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NOTE

EFFICIENTLY INEFFICIENT: REGULATORY OPTIMIZATION THAT CARES ABOUT TOMORROW'S LOST CIVILIZATIONS

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ABSTRACT

Climate change has been an issue on the global stage for more than 40 years, and regulatory action has evolved as the consequences of climate change become closer to reality. While governmental action during that period has resulted in great reductions in pollution, some nations are beginning to see devastating impacts of climate change. For some island nations, entire cultures will be wiped out within the next few generations. Despite the severity of the climate crisis, the United States has clung to a traditional economic framework to measure and evaluate environmental regulations—one that values cost efficiency over successful conservation, even when vast degrees of uncertainty severely limit the framework's empirical value. While the international stage has moved on from trying to measure the value of preserving threatened ecosystems, shrinking landmasses, and entire cultures, the United States leans on manipulable and arbitrary assumptions to drive its evaluation of environmental regulation standards. The United Kingdom has adopted a middling approach using marginal

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This Note is dedicated to Professor Alex C. Geisinger, who was an amazing mentor to me and many others who have had the privilege of learning from him. I will forever look up to him and remember all he's done over the past few years. You will be missed, Geis.

abatement costs (MACs)—the total cost necessary to achieve a specific climate goal—which the United States has rejected for exhibiting the same suboptimal tendencies as the international precautionary principle.

The MAC framework removes a significant amount of uncertainty that plagues the traditional cost-benefit model by ensuring that climate goals are met. In the case of the environment, certainty of outcome is an incredibly valuable element of any model. Optimization is also important where administrative resources are scarce and overinvestment in the environment means underinvestment in other areas of public welfare. Recognizing the degree to which the United States values optimization, this Note suggests legislation adopting a modified MAC approach to valuing environmental regulation that provides the outcome security that traditional models lack while maintaining a trend toward optimized cost efficiency.

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INTRODUCTION

Within the next century, the nation of Tuvalu is set to join a short list of lost underwater civilizations.[1] Despite pleas from Tuvalu's foreign minister asking wealthier nations to take responsibility for their impact on rising sea levels and to fund the preservation of the island nation's existence,[2] Tuvalu has had to look toward virtual reality to preserve its history and culture.[3] While the climate crisis may have seemed like a nonthreatening issue for tomorrow's generation when it first came onto the world stage in the 1980s, places around the world are starting to see increasingly drastic effects of climate change today.[4] Forty percent of Tuvalu's capital is already underwater, and projections suggest the entire nation will be underwater within the next century.[5]

1. Roselyne Min, *Tuvalu Is Recreating Itself in the Metaverse as Climate Change Threatens to Wipe It off the Map*, EURONEWS.NEXT (Nov. 23, 2022), https://www.euronews.com/next/2022/11/23/tuvalu-is-recreating-itself-in-the-metaverse-as-climate-change-threatens-to-wipe-it-off-th [https://perma.cc/6AR9-6RSC]; *see* PLATO, TIMAEUS AND CRITIAS 13–14 (Andrew Gregory ed., Robin Waterfield trans., Oxford Univ. Press 2008).

2. *See* Min, *supra* note 1; Memoranda, General Assembly, Ahead of Climate Conference, Small Island Developing States Call Out Rich Countries in General Assembly for Lacking Political Will to Stop Global Warming, U.N. Meetings Coverage GA/12369 (Sept. 25, 2021).

3. Min, *supra* note 1.

4. *See, e.g.*, *id.* (noting that Tuvalu "could be completely swallowed up by rising sea levels by the end of the century" and that "[i]slands like this one won't survive rapid temperature increases, rising sea levels, and droughts"); *Kiribati, the First Country Rising Sea Levels Will Swallow Up as a Result of Climate Change*, IBERDROLA, https://www.iberdrola.com/sustainability/kiribati-climate-change [https://perma.cc/8H4W-5KEJ] (describing how Kiribati, a nation comprised of 33 atolls that largely exist under sea level, is now threatened by increased sea levels and storm surges).

5. Min, *supra* note 1; *see* NASA Sea Level Change Team, ASSESSMENT OF SEA LEVEL RISE AND ASSOCIATED IMPACTS FOR TUVALU 1 (2023) (reporting that the "[s]ea level in Tuvalu has risen by 0.15 m over the past 30 years, at an average rate of 5 mm/year since 1993, and this rate will increase in the future, potentially more than doubling by 2100").

Tuvalu is not alone in this plight.[6] Kiribati, another island nation, has already seen some of its smaller islands engulfed by rising sea levels, and increased storm surges have caused increased flooding, contamination of freshwater, and negative impacts on farming and fishing.[7] Kiribati has also pled to wealthier member states of the United Nations for funding to help the country with preservation efforts, citing that more industrialized nations have caused a much larger portion of climate change than smaller island nations most suffering from it.[8] However, solutions like creating a floating platform similar to those used by oil companies, or dredging the seabed to heighten the island itself could cost billions of dollars—many times the gross domestic product (GDP) of Kiribati.[9] In other parts of the world, scientific projections suggest that rising sea levels will quickly lead to dramatic impacts for cities located in deltas, which will affect millions of people in places such as Kolkata, India; Bangkok, Thailand; and Shanghai, China.[10] Climate

6. *See* Adam Voiland, *Anticipating Future Sea Levels*, EARTH OBSERVATORY, https://earthobservatory.nasa.gov/images/148494/anticipating-future-sea-levels [https://perma.cc/N3FU-3DYT] (providing a consolidated analysis of predicted sea levels rising over the next 300 years); Frances Eleanor Dunn & Stephen Darby, *River Deltas Are 'Drowning,' Threatening Hundreds of Millions of People*, THE CONVERSATION (Nov. 1, 2019, 5:53 AM), https://theconversation.com/river-deltas-are-drowning-threatening-hundreds-of-millions-of-people-125088 [https://perma.cc/X87M-5KHU].

7. *Kiribati, the First Country Rising Sea Levels Will Swallow Up as a Result of Climate Change*, *supra* note 4.

8. Justin Worland, *Meet the President Trying to Save His Island Nation from Climate Change*, TIME (Oct. 9, 2015, 12:34 PM), https://time.com/4058851/kiribati-cliamte-change/ [https://perma.cc/5HYN-WRQQ] (quoting Kiribati's then-President Tong as saying, "the damage caused by the policies of Australia and other developed countries that have emitted the carbon that is endangering the very existence of Kirbati, where the average resident emits less than 1 ton of carbon dioxide each year or 7% of the global average"); *see* Oliver Milman, *'No Safe Place': Kiribati Seeks Donors to Raise Islands from Encroaching Seas*, THE GUARDIAN (Nov. 18, 2022), https://www.theguardian.com/environment/2022/nov/18/cop27-kiribati-donors-raise-islands-sea-level-rise [https://perma.cc/HQ8U-4TLT]. *See generally*, Marian Leimbach & Anastasis Giannousakis, *Burden Sharing of Climate Change Mitigation: Global and Regional Challenges Under Shared Socio-Economic Pathways*, 155 CLIMATE CHANGE 273, 274 (2019) (analyzing burden sharing fairness in the international effort to reduce emissions and recognizing the disproportionate costs to developing countries).

9. *Kiribati, the First Country Rising Sea Levels Will Swallow Up as a Result of Climate Change*, *supra* note 4; *see* Milman, *supra* note 8.

10. *See* Voiland, *supra* note 6. "The world's river deltas take up less than 0.5% of the global land area, but they are home to hundreds of millions of people." Dunn & Darby, *supra* note 6. Deltas are landforms that "form as rivers empty their water and sediment into another body of

change is no longer an issue that can be put off for tomorrow's generation to deal with: it is "the greatest challenge of our time."[11] Despite this, the United States' regulatory framework for environmental law clings to a traditional, cost-benefit methodology riddled with uncertainty.[12] While most of the world has developed more precautionary approaches to environmental regulation,[13] the United States insists on a regulatory framework that prefers to risk substantial costs of under-regulation for the *pursuit* of optimization rather than accept lost opportunity benefits from possible over-regulation.[14]

This Note analyzes the United States' cost-benefit approach against more modern frameworks around the world, highlighting the flaws in environmental regulation based on social costs and proposing that the United States adopt a modified marginal abatement cost (MAC) approach to better ensure climate goals are met while optimizing resource allocation. Part I of this Note

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water." *Delta*, NAT'L GEOGRAPHIC, https://education.nationalgeographic.org/resource/delta/ [https://perma.cc/9BJF-R8K4]. Fine sediments carried downstream are collected where the current slows, resulting in a wetland with soil rich in nutrients for plant life. *Id.* "With fertile soils and easy access to the coast, deltas are critical hotspots of food production." Dunn & Darby, *supra* note 6. "[M]any of the world's deltas are now facing an existential crisis." *Id.* "Sea levels are rising as a result of climate change, while deltas are themselves sinking, and together this means the relative sea level is rising extra fast." *Id.*

11. John Gillis, *U.N. Climate Panel Endorses Ceiling on Global Emissions*, N.Y. TIMES (Sept. 27, 2013), https://www.nytimes.com/2013/09/28/science/global-climate-change-report.html [https://perma.cc/Y776-AYJV] (emphasis added) (quoting Thomas F. Stocker of the Intergovernmental Panel on Climate Change).

12. *See generally* Amy Sinden, *All the Tools in the Toolbox: A Plea for Flexibility and Open Minds in Assessing the Costs and Benefits of Climate Rules*, 39 YALE J. ON REGUL. 908, 916 (2022) (discussing marginal abatement cost as a different approach to calculating the social cost of carbon (SCC) to avoid the current uncertainties involved in estimating the SCC).

13. *See* HARALD HOHMANN, PRECAUTIONARY LEGAL DUTIES AND PRINCIPLES OF MODERN INTERNATIONAL ENVIRONMENTAL LAW 5–10 (1994).

14. *Compare* Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003, 1023–24 (2003) [hereinafter Sunstein, *Beyond the Precautionary Principle*] (arguing against precautionary regulation for improperly dedicating resources to the environment where returns are uncertain and may be more efficiently used promoting welfare elsewhere), *with* IPCC, *Summary for Policymakers*, *in* GLOBAL WARMING OF 1.5°C 17–20 (Valérie Masson-Delmotte, Panmao Zhai, Hans-Otto Pörtner, Debra C. Roberts, James Skea, Priyadarshi R. Shukla, Anna Pirani, Wilfran Moufouma-Okia, Clotilde Péan, Roz Pidcock, Sarah Connors, J.B. Robin Matthews, Yang Chen, Xiao Zhou, Melissa I. Gomis, Elisabeth Lonnoy, T. Maycock, Melinda Tignor & Tim Waterfield eds., 2018) (reporting scientific data suggesting significant environmental consequences of overshooting global mean temperature stabilization goals) [hereinafter IPCC, *Summary for Policymakers 2018*].

provides an overview of the climate crisis itself and the market failures that environmental regulations seek to fix. Part II analyzes the three existing frameworks that have been applied to environmental regulation and explains the policy and problems behind each. Part III presents a modified MAC approach that adopts static-present assumptions to predictive calculations to prevent under-regulation and uses procedure adopted via legislation to incentivize optimization. This Note argues that traditional social costs do not guarantee climate goals will be met, and the modified MAC approach addresses this problem by providing a model that restricts the consequences of uncertainty while maintaining an empirical process that optimizes resource allocation. This modified MAC framework can maintain a trend toward optimization through legislation that ensures a process of periodic administrative reassessment.

I. In a World Where. . .

Climate change is a fast-approaching crisis that has been prevalent in political discourse for more than thirty years.[15] Before addressing existing regulatory frameworks and policies, an assessment of the current state of the environment is necessary to put the values and detriments of each policy into perspective. The latest research on climate change has evidenced that global mean temperature increases as low as 1.5 degrees Celsius above pre-industrial levels could cause severe and irreversible harms to the environment.[16] Present metrics place us at a 1.0-degree Celsius increase and rising.[17] More aggressive regulatory goals have developed recently in response to the growing threat of

15. *See* Peter Jackson, *From Stockholm to Kyoto: A Brief History of Climate Change*, UNITED NATIONS (June 2007) https://www.un.org/en/chronicle/article/stockholm-kyoto-brief-history-climate-change [https://perma.cc/TE4H-RWZH].

16. *See* Ove Hoegh-Guldberg, Daniela Jacob, Michael Taylor, Marco Bindi, Sally Brown, Ines Camilloni, Arona Diedhiou, Riyanti Djalante, Kristie L. Ebi, Francois Engelbrecht, Joel Guiot, Yasuaki Hijioka, Shagun Mehrotra, Antony Payne, Sonia I. Seneviratne, Adelle Thomas, Rachel Warren & Guangsheng Zhou, *Impacts of 1.5 Degrees C of Global Warming on Natural and Human Systems*, *in* Global Warming of 1.5°C, *supra* note 14, at 177–81.

17. *Id.* at 188.

climate change, but many of these initiatives are not enough.[18] The dire state of climate change emphasizes a need to re-address how regulatory bodies value and invest in the environment.

A. *A Brief Overview of the Present Climate*

Insect plagues, natural disasters, and great floods are not just biblical depictions of doomsday—they are very real consequences of climate change that the world has already begun to realize.[19] Over the last 10,000 years, the Earth experienced a relatively long period of climate stability until global industrialization took off in the 1950s.[20] Prior to industrialization, the natural world had evolved and grown accustomed to stability.[21] However, as human society began to industrialize, the Earth began warming at an alarming rate, in large part due to the addition of excess greenhouse gases to the atmosphere.[22]

As the Earth has increased in temperature, natural and ecological systems have experienced noticeable changes, some of which have significant effects on public welfare and entire ecosystems.[23] Notable increases in natural disasters like tropical storms and hurricanes have been attributed to climate change.[24] Additionally, rising sea levels have increased the rate and magnitude of flooding around the world beyond the patterns experienced over the last 100 years.[25] Earlier warm seasons have also

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18. *See* discussion *infra* Section I.C.

19. *See, e.g.*, Thomas E. Lovejoy, *Climate Change: Nature and Action*, *in* LEARNING FROM CATASTROPHES 170, 172 (Howard Kunreuther & Michael Useem eds., 2010) (more-intense tropical storms); Min, *supra* note 1 (rising sea levels); Barbara Bentz & Kier Klepzig, *Bark Beetles and Climate Change in the United States*, U.S. DEP'T OF AGRIC. (Jan. 2014), https://www.fs.usda.gov/ccrc/topics/bark-beetles-and-climate-change-united-states [https://perma.cc/7EQ5-CMTJ] (bark beetle overpopulation).

20. *See* Lovejoy, *supra* note 19, at 171; *Carbon Dioxide Levels Race Past Troubling Milestone*, NOAA, (Sept. 30, 2016), https://www.noaa.gov/stories/carbon-dioxide-levels-race-past-troubling-milestone [https://perma.cc/A5WP-JLHP].

21. *See* Lovejoy, *supra* note 19, at 171.

22. *See* *Greenhouse Effect 101*, NAT. RES. DEF. COUNCIL (June 5, 2023), https://www.nrdc.org/stories/greenhouse-effect-101#whatis [https://perma.cc/P2R6-3T8M].

23. *Id.*

24. *See* Lovejoy, *supra* note 19, at 170–76.

25. *See id.* at 170–73; *Greenhouse Effect 101*, *supra* note 22.

caused a shift in migratory and mating patterns of several species of animals with limited tolerance for warmer weather.[26] While these species move northward to colder climates, at some point they will no longer have anywhere to go.[27] Conversely, species that prefer warmer climates begin to thrive and cause large disruptions in local ecosystems.[28] For example, warmer climates have led to such a significant increase in bark beetles, a species that infests coniferous trees, that the amount of carbon released from trees killed by bark beetles exceeded the amount of carbon released from trees killed by fire.[29]

Leading climate scientists have warned about the exponentially negative impacts of an increasingly warmer climate that could occur as early as 2030.[30] The ocean has already seen noticeable increases in acidity due to increased absorption of carbon dioxide.[31] When absorbed by the ocean, carbon dioxide (CO_2) combines with water (H_2O) to form carbonic acid (H_2CO_3).[32] Additionally, the melting of glaciers adds neutral pH water to the oceans—which are otherwise basic—further increasing acidity.[33] These small increases in acidity can interfere

26. *See* Sofie Bates, *Arctic Animals' Movement Patterns Are Shifting in Different Ways as the Climate Changes,* NASA (Nov. 20, 2020), https://www.nasa.gov/feature/goddard/2020/arctic-animals-movement-patterns-are-shifting-in-different-ways-as-the-climate-changes [http://perma.cc/GF8B-6A6T] (citing three studies, including "a long-term study of eagle migrations, a massive study on caribou populations, and a multi-species study focusing on several predator and prey species").

27. *See* Lovejoy, *supra* note 19, at 172.

28. *See, e.g.*, Bentz & Klepzig, *supra* note 19. For example, warmer climates have led to such a significant increase in bark beetles, a species that infests coniferous trees, that the amount of carbon released from trees killed by bark beetles exceeded the amount of carbon released from trees killed by fire. *Id.*

29. *Id.*

30. IPCC, *Summary for Policymakers 2018*, *supra* note 14, at iv; *see, e.g.*, Brad Plumer, *Climate Change Is Speeding Toward Catastrophe. The Next Decade Is Crucial, U.N. Panel Says.*, N.Y. TIMES, https://www.nytimes.com/2023/03/20/climate/global-warming-ipcc-earth.html [https://perma.cc/78JF-NKU8] (Sept. 13, 2023) (stating that by the early 2030s, the earth will experience "the impacts of catastrophic heat waves, flooding, drought, crop failures and species extinction become significantly harder for humanity to handle").

31. *Ocean Acidification*, NOAA, https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification [https://perma.cc/9AXJ-ZN95] (Apr. 1, 2020).

32. *Id.*

33. Stacey C. Reisdorph, Jeremy T. Mathis & Lewis Sharman, *Ocean Acidification in Glacier Bay*, NAT'L PARK SERV., https://www.nps.gov/articles/oceanacidificationinglacierbay.htm [https://perma.cc/8BJA-EBBA] (Oct. 26, 2021); *see* Harold F. Upton & Peter Folger, Cong. Rsch.

with calcifying organisms—shelled animals such as coral, oysters, and clams—and their ability to form calcium carbonate necessary to develop their shell.[34] A decline in, or extinction of, shelled organisms could have dramatic effects on the marine ecosystem food chain.[35]

B. *The Global Mean Temperature*

On its face, an increase in global mean temperature of 2.0 degrees Celsius (or 3.6 degrees Fahrenheit)[36] may not sound too significant; after all, the temperature on any given day can fluctuate by at least 2.0 degrees and no one thinks twice. However, that 2.0 degrees represents an increase in the *average, annual* temperature of the Earth.[37] Because this reflects a global mean, some areas of the globe are projected to experience much greater increases than others.[38] This increase is relative to pre-industrial periods before the rate of warming began to significantly increase.[39] To maintain the goal of staying under a 2.0-degree increase, the Earth would have to reach a homeostatic average annual temperature below the limit of a 2.0-degree increase—that is, the Earth would have to maintain the same annual average temperature.[40] Climate scientists developed these

Serv., R40143, OCEAN ACIDIFICATION 1–2 (2013); *see also* Water Science School, *PH Scale*, U.S. GEOLOGICAL SURV. (June 19, 2019), https://www.usgs.gov/media/images/ph-scale-0 [https://perma.cc/VZ3L-CBEJ].

34. Upton & Folger, *supra* note 33, at 1–2; *Ocean Acidification*, INTEGRATED OCEAN OBSERVING SYS., https://ioos.noaa.gov/project/ocean-acidification [https://perma.cc/4M6K-UHYT].

35. *See* Upton & Folger, *supra* note 33, at 1–2; Scott C. Doney, *The Dangers of Ocean Acidification*, 294 SCI. AM. 58, 60 (2006); T. P. Sasse, B. I. McNeil, R. J. Matear & A. Lenton, *Quantifying the Influence of CO2 Seasonality on Future Aragonite Undersaturation Onset*, 12 BIOGEOSCIENCES 6017, 6028 (2015) ("Ocean acidification is a global issue which is likely to impact the entire marine ecosystem – from plankton at the base of the food chain to fish at the top.").

36. For the remainder of this Note, temperatures will be measured in degrees Celsius.

37. Rebecca Lindsey & Luann Dahlman, *Climate Change: Global Temperature*, CLIMATE.GOV (Jan. 18, 2024), https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature [https://perma.cc/A3ND-9X5K].

38. Hoegh-Guldberg et al., *supra* note 16, at 177.

39. *See* James Hansen, Makiki Sato, Reto Ruedy, Ken Lo, David W. Lea & Martin Medina-Elizade, *Global Temperature Change*, 103 PNAS 14288, 14288 (2006); *see also* Lindsey & Dahlman, *supra* note 37. "Pre-industrial periods" are usually assumed to start around 1850. *See id.*

40. Paris Agreement to the United Nations Framework Convention of Climate Change art. 2(1)(a), Dec. 12, 2015, T.I.A.S. No. 16-1104 [hereinafter Paris Agreement]; *see also* Lindsay Fendt,

predictions based on a system of "Representative Concentration Pathways" that analyze the environment under different conditions of pollution over time.[41] The global mean temperature data is based on an average of temperatures at locations across the world tracked over time.[42] While the "average temperature of the entire globe" may seem meaningless to any one region,[43] the data shows that the world has been getting hotter at an increasing rate.[44] Generally, a 1.5–2.0-degree increase is considered the point at which the effects of climate change become dangerous.[45]

Presently, studies have placed the global mean temperature at almost 1.0 degree above pre-industrial averages.[46] The Intergovernmental Panel on Climate Change ("IPCC") predicts that an increase in global temperature as small as 1.5 degrees could have significant environmental consequences including rising ocean levels and increasing heatwaves, droughts, and heavy precipitation.[47] A 2018 IPCC special report laid out the dangers of climate change if temperatures increase more than 1.5 degrees and identified significantly worse conditions if the Earth

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Why Did the IPCC Choose 2 Degrees Celsius as the Goal for Limiting Global Warming?, MIT CLIMATE PORTAL (June 22, 2021), https://climate.mit.edu/ask-mit/why-did-ipcc-choose-2deg-c-goal-limiting-global-warming [https://perma.cc/GUL6-HVJ8] (explaining two degrees Celsius was chosen as the upper limit for climate change because this increase would produce "dramatic alterations to the ability of the Earth's system to maintain the conditions that allow for human life and indeed other species' life") (internal citation omitted).

41. *See What Are RCPs?*, COASTADAPT, https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf [https://perma.cc/5CQB-FH8B].

42. Lindsey & Dahlman, *supra* note 37; *see also* NAT'L RSCH. COUNCIL, RECONCILING OBSERVATIONS IN GLOBAL TEMPERATURE CHANGE 7–9 (2000) ("In order to estimate globally averaged temperature changes with a high degree of accuracy, it is necessary to have a broad spatial distribution of observations that are made with high precision.").

43. NAT'L RSCH. COUNCIL, *supra* note 42, at 9. The numerical value can be translated to "how much sunlight Earth absorbs minus how much it radiates to space as heat." Lindsey & Dahlman, *supra* note 37.

44. *See* Lindsey & Dahlman, *supra* note 37; *see also* NAT'L RSCH. COUNCIL, *supra* note 42, at 9–10.

45. *See* Hoegh-Guldberg et al., *supra* note 16, at 177–81. Scientists have predicted severe and irreversible damage may begin to occur at a global mean temperature of 1.5 degrees Celsius above pre-industrial temperatures. *Id.* at 177.

46. Lindsey & Dahlman, *supra* note 37.

47. *See* Hoegh-Guldberg et al., *supra* note 16, at 187–88.

were to approach the 2.0-degree goal set by the Paris Agreement,[48] an international treaty that the United States rejoined in 2021.[49] Still, the goal of maintaining a global temperature less than 2.0 degrees above pre-industrial levels appears less and less attainable considering the rising global mean temperature despite extensive global environmental regulation.[50] For reference, the last time the Earth maintained an annual mean temperature 3.0 degrees above pre-industrial temperatures was three million years ago and when sea levels were up to 20 meters higher.[51] Scientists estimate current mean global temperature increases to be around 0.2 degrees per decade and rising over the last thirty years.[52] The IPCC's special report also notes that reaching temperatures above a 1.5-degree increase may result in significantly worse conditions, even if the Earth eventually returned to more acceptable levels.[53] These impacts include "increased wildfires, mass mortality of trees, drying of peatlands, and thawing of permafrost."[54] Because several severe effects of climate change are permanent or long lasting, environmental impacts would be significantly better if the Earth could maintain temperature stability at or below a 1.5-degree increase

48. *See id.* at 177–82; Paris Agreement, *supra* note 40.

49. Elian Peltier & Somini Sengupta, *U.S. Rejoins the Paris Climate Accord.*, N.Y. TIMES (Feb. 19, 2021), https://www.nytimes.com/2021/02/19/world/us-rejoins-paris-climate-accord.html [https://perma.cc/Z2NY-WXDG].

50. *See* Lindsey & Dahlman, *supra* note 37. *See generally* HOHMANN, *supra* note 13, at 6–10 (discussing the world's precautionary approach to environmental regulation).

51. *See* NICHOLAS STERN, JOSEPH STIGLITZ, KRISTINA KARLSSON & CHARLOTTE TAYLOR, A SOCIAL COST OF CARBON CONSISTENT WITH A NET-ZERO CLIMATE GOAL 5 at n.4 (2022) https://rooseveltinstitute.org/wp-content/uploads/2022/01/RI_Social-Cost-of-Carbon_202201-1.pdf [https://perma.cc/E2YT-MWUF] [hereinafter STERN ET AL., NET-ZERO].

52. Hansen et al., *supra* note 39, at 14288.

53. IPCC, *Summary for Policymakers*, *in* CLIMATE CHANGE 2022: IMPACTS, ADAPTATION AND VULNERABILITY 19 (Hans-O. Pörtner, Debra C. Roberts, Elvira Poloczanska, Katja Mintenbeck, M. Tignor, Andrés Alegría, Marlies Craig, Stefanie Langsdorf, Sina Löschke, Vincent Möller & Andrew Okem eds., 2022) [hereinafter IPCC, *Summary for Policymakers 2022*] ("Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (*medium confidence*) and some will be irreversible, even if global warming is reduced (*high confidence*).").

54. *Id.* at 20.

rather than exceeding 1.5 degrees and having to lower the temperature.[55]

C. *Net Zero Emissions Plans*

To achieve temperature stability before exceeding proposed mean global temperature caps, Earth would have to reflect the same amount of sunlight into space as it receives.[56] Pollution of greenhouse gases such as carbon dioxide reduce the amount of sunlight the Earth reflects back into space—this is known as the "greenhouse gas effect."[57] Maintaining a static global temperature requires long-term emissions plans to reach "net zero"—an environment where the amount of greenhouse gases emitted is equal to the greenhouse gases removed from the atmosphere.[58] In other words, if the level of "stuff" affecting the global temperature is maintained, global temperature will also remain the same.[59] Governments and corporations have begun to pledge their support for "net zero" emissions plans.[60] Notably, President Biden's net-zero emissions goal is based on the timeline used in the Paris Agreement[61] for the global mean

55. *See* Hoegh-Guldberg et al., *supra* note 16, at 177.

56. *See* Rebecca Lindsey, *Climate and Earth's Energy Budget*, EARTH OBSERVATORY (Jan. 14, 2009), https://earthobservatory.nasa.gov/features/EnergyBalance [https://perma.cc/3XGV-BY2T]; *For a Livable Climate: Net-Zero Commitments Must be Backed by Credible Action*, UNITED NATIONS, https://www.un.org/en/climatechange/net-zero-coalition [https://perma.cc/7HZ3-G6BZ] (defining "net-zero").

57. *See What Is the Greenhouse Effect?*, NASA, https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect/ [https://perma.cc/4664-ABRF] (explaining how gases such as carbon dioxide, methane, and nitrous oxide in the atmosphere trap heat in the Earth's atmosphere, producing a warming effect).

58. *For a Livable Climate: Net-Zero Commitments Must be Backed by Credible Action*, *supra* note 56.

59. *See id.*

60. *See, e.g.*, Press Release, White House, President Biden's FY 2023 Budget Reduces Energy Costs, Combats the Climate Crisis, and Advances Environmental Justice (Mar. 28, 2022), https://www.whitehouse.gov/omb/briefing-room/2022/03/28/president-bidens-fy-2023-budget-reduces-energy-costs-combats-the-climate-crisis-and-advances-environmental-justice/ [https://perma.cc/Q3YU-UHZP] [hereinafter White House Press Release: FY 2023 Budget] (noting that the Budget would "put America on a path to reduce greenhouse gas emissions 50-52 percent by 2030"); *The Climate Pledge*, AMAZON, https://www.aboutamazon.com/planet/climate-pledge [https://perma.cc/S3L5-S6MY].

61. The Paris Agreement required countries to set emission targets consistent with holding the increase in global average temperature below 2.0 degrees Celsius by 2050. *See* Paris

temperature.[62] This correlates with research that suggests that, at the current rate of increasing average global temperature, the world needs to reach net zero emissions by 2050.[63]

The move toward net zero emissions by countries and companies is certainly a significant step toward achieving global mean temperature stability goals, but not all emissions plans are created equal.[64] Generally, "net zero" means reducing emissions levels and investing in emission setoffs such that an entity's net impact results in no additional emissions in the atmosphere.[65] For example, if a factory produced 100 tons of carbon dioxide, it could plant trees or invest in other carbon dioxide removal projects to remove 100 tons of carbon dioxide from the atmosphere. However, this "net zero" can be deceptively limited to certain parts of the emission supply chain.[66] A company's "net zero" emissions plan could apply to its factories, where emissions *directly* produced by product manufacturing may be net zero, but might fail to reduce the emissions produced by product shipment, workers' transportation, raw material usage, or even emissions by the product itself.[67] In 2021, President Biden issued an executive order announcing his intent to supply zero emission vehicles for government fleets and pledged a goal of a net zero emission economy by 2050.[68] This net zero emissions trend is certainly a positive sign for reaching climate goals, but the global mean temperature can only be sustained

Agreement, *supra* note 40, at art. 2, ¶1(a); *For a Livable Climate: Net-Zero Commitments Must be Backed by Credible Action*, *supra* note 56; White House Press Release: FY 2023 Budget, *supra* note 60.

62. *See* Exec. Order No. 14008, 86 Fed. Reg. 7622 (Jan. 27, 2021); *see also* White House Press Release: FY 2023 Budget, *supra* note 60.

63. *For a Livable Climate: Net-Zero Commitments Must Be Backed by Credible Action*, *supra* note 56; *see* Joeri Rogelj, Drew Shindell, Kejun Jiang, Solomone Fifita, Piers Forster, Veronika Ginzburg, Collins Handa, Haroon Kheshgi, Shigeki Kobayashi, Elmar Kriegler, Luis Mundaca, Roland Séférian & Maria Virginia Vilariño, *Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development*, *in* GLOBAL WARMING OF 1.5°C 32, 95 (2018).

64. *See* Emily Pontecorvo & Jesse Nichols, *Companies Say They Are Going Net-Zero. Can We Trust Them?*, GRIST (Nov. 10, 2020), https://grist.org/energy/companies-say-they-are-going-net-zero-can-we-trust-them/ [https://perma.cc/5EQN-BZ9C].

65. *See* Rogelj et al., *supra* note 63, at 95–97.

66. *See id.*

67. *See id.*

68. Exec. Order No. 14008, 86 Fed. Reg. 7622, 7624 (Jan. 27, 2021).

by a transition to "true" net zero emissions, where every element of production, shipping, and energy use has a net zero impact.[69] Net zero emissions plans have expanded the sustainability reporting industry and several firms have emerged to advise companies on how to monitor and plan for true net zero goals.[70]

The final transition to net zero emissions will ultimately require widespread shifts toward electric vehicles and clean power such as wind and solar.[71] Existing net zero models allow for cap-and-trade regimes which offset the net emissions from a given source, but sequestration credits are often overvalued compared to their long-term impact on atmospheric emissions.[72] In theory, this works just fine: an entity produces X tons of carbon dioxide and pays to plant trees projected to remove an equal amount of carbon from the atmosphere.[73] This is called carbon sequestration.[74] In practice however, the planted trees do not permanently sequester carbon: if a natural forest fire burns them down, the trees are later cut down for development, or they otherwise die and decompose, carbon is released back into the atmosphere.[75] This leaves the carbon produced by the emitting entity unaccounted for.[76] Therefore, providing credits for investment in temporary carbon storage simply absolves liability and defers emissions in a way inconsistent with net zero

69. *See id.* at 7622; Pontecorvo & Nichols, *supra* note 64.

70. *See, e.g.*, Maria Mendiluce, *A Guide to Achieving Net Zero Emissions*, HARV. BUS. REV. (Nov. 10, 2022), https://hbr.org/2022/11/a-guide-to-achieving-net-zero-emissions [https://perma.cc/CHM4-P6PW].

71. *See* INT'L ENERGY AGENCY, NET ZERO BY 2050: A ROADMAP FOR THE GLOBAL ENERGY SECTOR, 14 (Edmund Hosker & Debra Justus eds., 4th rev. 2021).

72. *See* James Temple, *Landowners Are Earning Millions for Carbon Cuts that May Not Occur*, MIT TECH. REV. (Apr. 18, 2019), https://www.technologyreview.com/2019/04/18/65883/californias-cap-and-trade-program-may-vastly-overestimate-emissions-cuts/ [https://perma.cc/27NS-SCHZ]; Kenneth R. Richards, *A Brief Overview of Carbon Sequestration Economics and Policy*, 33 ENV'T MGMT. 545, 552, 554–55 (2004).

73. *See* Richards, *supra* note 72, at 545–46, 550.

74. *See id.* at 545, 554.

75. *See id.* at 554; Hal Bernton, *A Giant Oregon Wildfire Shows the Limits of Carbon Offsets in Fighting Climate Change*, OPB (Aug. 2, 2023, 8:00 AM), https://www.opb.org/article/2023/08/02/climate-change-carbon-offset-oregon/ [https://perma.cc/53CX-CXSN].

76. Richards, *supra* note 72, at 553–54; Bernton, *supra* note 75.

emissions and temperature stability goals. The foregoing evidence of the high-impact, negative effects of failing to meet emissions goals highlights the need for legislation and supporting regulation to ensure such consequences are never realized.

II. REGULATION AROUND THE GLOBE

Over the last 30 years, environmental regulation has evolved and diverged into three primary schools of thought: a cost-benefit model that seeks to manipulate incentives to correct the market failure of the environment, a precautionary model that favors regulating to prevent as much harm as reasonably possible, and a target-consistent model that uses economic analysis to meet a specific goal set with precaution in mind.[77] Traditional cost-benefit environmental regulation uses economic principles to identify the value of environmental harms and regulates in accordance with projected costs.[78] Critics of this model identify the significant—sometimes paralyzing—uncertainty that characterizes its predictive valuations.[79] Additionally, the traditional framework provides no guarantee that it will meet its stated climate goals because its method for valuing environmental regulation does not account for whether these goals are met.[80] In response to these criticisms, several countries have adopted a precautionary approach that favors regulation any time there is a probability of significant harm.[81] However, the precautionary principle has been criticized for being inherently suboptimal and neglecting the scarcity of resources.[82] The target-consistent approach has been employed in the UK and finds

77. *See* HOHMANN, *supra* note 13, at 9–12; DEP'T OF ENERGY & CLIMATE CHANGE, Carbon Valuation in UK Policy Appraisal: A Revised Approach 2–3 (2009).

78. Tommi Ekholm, *Climatic Cost-Benefit Analysis Under Uncertainty and Learning on Climate Sensitivity and Damages*, 154 ECOLOGICAL ECONS. 99, 99–100 (2018).

79. *Id.*

80. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 5–6, 11–12.

81. OECD, UNDERSTANDING AND APPLYING THE PRECAUTIONARY PRINCIPLE IN THE ENERGY TRANSITION 24–25 (2023); *see* Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1013–14. ("The Final Declaration of the First European Seas at Risk Conference says that if 'the "worst case scenario" for a certain activity is serious enough then even a small amount of doubt as to the safety of that activity is sufficient to stop it taking place.'").

82. Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1004–05, 1019.

a balance by using marginal abatement costs to calculate the regulation necessary to meet specific climate goals.[83] However, this model is still subject to some uncertainty.[84] In the following sections, this Note will take a closer look at each framework to highlight their policies and concerns next to one another.

A. *The Traditional Economic Approach: The American Model*

Traditional environmental regulation is founded on economic principles.[85] This framework internalizes environmental externalities—applies a value to the environment and a cost for harming it—using market forces to incentivize climate goals.[86] The United States still uses this model based on a cost-benefit analysis.[87]

1. *Economics and environmental law*

The traditional economic approach to environmental regulation treats the environment as a common good.[88] This model applies principles of economic optimization to climate change to address the natural race to the bottom incentivizing entities to create as much pollution as fast as possible.[89] Economists dub

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83. DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 2–3; James Ashworth, *The Cost of Carbon Dioxide May Be Four Times Higher than Thought*, NAT. HIST. MUSEUM (Sept. 1, 2022), https://www.nhm.ac.uk/discover/news/2022/september/cost-carbon-dioxide-four-times-higher-than-thought.html [https://perma.cc/XF2B-BB2Q].

84. *See* Justin Gundlach & Michael A. Livermore, *Costs, Confusion, and Climate Change*, 39 YALE J. ON REGUL. 564, 583 (2022) (discussing marginal abatement cost curves).

85. *See generally* Ronald C. Griffin, *The Fundamental Principles of Cost-Benefit Analysis*, 34 WATER RES. RSCH., 2063, 2063 (1998) (discussing cost-benefit analyses based on welfare economics).

86. *See* Cass R. Sunstein, *Cost-Benefit Analysis and the Environment*, 115 ETHICS 351, 351–53 (2005) [hereinafter Sunstein, *CBA and the Environment*]; OECD, COST-BENEFIT ANALYSIS AND THE ENVIRONMENT: FURTHER DEVELOPMENTS AND POLICY USE 3 (2018); U.S. AGENCY FOR INT'L DEV.: OFF. OF ENERGY & INFRASTRUCTURE, ENVIRONMENTAL EXTERNALITIES: AN ASEAN APPLICATION TO COAL-BASED POWER GENERATION 2–3 (1992) (defining environmental externalities).

87. *See CGE Modeling for Regulatory Analysis*, EPA, https://www.epa.gov/environmental-economics/cge-modeling-regulatory-analysis [https://perma.cc/R4E6-BDKL] (Sept. 8, 2023).

88. *See* Barton H. Thompson, Jr., *Tragically Difficult: The Obstacles to Governing the Commons*, 30 ENV'T L. 241, 242 (2000).

89. *See id.*

this game-theoretic model the "tragedy of the commons."[90] The tragedy of the commons occurs where a free good—in this case clean air—is limited in quantity and owned by multiple entities—in this case the world.[91] Because clean air is free and limited in quantity, everyone is incentivized to take—in this case pollute—as much as possible to gain the most benefit out of the limited resource before someone else does the same.[92] Environmental regulation responds to this scenario by setting a price for pollution through regulation—establishing liability for polluters, limiting the quantity and efficiency of polluting sources through permitting, and pursuing lower emission goals by imposing increasingly stringent standards.[93]

A market failure also results from the reality that environmental regulations passed today will have the greatest impact on future generations, rather than the decisionmakers of today.[94] This leads to an inherent undervaluation of the environment.[95] Environmental regulations seek to address this problem by creating a more concrete price for future, long-lasting harms.[96] To accomplish this, environmental regulators must understand the value of the harm to effectively incentivize preferable behavior and evaluate government investment in regulation.[97] Enter: the social costs of climate change.

90. *See id.* at 242, 246.

91. Alexandra Spiliakos, *Tragedy of the Commons: What It Is and 5 Examples*, HARV. BUS. SCH. (Feb. 6, 2019), https://online.hbs.edu/blog/post/tragedy-of-the-commons-impact-on-sustainability-issues [https://perma.cc/3C79-NVSH] ("The tragedy of the commons refers to a situation in which individuals with access to a public resource (also called a common) act in their own interest and, in doing so, ultimately deplete the resource.").

92. *See* Thompson, *supra* note 88, at 242.

93. *See, e.g.*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. §§ 9602, 9607, 9609.

94. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 4, 7.

95. *See id.* at 4, 7–9.

96. *See id.* at 11–13.

97. *See id.*

2. *Social costs*

The United States uses social costs to determine the value of environmental regulation.[98] Social costs are the societal cost of a decision or course of action based on what society is willing to pay to obtain or avoid the consequences.[99] For example, the social cost of carbon represents the societal cost, including the harm to the environment, of emitting a marginal amount of additional carbon dioxide into the atmosphere.[100] Generally, the cost is measured in dollars per ton of carbon dioxide.[101] The social cost of carbon is perhaps the most commonly referred-to social cost of climate change, but the concept applies to other emission sources like methane and nitrous oxide as well.[102]

The social cost of carbon was first considered in a cost-benefit analysis by the courts in *Center for Biological Diversity v. National Highway Safety Administration*, where the Center for Biological Diversity challenged fuel economy standards that valued climate damage at zero dollars because they failed to consider the future impact on climate change.[103] In response, President Obama established an Interagency Working Group (IAWG) to determine the social cost of greenhouse gas emissions.[104] The IAWG used three Integrated Assessment Models (IAMs) to

98. Renee Cho, *Social Cost of Carbon: What Is It, and Why Do We Need to Calculate It?*, COLUMBIA CLIMATE SCH. (Apr. 1, 2021), https://news.climate.columbia.edu/2021/04/01/social-cost-of-carbon/ [https://perma.cc/8F8B-W8R6]; *see* INTERAGENCY WORKING GRP. ON SOC. COST CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866 3–4 (2010) [hereinafter OBAMA ADMIN. IAWG REPORT].

99. *See* 40 C.F.R. § 125.92(y) (2024). ("[A social cost] is the sum of all opportunity costs associated with taking actions. [It] consist[s] of the value lost to society of all the goods and services that will not be produced and consumed . . . .").

100. Cho, *supra* note 98.

101. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 1.

102. *Social Cost of Carbon*, ENERGY POL'Y INST. UNIV. CHI., https://epic.uchicago.edu/area-of-focus/social-cost-of-carbon/ [https://perma.cc/BA3W-NBD7]; *see* INTERAGENCY WORKING GRP. ON SOC. COSTS OF GREENHOUSE GASES, U.S. GOV'T, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON, METHANE, AND NITROUS OXIDE INTERIM ESTIMATES UNDER EXECUTIVE ORDER 13990 2 (2021) [hereinafter BIDEN ADMIN. IAWG REPORT].

103. *See* Ctr. for Biological Diversity v. Nat'l Highway Safety Admin., 508 F.3d 508, 513 (9th Cir. 2007), *vacated*, 538 F.3d 1172 (2008).

104. OBAMA ADMIN. IAWG REPORT, *supra* note 98, at 1; STERN ET AL., NET-ZERO, *supra* note 51, at 3.

calculate the social cost of carbon: Dynamic Integrated Climate-Economy (DICE); Climate Framework for Uncertainty, Negotiation, and Distribution (FUND); and Policy Analysis of the Greenhouse Effect (PAGE).[105] Each IAM uses distinct equations to calculate the social cost of carbon by considering different measurements of predicted damages, assumed preferences, and assumed variables affecting preferences.[106] Of course, predicting future environmental damage comes with many assumptions and much uncertainty, which is a major criticism of this approach.[107]

The social cost of carbon is calculated using the predicted damages caused by climate change per additional ton of carbon added to the atmosphere, discounted by an assumed percentage for future damages.[108] The discount rate presents a significant point of contention that critically affects final calculations.[109] Generally, economists account for the value of goods received—or damages realized—in the future by discounting part of the value on the principle that having something now is preferable to having it in the future.[110] For example, $100 today is worth more than $100 in 10 years because of its immediate liquidity and potential increase in value if invested. When applied to climate change, most damages to the environment are realized years after emissions enter the atmosphere, so the present value of future damages can be greatly affected by the discount rate.[111] In other words, a discount rate of 5% would mean that $100 of climate damages next year would be equivalent to

105. OBAMA ADMIN. IAWG REPORT, *supra* note 98, at 5–8; *see* William D. Nordhaus, *Revisiting the Social Cost of Carbon*, 114 PNAS 1518, 1521–22 (2017) (comparing the DICE IAM social cost of carbon estimates with PAGE and FUND).

106. OBAMA ADMIN. IAWG REPORT, *supra* note 98, at 5–9; *see* Nordhaus, *supra* note 105, at 1518–23.

107. *See* Nicholas Stern, Joseph Stiglitz & Charlotte Taylor, *The Economics of Immense Risk, Urgent Action, and Radical Change: Towards New Approaches to the Economics of Climate Change*, 29 J. ECON. METHODOLOGY 181, 189–91 (Feb. 24, 2022) [hereinafter Stern et al., *Towards New Approaches*].

108. *See* OBAMA ADMIN. IAWG REPORT, *supra* note 98, at 1–3.

109. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 3–4, 7–8.

110. *See id.* at 7–8; David J. Torgerson & James Raftery, *Discounting*, 319 BMJ 914, 914–15 (1999) (providing an overview of discounting in economics).

111. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 7.

$95 dollars of damages in the present, and a rational investor would be willing to spend up to $95 to avoid the loss. The yearly compounding of discounts can lead to significant undervaluation of damages in the future. If the discount rate is high, this signals that the government should only invest a small amount of resources today to prevent damages in the future.[112] While the discount rate is sensible in theory, it is highly manipulable.[113] Under the Trump Administration, the Environmental Protection Agency (EPA) evaluated costs using discount rates at 3 and 7 percent—as opposed to the previous administration's 2.5, 3, and 5 percent—and accounted only for the proportionate impact to the United States rather than the global environment.[114] The result was a reduced social cost of carbon to $8 per ton projected in 2030 compared to $50 per ton in 2030 under President Obama.[115] Economists typically recommend between a one percent and three percent discount rate for the social cost of carbon.[116] When President Biden took office, he reinstated the IAWG to recalculate the social costs of greenhouse gases, which opted to revert to the numbers used under the Obama Administration.[117]

The social cost of climate change is inexplicably tied to the use of an economic cost-benefit analysis to determine damages and evaluate policy regulations.[118] As applied, the government can use the social cost of carbon to consider the value of limiting carbon dioxide in the ambient air and efficiently allocate resources to limit emissions.[119] For example, a proposed

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112. *See id.* at 7–8.

113. *See, e.g.*, Brad Plumer, *Trump Put a Low Cost on Carbon Emissions. Here's Why It Matters.*, N.Y. TIMES (Aug. 23, 2018) https://www.nytimes.com/2018/08/23/climate/social-cost-carbon.html [https://perma.cc/72NL-AV3F] [hereinafter Plumer, *Trump Put a Low Cost on Carbon Emissions*].

114. *Id.*

115. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 3.

116. Cho, *supra* note 98.

117. STERN ET AL., NET-ZERO, *supra* note 51, at 3–4; *see* Exec. Order No. 13990, 86 Fed. Reg. 7037, 7040 (Jan. 20, 2021).

118. KEVIN RENNERT & CORA KINGDON, RES. FOR THE FUTURE, SOCIAL COST OF CARBON 101 (2019), https://media.rff.org/documents/SCC_Explainer.pdf [https://perma.cc/P36U-6DN3].

119. *See id.*

regulation that costs $10 million dollars to implement and removes or prevents $12 million worth of carbon dioxide emissions is a worthwhile return on investment of government funds. While subjective assumptions, scientific uncertainty, and concerns about application to climate goals underlie the calculation of the social cost of carbon, it remains the traditional method of environmental regulation in the United States.[120]

3. *Cost-benefit is overly quantitative*

In theory, social costs provide a straightforward analysis that objectively optimizes government resources to provide the greatest societal benefit. If calculated perfectly, the social cost of carbon could provide regulating bodies with the exact cost necessary to safeguard against climate change, assuming society values sustainability.[121] However, high degrees of uncertainty and the propensity for data manipulation are valid criticisms of the economic framework. Because there is no way to definitively predict the future, the model can only guarantee a cost-effective environment, not necessarily a habitable one.

As with any economic model, imperfect information and uncertainty are limits to the efficacy of the traditional cost-benefit framework. Generally, economic models assume "perfect information," meaning that all entities in the problem know all elements of the problem, but this is seldom—if ever—the case.[122] In terms of the environment, there are an innumerable amount of unknown variables, including the complete consequences of climate change at different pollution levels, the temperature increase for each unit of emissions, the actual costs of future

120. *See* Sunstein, *CBA and the Environment*, *supra* note 86, at 351–52, 355–56.

121. *Cf.* Nordhaus, *supra* note 105, at 1518–19 (explaining the DICE IAM and its underlying equations that calculate the social cost of carbon, if certain assumed variables are correct, such as the discount rate on welfare).

122. *Game Theory I: Perfect Information*, POLICONOMICS, https://policonomics.com/lp-game-theory1-perfect-imperfect-information/ [https://perma.cc/8HFF-FSK2]. "Perfect information refers to the fact that each player has the same information that would be available at the end of the game." *Id.* In contrast, "[i]mperfect information appears when decisions have to be made simultaneously, and players need to balance all possible outcomes when making a decision." *Id.*

damages, the development and cost of new technologies to combat climate change and the cost to develop them—the list continues.[123] Even the world's leading climate scientists cannot predict the effects of climate change with absolute certainty.[124] The most severe effects of climate change cannot be modeled or quantified accurately because the long-term and compounding environmental changes are not well studied.[125] For example, the long-term severe effects of climate feedback loops[126] are understood well enough to know they are a predictable result of climate change, but not enough to know exactly how those effects will be realized.[127] Despite this uncertainty, the international goal to limit the global mean temperature increase to 1.5 or 2.0 degrees was created considering the existing social cost of carbon and the extreme risk suggested by scientific evidence.[128]

The existing formula for calculating the social cost of carbon assumes economic growth is independent of the harms that result from climate change.[129] This faulty assumption leads to a gross underestimation of the social costs.[130] The known and

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123. *See generally* STERN ET AL., NET-ZERO, *supra* note 51, at 5–6 (describing some inherent uncertainties).

124. *See, e.g.*, Hoegh-Guldberg et al., *supra* note 16, at 177, 183 (noting the uncertainty in the IPCC report on global warming above 1.5 degrees Celsius); *see also* STERN ET AL., NET-ZERO, *supra* note 51, at 5 ("These models also cannot deal with the unknown unknowns of climate change and never will be able to, even if the models are improved.").

125. *See generally* RUTH DEFRIES, OTTMAR EDENHOFER, ALEX HALLIDAY, GEOFFREY HEAL, TIMOTHY LENTON, MICHAEL PUMA, JAMES RISING, JOHAN ROCKSTRÖM, ALEX C. RUANE, HANS JOACHIM SCHELLNHUBER, DAVID STAINFORTH, NICHOLAS STERN, MARCO TEDESCO & BOB WARD, THE MISSING ECONOMIC RISKS IN ASSESSMENTS OF CLIMATE CHANGE IMPACTS 3 (2019) (recognizing scientists' blind spots regarding potential future risks during an unprecedented era of climate change).

126. Climate feedback loops are cause-and-effect chains where one effect of climate change causes another, which then has an additional positive or negative effect on climate change. *See* Andrew Moseman, *Will Climate Feedback Loops Push Us Past a "Point of No Return"?*, MIT Climate Portal (Oct. 4, 2022), https://climate.mit.edu/ask-mit/will-climate-feedback-loops-push-us-past-point-no-return [https://perma.cc/SB8A-7W6B]. For example, when permafrost begins to melt, it releases greenhouse gases into the air, which then contributes to climate change, which increases the rate at which the permafrost melts and so forth. *See id.*

127. *See* DEFRIES ET AL., *supra* note 125, at 13 (describing several physical processes that are not well understood including ice shelf hydrology and dynamics, severe storms and floods, coastal erosion, and feedback loops like permafrost thaw).

128. Hoegh-Guldberg et al., *supra* note 16, at 264–65.

129. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 6–7.

130. *See id.*

realized effects of climate change alone—drought, severe weather, and wildfires, for example—have already had significant secondary effects on the economy.[131] For example, studies have found that climate change has direct impacts on labor productivity as well as research and development expenditure.[132] One study predicted that "rising temperatures could reduce U.S. economic growth by up to one-third over the next century."[133] Even small hinderances to economic growth can lead to large losses over time when left unaccounted for in calculations of the social cost of carbon.[134] Common sense provides that "loss of life, destruction of capital, collapses in biodiversity, mass migration and conflict [makes] this assumption appear[] untenable."[135] Loss of human life and permanent damage to the environment are arguably unquantifiable harms.[136] To the extent tort law has claimed a method of valuing intangible harms such as loss of human life or pain and suffering, the general harms attributable to climate change are far too widespread for any model to justify.[137]

131. *See* DEFRIES ET AL., *supra* note 125, at 13; Samer Fawzy, Ahmed I. Osman, John Doran & David W. Rooney, *Strategies for Mitigation of Climate Change: A Review*, 18 ENV'T CHEMISTRY LETTERS 2069, 2070 (2020) (explaining the economic losses associated with climate change induced natural disasters).

132. *See generally* Michael Donadelli, Patrick Grüning, Marcus Jüppner & Renatas Kizys, *Global Temperature, R&D Expenditure, and Growth*, 104 ENERGY ECON. 1, 1–3 (2021).

133. Riccardo Colacito, Bridget Hoffmann & Toan Phan, *Temperature and Growth: A Panel Analysis of the United States*, 51 J. MONEY, CREDIT & BANKING 313, 313 (2019).

134. STERN ET AL., NET-ZERO, *supra* note 51, at 6.

135. *Id.*

136. *See* Donald T. Hornstein, *Reclaiming Environmental Law: A Normative Critique of Comparative Risk Analysis*, 92 COLUM. L. REV. 562, 571–72 (1992).

137. *See generally Historic $5.15 Billion Environmental and Tort Settlement with Anadarko Petroleum Corp. Goes into Effect*, U.S. DEP'T OF JUST. (Jan. 23, 2015), https://www.justice.gov/opa/pr/historic-515-billion-environmental-and-tort-settlement-anadarko-petroleum-corp-goes-effect-0 [https://perma.cc/3LRJ-GYSN] (claiming that the trust receiving the compensation was still "expected to distribute more than $4.4 billion to fund environmental clean-up and for environmental claims" out of their $5.15 billion compensation); Pat Rizzuto, *PFAS Settlements of $11 Billion Only a Start for Water Utilities*, BLOOMBERG L. (June 8, 2023, 1:50 PM) https://news.bloomberglaw.com/environment-and-energy/pfas-settlements-of-11-billion-only-a-start-for-water-utilities [https://perma.cc/V9YE-62ZA] (claiming that even an $11 billion tort settlement against a polluting company is unlikely to be enough for water companies to deal with the long-term filtration requirements).

Social costs are also highly manipulable. Namely, manipulation of the discount rate, as shown by the differences between the Obama, Trump, and Biden Administrations' values, places the current methodology under great scrutiny.[138] On one hand, calculating the social cost of climate change creates a tangible, workable standard to compare and evaluate climate policy, but when the value being used is grossly subjective, the numerical value generated is somewhat arbitrary.[139] Even the lower discount rate applied by the Obama and Biden Administrations did not comport with economic literature that suggests an appropriate discount rate closer to 1%.[140]

Perhaps the most profound shortcoming of the economic framework is that it generally fails to consider net zero and global mean temperature goals recommended by prevailing scientific evidence.[141] The cost-benefit analysis in emissions regulation only reflects how much society is willing to pay to avoid climate change damages at the given price.[142] However, this algorithm provides no guarantee that society should prefer to meet set climate goals, nor does it guarantee a stable environment even if it could be calculated perfectly.[143] In some ways, the traditional economic approach attempts to answer whether the environment is worth saving at all, rather than making progress toward any solution.

B. *The Precautionary Principle: The International Model*

In response to the problems of the economic framework and a need for stricter environmental standards, many nations have

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138. *See supra* pp. 119–20.

139. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 1, 10–11.

140. *Compare* OBAMA ADMIN. IAWG REPORT, *supra* note 98 (electing to use discount rates of 2.5, 3, and 5 percent), *and* BIDEN ADMIN. IAWG REPORT, *supra* note 102, at 22 (electing to use discount rates of 2.5 to 5 percent), *with* STERN ET AL., NET-ZERO, *supra* note 51, at 8 (finding a discount rate of 1 percent).

141. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 11–12.

142. *See* Cho, *supra* note 98.

143. *See* Stern et al., *Towards New Approaches*, *supra* note 107, at 201; *see also Discounting and Time Preference*, NAT'L OCEANIC AND ATMOSPHERIC ADMIN., https://www.sfu.ca/~heaps/483/discounting.htm [https://perma.cc/G49D-NZX4].

moved toward a more precautionary approach to environmental regulation.[144] Whereas market forces created the environmental issue in the first place by creating a tragedy of the commons scenario, the precautionary principle removes risk and market incentives from the equation altogether.[145] While the precautionary principle exists to varying degrees of specificity,[146] it generally calls for regulation where there is risk of significant harm and gives much less consideration, if any, to the likelihood of that risk.[147] For the purposes of this Note, the precautionary principle will generally be construed in its more demanding form, since its weaker versions are so broad "to which no reasonable person could object."[148]

1. *Precautionary regulation*

International environmental law has seen a shift from a traditional economic model to a more precautionary model, dubbed the "precautionary principle."[149] The precautionary principle itself stems from the German policy of Vorsorgeprinzip that developed in the 1970s.[150] Many nations and treaties have developed varying degrees of required precautionary action, but the

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144. Cass R. Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1005 ("[The precautionary principle] is fast becoming a staple of regulatory policy.").

145. *Cf.* Jonathan B. Wiener, *The Rhetoric of Precaution*, *in* THE REALITY OF PRECAUTION: COMPARING RISK REGULATION IN THE UNITED STATES AND EUROPE 10 (Jonathan B. Wiener, Michael D. Rogers, James K. Hammitt & Peter H. Sand eds., 2011) (noting disputes in the World Trade Organization as to whether the precautionary principle is excluded where risk assessment is required).

146. *See generally* John S. Applegate, *The Taming of the Precautionary Principle*, 27 WM. & MARY ENV'T L. & POL'Y REV. 13 (2002) (providing an analysis of the varying definitions of the precautionary principle).

147. *See* Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1012–13.

148. *See id.* at 1012.

149. HOHMANN, *supra* note 13, at 11–12; *see also* Wiener, *supra* note 145, at 10–11 ("In international environmental law, the [precautionary principle] has been adopted in over 50 multilateral instruments . . . . Some have asserted that the [precautionary principle] may now be so widely adopted that it is ripening into an enforceable norm of customary international law.") (internal citations omitted).

150. Wiener, *supra* note 145, at 9. Vorsorgeprinzip is a policy that scientific uncertainty is not an excuse for failing to take reasonable measures to protect the environment. *Vorsorgeprinzip*, GEMET, https://www.eionet.europa.eu/gemet/de/concept/6623 [https://perma.cc/PQM3-R9V3] (Dec. 6, 2021).

strictest standards require regulatory action whenever there is risk of significant harm, no matter how small the risk.[151] Stated differently, the precautionary principle seeks to minimize harm rather than maximize benefit.[152] While the United States contains some elements of precaution in its environmental statutes,[153] it still maintains a largely economic analysis of environmental regulation overall.[154] The precautionary principle seeks to avoid worst-case scenario environmental catastrophe and places a high value on conservation at the expense of optimization.[155] Rather than assigning values to the environment and trying to optimize regulation, the precautionary principle treats the environment as an issue of utmost importance and favors environmental protection.[156] The precautionary principle also curbs regulatory inaction in the face of uncertainty.[157]

The precautionary principle ultimately seeks to address climate change to maintain a habitable Earth—a goal the traditional economic model lost in its efforts to maximize the allocation of resources.[158] Whereas the economic model seeks only to determine the amount of resources to invest in preserving the environment—and if it is worth the cost of saving—the

151. "According to the precautionary principle, potentially dangerous emissions and pollution must be prevented even if damage cannot be proven." HOHMANN, *supra* note 13, at 10. *See* Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1005–06; Wiener, *supra* note 161, at 10–11.

152. *See* Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1006.

153. *See, e.g.*, Clean Air Act, 42 U.S.C. § 7409 (requiring National Ambient Air Quality Standards be set "allowing an adequate margin of safety"); Tenn. Valley Auth. v. Hill, 437 U.S. 153, 194 (1978) (holding the Endangered Species Act of 1973 "afford[ed] endangered species the highest of priorities" by adopting "institutionalized caution").

154. *See generally* Sinden, *supra* note 12 (advocating for the United States to broaden its consideration beyond purely social costs).

155. *See, e.g.*, Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1013–14 ("The Final Declaration of the First European Seas at Risk Conference says that if 'the "worst case scenario" for a certain activity is serious enough then even a small amount of doubt as to the safety of that activity is sufficient to stop it taking place.'").

156. *See* HOHMANN, *supra* note 13, at 11–12.

157. Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1012.

158. *See* HOHMANN, *supra* note 13, at 11–12, 32.

precautionary principle primarily seeks to solve the problem first and determines the costs second, if at all.[159]

2. *Precaution is overly qualitative*

Although prioritization of safety may seem to be a sensible decision, the precautionary principle is far from perfect. The precautionary principle is inherently suboptimal, which is problematic when regulatory resources are finite and scarce.[160] Because regulating entities do not have unlimited resources, additional resources spent on the environment means less resources are available to be spent elsewhere.[161] In other words, if a nation were to adopt every method possible to prevent harm without regard for cost or risk probability, they would be foregoing actions that could provide more benefit to society, such as investing in infrastructure.[162] There is no rational[163] reason to take such precautions in one area of uncertain regulation over another area that may be a much more certain and consistent investment.[164] In fact, the precautionary principle involves very little empirical data, serving only as a loose guideline to regulate using precautionary standards set by a particular treaty or statute.[165]

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159. *See id.* at 10–12; *see also* ELLI LOUKA, INTERNATIONAL ENVIRONMENTAL LAW 73–75 (2006) (recognizing the international focus on equity in environmental law as opposed to domestic systems that are more cost-efficiency concerned).

160. *See* Sunstein, *Beyond the Precautionary Principle*, *supra* note 14, at 1017, 1019. The precautionary principle can be seen as inherently suboptimal because it inherently over-allocates resources to the environment—resources that could be more efficiently spent on other problems. *Id.*

161. *See id.* at 1019.

162. *See id.* at 1023.

163. Here, and throughout this Note, "rationality" (and by association, "irrationality") refers to the term in the economic sense that assumes decisions are made to optimize overall outcomes. *See What Is 'Rationality'?*, OUR ECON., https://www.ecnmy.org/learn/you/choices-behavior/what-is-rationality [https://perma.cc/CZ3Z-F3XE] ("Rationality, for economists, simply means that when you make a choice, you will choose the thing you like the best.").

164. *See* Sunstein, *Preferences and Rational Choice*, *supra* note 144, at 1028–29 ("[T]he selectivity of precautions is not merely an empirical fact; it is a conceptual inevitability. Simply as a logical matter, no society can be highly precautionary with respect to all risks.").

165. *See* Jose Felix Pinto-Bazurco, *The Precautionary Principle, Still Only One Earth: Lessons from 50 Years of UN Sustainable Development Policy*, IISD 2 (Oct. 2020), https://www.iisd.org/system/files/2020-10/still-one-earth-precautionary-principle.pdf [https://perma.cc/HDH5-PGPT].

Construed broadly, the precautionary principle is contradictory and paralyzing because environmental regulation can have detrimental side effects.[166] For example, while ground-level ozone has been found to cause certain health risks that warrant regulation, there is also evidence that it reduces the risks of cataracts and skin cancer.[167] A broad application of the precautionary principle would be contradictory when applied to this scenario, as the risk of health problems warrants regulation of ground-level ozone, but the risk of skin cancer and cataracts favors nonregulation.[168]

The rise of the precautionary principle has been attributed to *irrational* behavior explained by behavioral economic theories such as loss aversion and the availability heuristic.[169] Loss aversion is an economic phenomenon where losses are received more impactfully than equivalent gains.[170] In other words, a person's "happiness" decreases more from a loss more than it increases from a gain of the same amount.[171] The availability heuristic describes the tendency of people to assume the likelihood of an event based on how easily it comes to mind.[172] For example, a person would think plane crashes happen more often if they recently saw a plane crash on the news.[173] Professor Cass R. Sunstein, a well-known scholar in law and economics,[174] suggests that opportunity benefits are less obvious than the value of protecting the environment, and as such, the availability heuristic explains the irrational favor toward precautionary

166. *See* Sunstein, *Preferences and Rational Choice*, *supra* note 144, at 1023–24 (identifying situations where regulation would "run afoul of the precautionary principle" and deprive society of benefits such as the regulation of drugs, genetically modified foods, and ground-level ozone).

167. *Id.* at 1024.

168. *Id.* at 1023–24.

169. *See id.* at 1036–38, 1041–44.

170. Amos Tversky & Daniel Kahneman, *Loss Aversion in Riskless Choice: A Reference-Dependent Model*, 106 Q.J. ECON. 1039, 1047–48 (1991).

171. *See id.*

172. Amos Tversky & Daniel Kahneman, *Judgment Under Uncertainty: Heuristics and Biases*, 185 SCI. 1124, 1127–28 (1974).

173. *See id.* at 1127.

174. *Cass R. Sunstein*, HARV. L. SCH., https://hls.harvard.edu/faculty/cass-r-sunstein/ [https://perma.cc/93WA-G4QC].

regulation.[175] In the context of climate change, "[t]he precautionary principle often becomes operational only because of loss aversion, as people take precautions against potential losses from the status quo, but neglect potential benefits that would be unmistakable gains."[176] Sunstein also attributes the irrational popularity of the precautionary principle to "the myth of a benevolent nature,"—the belief that nature is, by default, good and the remaining health and safety risks are caused only by human intervention.[177] While human intervention has contributed to climate change and pollution, industrialization has provided some indirect benefits, such as technological advancement and greater life expectancy.[178] The irony is that the cost-benefit model also relies on an assumption of "benevolent" markets.[179] There is no guarantee that market preferences will favor sustainability and survival in the face of an uninhabitable environment given that profits are not necessarily maximized in a sustainable environment, especially in the face of uncertainty.[180] With these significant flaws plaguing both the precautionary principle and the cost-benefit model, a new framework that neither relies on social costs nor allows for wanton over-regulation is necessary.

C. *The Marginal Abatement Cost (MAC) Framework: The United Kingdom's Compromise*

In 2008, the United Kingdom shifted from a traditional economic approach that used social costs to a target-consistent approach to valuing atmospheric carbon that uses marginal

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175. *See* Sunstein, *Preferences and Rational Choice*, *supra* note 144, at 1041–43.

176. *Id.* at 1008.

177. *Id.* at 1009.

178. Lindsey & Dahlman, *supra* note 37; *see* Clark Nardinelli, *Industrial Revolution and the Standard of Living*, ECONLIB, https://www.econlib.org/library/Enc/IndustrialRevolutionandtheStandardofLiving.html [https://perma.cc/7CQK-DWGG]; *see, e.g.*, Brian Duignan & Ernest Leong, *Inventors and Inventions of the Industrial Revolution*, ENCYC. BRITANNICA, https://www.britannica.com/list/inventors-and-inventions-of-the-industrial-revolution [https://perma.cc/5793-YDM2].

179. *See generally* discussion *supra* Section II.A.3.

180. *See* discussion *supra* Section II.A.3.

abatement costs (MACs).[181] In 2022, Professor Nicholas Stern, a prominent scholar in the field of climate change economics,[182] coauthored a brief with Nobel Prize-winning economist Joseph Stiglitz[183] and other prominent economists to propose the MAC framework to the Biden administration.[184] The MAC framework retains the quantitative analysis from the cost-benefit framework, but also incorporates an element of precaution to help achieve climate goals.[185]

1. *The middle approach*

As opposed to social costs, abatement costs represent the total cost of avoiding a particular outcome.[186] To illustrate, an abatement approach is like going to the grocery store with a list of items you need for the week and then buying the cheapest items to complete the list. On the other hand, the social cost model is like going to the grocery store with $50—the amount you think will be enough—and buying what you can afford. In the second example, you might run out of food for the week if you didn't set aside enough money or your money didn't go as far as predicted, but in the first example, you won't run out of food as long as you know how much food you are planning to eat. If you had perfect information—knowing the prices at the store before you budget, exactly how much food you are going to eat, etc.—these numbers would be the same. Instead,

181. DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 2.

182. *See Nicholas Stern*, THE LONDON SCH. OF ECON. & POL. SCI., https://www.lse.ac.uk/granthaminstitute/profile/nicholas-stern/ [https://perma.cc/APY3-4AVW].

183. *Joseph E. Stiglitz*, THE NOBEL PRIZE, https://www.nobelprize.org/prizes/economic-sciences/2001/stiglitz/facts/ [https://perma.cc/APY3-4AVW].

184. *See* STERN ET AL., NET-ZERO, *Net-Zero*, *supra* note 51.

185. *See* DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 21, 37.

186. *See* Gundlach & Livermore, *supra* note 84, at 566; *see also* Stéphane Hallegatte, *Proper Use of the Abatement Cost to Steer the Transition*, INST. FOR CLIMATE ECON. (Apr. 4, 2023), https://www.i4ce.org/en/proper-use-abatment-cost-streer-transition-climate/ [https://perma.cc/8PBQ-9K4V] ("The abatement cost is simply the cost of an intervention that will reduce greenhouse gas emissions by one tonne.").

uncertainty makes you choose between risking going over budget or risking starving.[187] A MAC model prefers not to starve.

When it comes to carbon emissions, MAC refers to the cost required to avoid the emission of carbon dioxide that would exceed climate goals.[188] MAC is calculated by considering a desired goal—stabilization of the global temperature under 2.0 degrees above pre-industrial levels by 2050—and working backwards to find the minimum cost required to reach that goal.[189] Under ideal market conditions with perfect information, the social cost of carbon would be equal to MAC when utilizing the optimal emissions goal.[190] In practice, this is not the case for several reasons: there is no free market that could utilize a single price for carbon that could encompass the whole economy, large degrees of uncertainty surround damages and (to a lesser extent) abatement costs, and emissions targets consider factors outside scientific models.[191]

The MAC framework balances the traditional economic approach and the precautionary principle by using a quantitative analysis to optimize decision making by seeking "the most cost-effective way to reach an agreed upon goal," while also providing a guardrail to stay within climate goals.[192] By setting an upper limit on emissions, the MAC approach removes the uncertainty of damages from future environmental harm and limits the consequences of varying discount rates.[193] This approach grounds its calculations in the environmental limits identified by modern science and produces an emissions measurement rather than a dollar amount, thus removing the uncertainty

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187. It is worth acknowledging that a MAC plan could still result in not having enough food in this example if you underestimated the number of meals you need to prepare for the week. Importantly, this is the only source of uncertainty affecting whether you buy enough in a MAC model, while a cost-benefit model suffers from additional uncertain variables affecting the outcome. *See* discussion *supra* Section II.A.3.

188. Gundlach & Livermore, *supra* note 84, at 566.

189. DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 66.

190. Sinden, *supra* note 12, at 952.

191. DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 11.

192. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 11.

193. *See* Sinden, *supra* note 12, at 950.

associated with damage calculations; MAC creates a schedule of allowable emissions per year to meet the desired goal rather an cost of intended investment.[194] The MAC framework considers elements such as: (1) the cost of transitioning from less efficient technology to more sustainable alternatives; (2) models of the price of carbon required to incentivize adoption of decarbonization; and (3) models that map technological and socioeconomic development at different global temperature targets.[195] This approach guides regulations to keep the world on track to outpace climate change and provides more security than the traditional economic model which merely considers what society is willing to do and hopes society's preferences are enough.[196]

2. *A solution to social costs*

While Stern and colleagues' proposal characterizes the target-consistent approach as a way to calculate the social cost of carbon, the difference between a social cost and marginal abatement cost is the key strength of the MAC approach.[197] Whereas social costs reflect costs to *society*, the MAC framework uses a fixed preference determined by the climate goal to create a scheme that ignores society's preferences and valuations.[198] The MAC methodology first creates the most cost-effective regulatory scheme and then uses the cost of the plan to determine the "social cost of carbon."[199] Calling the resultant value a "social cost of carbon" hides key differences in the underlying process

194. *See* DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 11.

195. STERN ET AL., NET-ZERO, *supra* note 51, at 11.

196. *See id.* at 13–14.

197. *See* Sinden, *supra* note 13, at 950–53.

198. *See* Stern et al., *Towards New Approaches*, *supra* note 107, at 191–92. *But see* Lina Isacs, Göran Finnveden, Lisbeth Dahllöf, Cecilia Håkansson, Linnea Petersson, Bengt Steen, Lennart Swanström & Anna Wikström, *Choosing a Monetary Value of Greenhouse Gases in Assessment Tools: A Comprehensive Review*, 127 J. CLEANER PROD. 37, 42 (2016) (recognizing that discounting uncertainty still applies to MAC models, albeit to a lesser degree).

199. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 11.

of the MAC framework, namely that it is constrained by climate goals.[200]

The assumptions embedded in the MAC model avoid several pitfalls of the traditional social cost analysis.[201] First, the MAC model circumvents the severe underestimation of risks that social costs experience.[202] As the Earth approaches a severely deprived state, a social cost approach prioritizes current values over long-term habitability and welfare, but a MAC approach prioritizes overall sustainability over unobtainable perfect efficiency.[203] The key difference here is priority: cost-benefit prioritizes value expended over the achievement of a climate goal and the precautionary principle prioritizes returns to the environment to the greatest degree possible,[204] but MAC prioritizes climate goals while recommending only the most cost-effective way to get there.[205] Second, existing social cost models treat economic growth as independent from climate change, but an abatement scheme avoids this issue altogether by identifying a cost-effective pathway to reach specific goals.[206] Third, the MAC approach is far less vulnerable to uncertainty, as environmental outcomes are largely unaffected by the discount rate, targets are determined by empirical scientific findings, and variables are minimized.[207] Therefore, this model is less susceptible to statistical manipulation.

The MAC model is not subject to the same issue of over-regulation as the precautionary principle because it grounds itself in empirical data derived from leading environmental experts and quantitative analysis by holding a country accountable to

200. *See id.* at 2.

201. *See generally id.*

202. *See id.* at 5–6.

203. *See id.* at 2, 6–7.

204. *See* discussion *supra* Section II.B.2.

205. *See* N.Y. STATE ENERGY RSCH. & DEV. AUTH. & RES. FOR THE FUTURE, ESTIMATING THE VALUE OF CARBON: TWO APPROACHES 1 (2021).

206. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 11 (discussing the various social cost models).

207. N.Y. STATE ENERGY RSCH. & DEV. AUTH. & RES. FOR THE FUTURE, *supra* note 205, at 17.

their recommended climate goals.[208] Rather than heedlessly regulating—and therefore spending—wherever there is *prima facie* evidence of a risk of significant harm, the MAC model only requires regulation necessary to prevent harm known to be significant as supported by empirical findings.[209] Moreover, by using the most cost-effective way to reach established climate goal(s), the MAC approach likely leads regulators to take the *slowest* course of action to reach sustainability, thus minimizing the risk of over-regulation while providing security against under-regulation by establishing a limit.[210] Because discounting would still occur while developing the path to reach climate goals, there is still an incentive to spend less money in the present.[211] Although some aspects of the MAC model are uncertain, and there will always be unconsidered extraneous factors, the model itself seeks to maintain completion of the overall climate goal as a constant, certain variable.[212]

3. *An (almost) perfect compromise*

Altogether, the MAC approach marries the traditional economic analysis and the reasonable cautionary elements of the precautionary principle, but it nonetheless is criticized by "[cost-benefit analysis] purists."[213] These critiques mainly concern the uncertainty of abatement costs, the politicization of choosing climate targets, and the theoretical optimization sought by the social cost of carbon.[214] While involving less uncertainty overall, abatement costs are still vulnerable to uncertainty where technological improvements and target selection

208. *See* Pinto-Bazurco, *supra* note 165, at 2. *See generally* Jennifer Morris, Sergey Paltsev & John Reilly, *Marginal Abatement Costs and Marginal Welfare Costs for Greenhouse Gas Emissions Reductions: Results from the EPPA Model*, 17 ENV'T MODELING & ASSESSMENT 325 (2012).

209. *See* Pinto-Bazurco, *supra* note 165.

210. *See* Stern et al., *Towards New Approaches*, *supra* note 107, at 191–92.

211. *See* Stephen Polasky & Nfamara K. Dampha, *Discounting and Global Environmental Change*, 46 ANN. REV. ENV'T & RES. 691, 709 (2021).

212. *See* Stern et al., *Towards New Approaches*, *supra* note 107, at 191–92; Isacs et al., *supra* note 198, at 41–42.

213. Sinden, *supra* note 12, at 948.

214. *See id.* at 948–50, 955–56.

rely on predictive data.[215] This is especially apparent in the United Kingdom's use of MACs that consider targets in part using social costs and traditional IAMs.[216] As to improvements in technology, MACs attempt to calculate advances in technology to determine long-term goals, subjecting them to uncertainty that could lead to falling behind on attainment goals if advancements do not happen on schedule.[217] Politicization of climate goals, while a relevant concern, is somewhat unavoidable; international climate goals are inherently less politicized than country-specific policies due to the global nature of the climate crisis, especially considering the burden sharing nature of climate change.[218] As compared to the precautionary principle and traditional economic approach, the MAC framework is more balanced and its pitfalls are less damaging, but there is still room for improvement.

III. STAYING AHEAD OF THE CURVE: SECURING THE FUTURE WITH CERTAINTY

While the MAC approach to environmental regulation retains many of the values of the cost-benefit system, it is still vulnerable to uncertainty and fails to guarantee climate goals will be met. Utilizing static-present assumptions alongside a MAC approach would allow regulators to minimize uncertainty while maintaining an optimization scheme. Legislation to create a

215. *See id.* at 950, 950 n.239; Isacs et al., *supra* note 198, at 42 ("Indeed, some of the most important uncertainties of MAC curves concern their dependency on forecasts about technological development. . . . ").

216. *See* discussion *supra* Section II.C.

217. *See* Isacs et al., *supra* note 198, at 43; DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 92–93.

218. *See* DEP'T OF ENERGY & CLIMATE CHANGE, *supra* note 77, at 22; Jacob Poushter, Moira Fagan & Sneha Gubbala, *Climate Change Remains Top Global Threat Across 19-Country Survey*, PEW RSCH. CTR. (Aug. 31, 2022), https://www.pewresearch.org/global/2022/08/31/climate-change-remains-top-global-threat-across-19-country-survey/ [https://perma.cc/GMK5-J67Z]. *See generally* Elaine Kamarck, *The Challenging Politics of Climate Change*, BROOKINGS INST. (Sept. 23, 2019), https://www.brookings.edu/articles/the-challenging-politics-of-climate-change/ [https://perma.cc/E8PX-2Y9P] (comparing Republican and Democrat views on addressing climate change).

schedule of periodically updating these assumptions would create a process that self-optimizes in aggregate.

A. *Static-Present Assumptions*

The MAC approach is vulnerable to two main sources of uncertainty: the advancement of technology and target selection.[219] The proposed static-present assumptions would use the values of these variables at the time of regulatory action to maintain a degree of limited over-regulation. For example, the static-present assumptions would use the present best available control technology (BACT)[220] as used in the Clean Air Act and develop its own IAM required to meet an acceptable level of attainment by the desired goal without speculating as to future technological development. Similarly, scientific uncertainty and attainment goals would be set using the "best available" present information based on globally accepted scientific research. Presently, these goals would include global temperature stabilization at 1.5 to 2.0 degrees (or less) of warming by 2050.[221]

This modified framework would maintain the significant aspects of MAC, cost-benefit, and the precautionary principle. Like the standard MAC approach, the modified framework eliminates the use of arbitrary manipulable variables by connecting the cost of regulation to defined climate goals grounded in science.[222] It also embodies the precautionary principle's desire to put the world's "best foot forward" by avoiding under-

219. Isacs et al., *supra* note 198, at 42; Sinden, *supra* note 12, at 950, 950 n.239.

220. "Best Available Control Technology" is a term used in the Clean Air Act to set technology standards. *See* 42 U.S.C. § 7479(3). The statute defines "best available control technology" as:

> an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant.

Id.

221. *See* Paris Agreement, *supra* note 40, at art. 2(a).

222. *See* STERN ET AL., NET-ZERO, *supra* note 51, at 10–11.

regulation[223] while also providing the quantitative aspects of the cost-benefit framework.[224]

Cost-benefit purists may object to the modified MAC approach by arguing that the social cost of carbon best seeks optimization and avoids the selection of politically determined targets. However, the climate crisis is a global issue, so a global scientific community is much better suited to select targets than an individual nation deciding entirely arbitrary metrics—such as a discount rate—as is the case in the existing cost-benefit models.[225] Additionally, the modified approach moves toward optimization similar to cost-benefit models when assessed at regular intervals. After regulatory parties assume present variables are static, the "present" variables can be reassessed at regular intervals to approach optimization in the aggregate. Present assumptions do not account for future technological developments that can lower costs to reach a certain level of emissions, so costs will initially be over-estimated[226]—and therefore the model allows for limited over-regulation. At first glance, this seems like the type of loss of optimization that cost-benefit purists would abhor, but reassessment at a future date introduces new information into the equation and creates a then-more-optimized regulatory scheme. This approach considers optimization based on the *frequency* of reassessment rather than the accuracy of uncertain information.[227] Both methods rely on having the best information possible, but the modified MAC approach relies on existing known information

223. *See* Victor Anderson & Rupert Read, *Take Back Control! A Green Response to Brexit*, THE ECOLOGIST (July 18, 2016), https://theecologist.org/2016/jul/18/take-back-real-control-green-response-brexit [https://perma.cc/RP44-GQGT].

224. *See* Sinden, *supra* note 12, at 950.

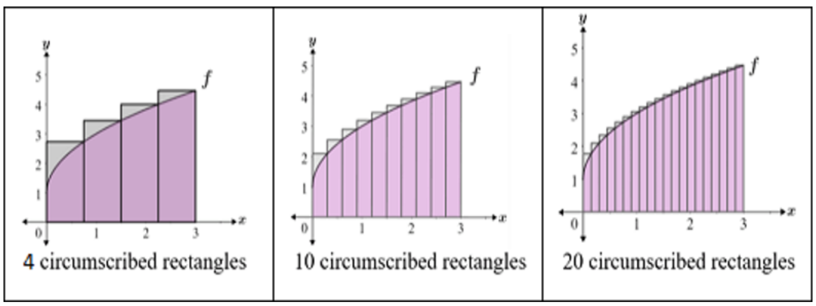
225. *See* LOUKA, *supra* note 159, at 73–75 (highlighting the international concern for equity over pure cost efficiency).

226. As long as climate goals are not underestimated, the cost of carbon abatement will be overestimated when predictions opt not to account for technological development since technology inevitably improves over time, resulting in cost reductions that were purposefully not accounted for in the original estimations. Isacs et al., *supra* note 219, at 42.

227. Sometimes information is simply unavailable, and regulators must do the best they can in the face of uncertainty. CASS R. SUNSTEIN, AFTER THE RIGHTS REVOLUTION 91 (1990) (arguing for a cost-driven approach to regulation). As this Note points out, in the case of environmental regulation, "the best they can" does not address the risk of failing to meet climate goals.

that will eventually become an overestimation rather than the traditional economic approach that relies on predictive information about the future that carries uncertainty.[228] The key difference between the traditional method of seeking optimization and the modified MAC approach is that traditional regulatory models have a margin of error that may result in over-regulation or under-regulation, but an interval model does not result in under-regulation.[229] The interval optimization can be modeled as a Riemann-Sum Integration, illustrated in Figure 1:[230]

Figure 1[231]



As portrayed in Figure 1, the area underneath function *f* is the optimal amount of regulation to reach the target goal, and each rectangle graphs the amount of regulation over an interval. The excess portion of the rectangles above function *f* is the amount of over-regulation. The interval model guarantees some error, but as the number of intervals increase, the margin of error approaches zero.[232] This margin of error, as applied to the proposed framework represents a level of over-regulation.[233] This

228. *See* Sinden, *supra* note 12, at 950.

229. *See* *Riemann Sum*, MATH.NET, https://www.math.net/riemann-sum [https://perma.cc/LK3A-TYXV].

230. Riemann Sums are a method of measuring integrals (the area underneath a curve) using a series of interval measurements of rectangles whose area is easy to calculate. *Id.* As the number of intervals used approaches infinity, the lower the error is (as shown by the decreasing area above the curve as the number of intervals increase in Figure 1). *Id.*

231. *Id.* (depicting right Reimann's sum).

232. *Id.*

233. A key feature of the proposed modified framework is that it only accepts the risk of over-regulation, as opposed to the traditional economic framework—and to a lesser degree the

improves upon the traditional model's benefit of providing quantitative values[234] because the frequency of intervals is a known and controllable variable, as opposed to completeness of information—accuracy of uncertain variables—which is impossible to know. Most importantly, sustainability—whether the overarching environmental goals are met—is a known constant.

B. *Incentivizing Optimization: Statutory Implementation*

The modified MAC interval model of regulation would be best implemented in the United States through legislation to properly incentivize optimization. The rigid nature of legislative action and mutability of administrative action in the United States make this course of action ideal.[235] The statutory provision would require the formation of a temporary Interagency Working Group similar to those ordered to calculate the social cost of carbon.[236] Instead of calculating the social cost of carbon, this Interagency Working Group would be employed to assess the state of control technologies and determine the most cost-effective path to meet goals consistent with the most recent IPCC report.[237] This provision would also require the Interagency Working Group to be reformed at least every four years to readdress climate goals and existing technology.[238]

MAC framework—which accepts the risks of over- and under-regulation due to uncertainty. *See* discussion *supra* Sections II.A.3, II.B.2.

234. Sinden, *supra* note 12, at 936–37; *see also supra* discussion Section II.A.3.

235. *See* Chevron U.S.A., Inc. v. Nat. Res. Def. Council, 467 U.S. 837, 865–66 (1984) (internal quotations omitted) (citations omitted) (recognizing that the executive branch has the power to administer statutes "in light of everyday realities"). "The power of an administrative agency to administer a congressionally created . . . program necessarily requires the formulation of policy and the making of rules to fill any gap left . . . by Congress." *Id.* at 843.

236. *See generally* Obama Admin. IAWG Report, *supra* note 98, at 1; Biden Admin. IAWG Report, *supra* note 102, at 13–14 (creating an Interagency Working Group comprised of members from several specialized executive agencies).

237. *See* Hoegh-Guldberg, *supra* note 16.

238. This four-year suggestion is somewhat arbitrary but aligns with the trend of new administrations conducting their own evaluations. A minimum interval needs to be set to continue the trend toward optimization and lower the degree of overinvestment, but the more frequent the intervals, the closer to optimization. Four years is a convenient number that, on its face,

Because technology inevitably marches forward, reassessment of existing technologies would reduce the cost of regulation—both by readjusting over-regulation and because more efficient technology reduces the cost of adhering to emissions requirements.[239] This would incentivize the executive branch to reassess the state of environmental control technology whenever advancements are made to reduce regulatory costs to industry.[240] Additionally, this would provide further incentive for the advancement of control technology since pollution sources would have another reason to invest in improved control technology to relax the cost of regulation.[241] This causes the modified MAC model to approach perfect optimization as the frequency of technological advancement and the rate of reassessment increases.

CONCLUSION

Climate change is not an issue that can be left for future generations. The most severe consequences of climate change are occurring in some parts of the world today, and for some it may already be too late to reverse the damage being done. The Earth is getting warmer at an alarming rate, and the United States' adherence to traditional economic environmental regulation framework dangerously disregards climate goals required to avoid substantial future harm. Present empirical data reveals that the Earth is about 1.0 degree warmer than pre-industrial levels and that significant, irreversible harm may occur when this figure rises to 1.5 degrees Celsius.[242] The international

seems frequent enough to generally keep up to date without over-imposing the cost of performing a reassessment. Other intervals, of course, may be chosen to balance these considerations.

239. *See* Jay P. Kesan & Rajiv C. Shah, *Shaping Code*, 18 HARV. J.L. & TECH. 319, 333–37 (2005) (comparing technology-forcing regulation to market incentives as ways to drive industries to invent new technologies); Isacs et al., *supra* note 198, at 43.

240. *See* Kesan, *supra* note 240, at 333–37.

241. *Id.*

242. *See supra* notes 44–50 and accompanying text. Other sources have slightly varying values depending on date ranges used, but at the time of publication, the most recent report from the Intergovernmental Panel on Climate Change—the United Nations' body for addressing climate change—reported 0.87 degrees of warming between 2006 and 2015. IPCC, *Summary for Policymakers*, *supra* note 15, at 4; *see also, e.g.*, Press Release, World Meteorological Org., Glob.

precautionary principle standard may reflect irrational risk behavior, but a pure social cost analysis exhibits an unacceptable level of uncertainty.

While the MAC approach to environmental regulation balances the foundational elements of the precautionary principle and traditional social costs, a static-present interval model better reconciles the flaws of each approach while rooting itself in quantitative analysis and optimization. Traditional social cost methods approach optimization by seeking an impossible standard: perfect information. Conversely, the static-present approach calculates marginal abatement costs limited to present assumptions without consideration for technology advancements to intentionally overestimate necessary regulation and approach optimization by increasing the frequency of reassessment intervals—a known and controllable variable. As such, the United States should adopt legislation to solidify a static-present interval approach to best incentivize an increasing interval of assessment by regulatory authority and perpetuate a trend toward optimization by creating a pathway of marginally decreasing costs.

Temperatures Set to Reach New Records in Next Five Years (May 17, 2023), https://wmo.int/news/media-centre/global-temperatures-set-reach-new-records-next-five-years [https://perma.cc/KX38-2837] (reporting that "[t]he average global temperature in 2022 was about 1.15°C above the 1850–1900 average.").