Regime are not resulting in material commitments to reduce emissions of the most important source of GHGs. Pursuit of an effective agreement to limit energy-related CO_2 has not significantly altered the trajectory of emissions or atmospheric concentrations.[316] The Paris Agreement has not altered this

314. Some have suggested that the UNFCCC monitoring and reporting mechanisms might be utilized by other agreements for compliance purposes. *See* Stewart et al., *supra* note 302, at 2–3.

315. *See* UNFCCC, Copenhagen Accord, *supra* note 101, at paras. 5, 6; *see also* INT'L INST. FOR SUSTAINABLE DEV., A BRIEF ANALYSIS OF THE COPENHAGEN CLIMATE CHANGE CONFERENCE: AN IISD COMMENTARY 5 (2009), http://www.iisd.org/sites/default/files/publications/enb_copenhagen_commentary.pdf [https://perma.cc/DY2E-GL7W] (asserting that measurement, reporting, and verification for developing countries was a key stumbling block in lead-up to Copenhagen Conference of the Parties).

316. For example, fossil fuel related carbon dioxide emissions increased from a global total of 21 Gt CO_2 in 1990 to 29 Gt CO_2 in 2009. Thus emissions of GHGs from fossil fuel combustion have increased more than thirty-eight percent since the advent of the Climate

reality.[317] One reason for this is that countries struggle to coordinate their energy policies.[318] An optimistic gloss on this debacle is that parties within the Climate Regime are trying to run before they learn to walk. They are attempting to address the most difficult, uncertain, and costly energy-related aspects of the climate problem before other less contentious, costly, and hence more tractable issues.

In this context, a sequence of successful agreements on non-CO_2 related GHGs has the potential to lead to a number of desirable outcomes for the Climate Regime. A succession of deepening commitments via amendments to Nationally Determined Contributions in the Paris Agreement that were actually implemented and for which compliance was verified would build trust between partners. It would also serve to entangle important parties within the regime in deeper and more significant cooperation. Such a sequence of agreements would help to build trust in a more intrusive compliance regime. And such a regime will likely be necessary to avoid the temptation to cheat on an eventual more costly agreement to limit carbon dioxide emissions.[319] Finally, successful implementation of multiple agreements would build institutional competence within the Climate Regime that will be necessary if it is to tackle anything as significant as coordinating energy policy at the international level. By contrast, pursuit of separate agreements to limit SLCPs would likely deprive the multilateral process of all of these benefits while forcing these standalone agreements to invest resources in reinventing the institutions that already exist within the Climate Regime.

Developing cooperative approaches on environmental problems is hard.[320] Indeed, many scholars approach issues of international environmental cooperation seeking to explain why any cooperation exists at all rather than to explain why cooperation is not

Regime. By comparison, emissions grew from 14 Gt CO_2 to 21 Gt CO_2 or forty-nine percent in the period from 1971 to 1990. INT'L ENERGY AGENCY, CO2 EMISSIONS FROM FUEL COMBUSTION 2011 – HIGHLIGHTS 46 (2011), http://www.iea.org/media/statistics/co2highlights.pdf [https://perma.cc/N94P-YNGS].

317. UNFCCC, *Paris Agreement*, *supra* note 72.

318. *See, e.g.*, KEOHANE, *supra* note 18, at 237–40; *see also* VICTOR, *supra* note 15, at 203–41.

319. And the temptation to cheat or simply free ride is likely to be very strong. *See* William Nordhaus, *Climate Clubs: Overcoming Free Riding in International Climate Policy*, 105 AM. ECON. REV. 1339, 1341–43 (2015).

320. *See* KEOHANE, *supra* note 18, at 1.

stronger.[321] International relations scholars have suggested a number of reasons that may explain some level of international cooperation. Cooperation may occur because states create institutions that reduce uncertainty about other parties' behaviors.[322] Cooperation may occur because it increases a state's ability to derive benefits from future cooperation.[323] It may occur because the costs of non-cooperation are felt across a large number of issue areas in which a state has interests to protect.[324] Whichever explanation is the correct one in a given context, what seems clear is that investment in trust, institutional capacity, and competence is critical to advancing cooperation. Trust, reputational capital, and reduced uncertainty regarding the current and likely future behavior of other states are critical to deepening cooperation on issues such as climate change.[325] To the extent that the preferences and interests of key parties to the UNFCCC favor meaningful limits on energy-related carbon dioxide, it is entirely possible that more effective agreements have not been forthcoming because of a lack of trust and transparency. Thus addressing this deficit and increasing institutional strength and competence may facilitate cooperation. To the extent that easier, less costly agreements have the potential to address these trust and capacity deficits within the UNFCCC, they may ultimately serve as confidence building steps on a journey toward tough global limits on CO_2 emissions.

Currently, as evidenced by the intense focus on monitoring, reporting, and verification under both the Copenhagen Accord and the Paris Agreement,[326] parties to the UNFCCC are deeply concerned about the level of trust to place in each other as they consider costly commitments on GHG emissions. Concerns about trust are so deep that all sides appear unwilling to offer commitments on energy-related carbon dioxide emissions that are anywhere close to adequate to reduce the risks presented by climate change. One way to improve upon this lack of trust is via agreement on less costly commitments. In Part IV, I showed how large cuts in SLCPs represent exactly this sort of opportunity for the climate change problem. Because reductions in these

321. BARRETT, *supra* note 196, at 1.

322. *See* KEOHANE, *supra* note 18, at 246.

323. *See* GUZMAN, *supra* note 18, at 212.

324. *See* CHAYES & CHAYES, *supra* note 16, at 27–28.

325. *See* GUZMAN, *supra* note 18, at 212.

326. UNFCCC, *Copenhagen Accord*, *supra* note 101, at 11–12; UNFCCC, *Paris Agreement*, *supra* note 72, at paras. 104–05.

pollutants create both benefits for individual states as well as global public goods, the costs of agreement are lower. These waypoints on the road to eventual cooperation on energy-related carbon dioxide could help to increase transparency about capacity and intention to implement agreements regarding climate change. They could help to build institutional norms of compliance around the issue that are currently lacking.[327] Today, nations do not trust each other enough to commit to effective controls on energy-related carbon dioxide emissions even if their welfare both individually and jointly would be improved by such agreement. A sequence of gradually more effective agreements could begin to overcome this deficit.

This first failure to agree leads to a second failure. Nations are unable to demonstrate to each other that they would comply with, rather than cheat on, agreements to cut GHG emissions. This issue is particularly problematic for the United States, which signed but ultimately did not ratify or implement the Kyoto Protocol.[328] Many parties are currently concerned that a U.S. presidential election in 2016 may undo many of the commitments made by the Obama Administration,[329] much as the transition from the Clinton Administration to the Bush Administration resulted in a change in U.S. climate policy.[330] Similarly, some in the United States doubt the ability of Chinese government planners to deliver on the commitments they have made given the weak environmental governance in that country.[331] Demonstrating to negotiating

327. For example, the United States heavily influenced the structure of the Kyoto Protocol, signed it, but did not ratify it. Australia, Canada, and New Zealand ratified the agreement but did not comply with their targets. CORINA HAITA, INT'L CTR. FOR CLIMATE GOVERNANCE, THE STATE OF COMPLIANCE IN THE KYOTO PROTOCOL 4 (2012), http://www.iccgov.org/wp-content/uploads/2015/05/12_Reflection_December_2012.pdf [https://perma.cc/8BD8-6TJB].

328. *Status of Ratification of the Kyoto Protocol*, UNFCCC, http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php [https://perma.cc/P3EY-SV8X] (last visited June 5, 2016).

329. Maria Gallucci, *Obama Climate Change Legacy Hangs in the Balance as 2016 Presidential Election Approaches*, INT'L BUS. TIMES (Apr. 6, 2016), http://www.ibtimes.com/obama-climate-change-legacy-hangs-balance-2016-presidential-election-approaches-2349293 [https://perma.cc/GZ2N-XS7D] (noting that Obama's environmental policies might change depending on the outcome of the 2016 presidential election).

330. Paul G. Harris, *Beyond Bush: Environmental Politics and Prospects for US Climate Policy*, 37 ENERGY POL'Y 966, 969 (2008) (noting the Bush administration's devotion of resources to prevent action on climate change).

331. *See* Elizabeth Economy, *China and Climate Change: Three Things to Watch After Paris*, DIPLOMAT (Dec. 19, 2015), http://thediplomat.com/2015/12/china-and-climate-change-three-things-to-watch-after-paris/ [https://perma.cc/5PNR-E283] (asserting that China's

partners that promises will be kept when made within the UNFCCC is thus an important precondition for all parties to commit to meaningful, potentially costly cuts in CO_2 emissions. Agreements to cut SLCPs have the potential to overcome this chicken and egg problem by providing avenues for parties to the UNFCCC to develop solid (or not) reputations for compliance with GHG emissions limits.

Inclusion of SLCP agreements within the UNFCCC would provide a set of opportunities for nations to make commitments to reduce emissions that are relatively low cost and so possible, given the lack of well-developed reputations for compliance. It would make sense in this context to front load SLCP reductions with the highest level of present-day non-climate related benefits and to defer action until later in this process on SLCP cuts with lower or no local air pollution benefits. In this way, SLCP agreements could create a pathway of increasingly effective and costly actions that would serve to increase mutual confidence within the regime. With reputations strengthened by this process of iterative agreement and observation of compliance, parties might be in a position to credibly commit to reductions in energy-related carbon emissions.

Knowing who to trust and how much to trust them can be one of the most challenging aspects of concluding international environmental agreements.[332] Domestic legal regimes that ultimately determine whether or not international commitments are met are often complex and opaque. This opacity makes it difficult for parties to both develop a reputation for and evaluate the reputations of prospective partners in international cooperation.[333] Because there is no external power upon which to rely for contract enforcement, as in the domestic legal context, this information problem can both prevent agreement and weaken agreements that are concluded. One means of overcoming this information problem is via parties mutually observing compliance with prior agreements. By demonstrating compliance, a nation shows potential partners that it can be trusted. By observing

record on delivering on environmental protection promises is poor and there is no reason to assume that Beijing will do what it says on climate change.).

332. Of course, this problem is not unique to environmental agreements but it is particularly severe there since strategies of retaliation or reciprocity are unlikely to be employed in response to noncompliance: retaliation because it is costly and because states will prefer that others incur these costs; reciprocity because it is ineffective in the context of environmental agreements. *See* GUZMAN, *supra* note 18; KEOHANE, *supra* note 18.

333. GUZMAN, *supra* note 18; KEOHANE, *supra* note 18.

compliance of other nations with agreements in a subject area, a nation can develop informed views as to the level of commitment it should take in reliance on other nations' future performance. Repeated compliance is the way out of a market for lemons.[334]

Demonstrating compliance with a requirement limiting emissions of a colorless, odorless gas discharged by thousands if not millions of devices across national economies is a challenging regulatory task, as recently demonstrated by China's restatement of its coal consumption data.[335] It is an impressive accomplishment that reported emissions by developed countries are more often than not credible.[336] On the other hand, these voluntary reports have historically been made in the absence of costly commitments to cut emissions. Whether reporting continues to be credible and how noncompliance issues are resolved when they inevitably occur are important unanswered questions for the UNFCCC and for the Paris Agreement's "framework for transparency of action."[337] These questions can only really be answered by development of a set of practices and processes in the non-compliance regime. To date, the UNFCCC compliance mechanisms have faced relatively unchallenging situations. In particular, they have been mostly focused on developed country emissions reporting requirements under the Kyoto Protocol and on eligibility to participate in the Kyoto Protocol's emissions trading mechanisms.[338] Moving forward under the Paris Agreement, expert review panels will face the challenge of judging progress toward Nationally Determined Contributions of widely varying scope and approach.

Compliance with agreements to cut SLCPs, particularly where such agreements bound developing countries with relatively limited environmental regulatory capacity, would no doubt present the new compliance regime with challenging work. This would likely be true even with intentions to comply on the part of all parties. Studies of international environmental agreements have shown

334. George Akerlof, *The Market for "Lemons": Quality Uncertainty and the Market Mechanism*, 84 Q.J. ECON. 488 (1970).

335. Chris Buckley, *China Burns Much More Coal than Reported, Complicating Climate Talks*, N.Y. TIMES (Nov. 3, 2015), http://www.nytimes.com/2015/11/04/world/asia/china-burns-much-more-coal-than-reported-complicating-climate-talks.html [https://perma.cc/4HK5-AM4A].

336. *But see id.*

337. UNFCCC, *Paris Agreement*, *supra* note 72, at art. 13, § 5.

338. *See* U.N. Framework Convention on Climate Change, *Procedures and Mechanisms Relating to Compliance Under the Kyoto Protocol*, U.N. Doc. FCCC/KP/CMP/2005/8/Add.3, Dec. 27/CMP.1 (Mar. 30, 2006).

that non-compliance is typically handled via "active management" in which parties attempt to increase the transparency of any alleged noncompliance, seek to compel the noncompliant party to explain its actions or lack thereof, and seek to assist any party that is struggling to comply with the terms of an agreement to do so.[339] Instances of punitive or retaliatory measures in instances of non-compliance, even when theoretically allowed under an agreement, are rare to non-existent.[340] The language in the Paris Agreement regarding transparency of action and support[341] closely tracks this literature and the experiences it points to, suggesting that the approach of the parties will be managerial rather than punitive in approach.

A series of increasingly significant agreements to cut SLCPs would facilitate the articulation of increasingly sophisticated and meaningful institutions, processes, and norms that support later agreement on energy-related carbon dioxide. In this way, far from being a distraction from its core mission, SLCPs offer the Climate Regime a series of confidence and capacity building opportunities. One example of this opportunity is the technical body that provides information to the Climate Regime. The institutional structure of the Climate Regime was designed to mirror the Montreal Protocol's. In particular, the Subsidiary Body for Technical and Scientific Advice created under the UNFCCC was modeled on the Technical and Economic Advisory Body of the Montreal Protocol.[342] Crucial differences between the two bodies as well as the overall trajectory of the negotiations have created radical differences in the output of these two institutions. The UNFCCC technical advising body is, by agreement, composed solely of "governmental representatives," while the Montreal Protocol's is composed of "experts qualified in the fields mentioned."[343] In practice, the Montreal Protocol's advice is derived from the private sector, includes substantial provision of confidential business information, and has allowed negotiators to make educated and accurate predictions about the feasibility and cost of various

339. *See* CHAYES & CHAYES, *supra* note 16, at 24–25.

340. *See id.* at 27–28.

341. UNFCCC, *Paris Agreement*, *supra* note 72, at paras. 85–99.

342. *Compare* UNFCCC, *supra* note 23, at art. 9, *with* Montreal Protocol, *supra* note 61, at art. 9.

343. *Compare* UNFCCC, *supra* note 23, at art. 9, *with* Montreal Protocol, *supra* note 61, at art. 9.

approaches to limiting pollutants.[344] By contrast, the work of the Climate Regime's technical advisory bodies amounts to assembling and compiling information that governments already have. Primarily, the UNFCCC technical body has focused on inventory and reporting of GHGs, resulting in widely accepted guidelines for emissions accounting and reporting.[345]

The technical advising bodies of the Climate Regime have been far less effective at producing relevant information regarding the capacity to reduce emissions. This is partly because these bodies lack members from the private sector that have expert knowledge in what reductions are technically and economically feasible. It is also partly because these bodies have mostly not been asked for much advice that would impact negotiations on commitments. And there is an interaction between these two issues. By contrast, the equivalent bodies under the Montreal Protocol are routinely asked for advice on the potential for emission reductions of particular gases, the costs of reductions, and the extent to which exceptions should be granted for particular industries.[346] The information provided in the reports of the Montreal Protocol's technical experts has been very influential in driving agreements between the parties.[347] It has also dramatically lowered the transaction costs of agreement for negotiators by providing a trusted source of information for negotiators seeking to ratchet down emissions via amendments to the Montreal Protocol.

Negotiation of agreements to control short-lived climate pollutants would seem to offer an avenue to strengthen and increase the role of the UNFCCC technical advisory bodies in ways that would increase the organizational competence and capacity. As discussed in Part IV, reductions of methane, ozone precursors, HFCs, and black carbon rely on technologies whose costs are best estimated by those that would provide them to developed and developing counties. Implementing a process whereby the

344. *See* PARSON, *supra* note 84.

345. *See, e.g.*, U.N. Framework Convention on Climate Change, *Updated UNFCCC Reporting Guidelines on Annual Inventories Following Incorporation of the Provisions of Decision 14/CP.11*, U.N. Doc. FCCC/SBSTA/2006/9 (Aug. 18, 2006).

346. Recently, the Technology and Economic Assessment Panel was asked by the parties to the Montreal Protocol to evaluate the feasibility of cuts to HFC emissions. *See* U.N. Environment Programme, *Response to the Report by the Technology and Economic Assessment Panel on Information on Alternatives to Ozone-Depleting Substances (Decision XXIV/7, Paragraph 1)*, U.N. Doc. UNEP/OzL.Pro.25/9, Dec. XXV/5 (Nov. 13, 2013).

347. *See* PARSON, *supra* note 84; BENEDICK, *supra* note 84.

UNFCCC technical capacity could begin to approach that of the Montreal Protocol's could do much to facilitate future agreements on other gases, and eventually on energy-related CO_2 emissions. This information generating capacity would help negotiators to understand what they could commit to in a current agreement rather than as currently, where negotiations are primarily informed by reference to what targets should be in order to achieve the objective of keeping warming at or below 2°C. Developing confidence in and experience with a system of providing negotiators with shared, credible information on feasible emission reductions could be accomplished within the relatively less ambitious framework of agreements to cut SLCPs. Having this sort of institutional capacity within the UNFCCC could then reduce the uncertainty and perceived risks of future cooperation on CO_2.

D. An All of the Above Negotiating Strategy

The arguments above notwithstanding, there are still important reasons to focus on agreements to limit short-lived climate pollutants in other negotiating fora. Bilateral and plurilateral negotiations provide important opportunities for key parties to reach agreement on principles that they can then bring to the larger UNFCCC negotiations. An important example of this strategy has unfolded recently in the efforts to cut emissions of one short-lived climate pollutant: HFCs. For several years, the United States, Mexico, and Canada have proposed at meetings of the Montreal Protocol to freeze and ultimately phase out HFC emissions under this treaty.[348] HFC emissions and their environmental impacts are a consequence of the Montreal Protocol—they are substitutes for the compounds phased out under the treaty—but do not harm the Ozone Layer.[349] At the Montreal Protocol meetings in late 2012, 118 nations supported the proposal to regulate HFCs under the Montreal Protocol. China and India were important holdouts.[350] These nations refused to consider amending the treaty to add HFCs, arguing instead that

348. *See* U.S. Dep't of State, *supra* note 301.

349. *See supra* note 163 and accompanying text.

350. *See India, China, & Brazil Kill Effort to Eliminate Super Greenhouse Gases*, ENVTL. INVESTIGATION AGENCY (July 25, 2012), https://eia-international.org/india-china-brazil-kill-effort-to-eliminate-super-greenhouse-gases [https://perma.cc/5X9M-AHYV].

these compounds should be regulated under the UNFCCC because they cause climate change, not ozone depletion.[351]

In early 2013, President Obama took advantage of a bilateral meeting with President Xi Jinping to conclude an agreement to support negotiation of limits on HFCs within the Montreal Protocol rather than the UNFCCC.[352] Later in the year, within a plurilateral forum, the G-20, President Obama successfully obtained assurances that the group, including Indian Prime Minister Manmohan Singh, would no longer block regulation of HFCs under the Montreal Protocol.[353] At the next meeting of the Montreal Protocol, the United States and its partners began the slow but deliberate process of crafting an amendment to the Montreal Protocol aimed at freezing and ultimately phasing down HFCs.[354]

Smaller negotiating fora can be important venues for producing cooperation on new climate agreements. They may even be essential to breaking key deadlocks in a negotiation process. But these alternative fora for negotiation are ultimately only valuable if they both produce cuts in the non-CO_2 gases and feedback into the larger negotiation aimed at CO_2. To date, and especially given the very limited degree if at all that success within the Ozone Regime has generated reputational capital for parties within the Climate Regime, nations should carefully weigh the tradeoffs between the UNFCCC and other negotiating contexts.

VI. CONCLUSIONS

While the climate benefits of deep cuts in SLCPs are not to be scoffed at, these benefits pale in comparison to those of a meaningful agreement on energy-related CO_2 emissions.[355] This is particularly true given the reality that developing nations will

351. *Id.*

352. *See* Steven Mufson, *President Obama and Chinese President Xi Jinping Agree to Wind Down Production and Use Of Hydrofluorocarbons, or HFCs*, WASH. POST (June 8, 2013), https://www.washingtonpost.com/business/economy/president-obama-and-chinese-president-xi-jinping-agree-to-wind-down-production-and-use-of-hydrofluorocarbons-or-hfcs/2013/06/08/92e4d79e-d08f-11e2-8845-d970ccb04497_story.html [https://perma.cc/26AE-XJFJ].

353. *See* Press Release, White House, United States, China, and Leaders of G-20 Countries Announce Historic Progress Toward a Global Phase Down of HFCs (Sept. 6, 2013), https://www.whitehouse.gov/the-press-office/2013/09/06/united-states-china-and-leaders-g-20-countries-announce-historic-progres [https://perma.cc/33D4-JNDZ].

354. *See id.*

355. *See supra* Table 1.

eventually reduce emissions of many of these pollutants as they grow richer. However, deals for rapid cuts in short-lived climate pollutants could serve to accelerate reductions and so reduce the pace of climate change. This is important in that it may buy the global community important time that it needs to develop and deploy new clean energy technologies. But in the long run, if we are to deal with the worst impacts of climate change to future generations, an agreement to international cooperation or, at a minimum, coordinated national actions on energy-related carbon dioxide emissions are necessary. In this Article, I have argued that besides buying time, an important reason to push for SLCP agreements within the UNFCCC is that these agreements may create a process and eventually conditions that allow for an effective deal on CO_2 emissions.

It is at least possible that by negotiating and implementing a sequence of SLCP agreements within the context of the Paris Agreement, that framework can begin a process of evolution and strengthening, as intended by its designers, that will someday produce a set of institutions capable of supporting agreements for deep cuts to CO_2 emissions. What seems clear from the Nationally Determined Contributions recently incorporated into the Paris Agreement is that the international community does not have the institutions and trust to support the progress it wants on energy-related CO_2. However, the open structure of allowed commitments under the Paris Agreement creates an opportunity for developed and developing countries to build trust in each other and in the institutions that will support strong commitments. Strong institutions built over a sequence of agreements are the hallmark of the most successful international regimes.[356] Currently, the Climate Regime lacks such a dynamic of iterative success and strengthening. By attempting more of the same—another deal based on the six-gas 100-year GWP framework—it is unlikely to

356. For example, the European Union evolved from the European Community which evolved from the European Economic Community which evolved from the European Coal and Steel Community. ERNST B. HAAS, THE UNITING OF EUROPE: POLITICAL, SOCIAL, AND ECONOMIC FORCES, 1950–1957 (1958). The World Trade Organization began as an outgrowth of a failed attempt to negotiate a wide-ranging agreement to create an International Trade Organization. Instead, a limited set of members agreed to the terms of the General Agreement on Tariffs and Trade ("GATT"), which gradually expanded in scope and membership through multiple negotiating rounds. John H. Jackson, *History of the General Agreement on Tariffs and Trade*, *in* WTO: TRADE IN GOODS 1 (Rüdiger Wolfrum, Peter-Tobias Stoll & Holger P. Hestermeyer eds., 2011).

create one. By contrast, a rapid succession of agreements to limit pollutants that cause both public health disasters in many developing countries and a significant fraction of current global warming might just buy the global community the time it needs to both invent the technological solutions to avoid the worst effects of climate change and build the legal institutions needed to support their deployment. Achieving these agreements is possible within the structure of the Paris Agreement but will require allowing a new understanding of mankind's impact on climate into the Agreement's legal framework.