Legal Pathways to Deep Decarbonization: Postscript

by John C. Dernbach

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Summary

With this Article, *ELR News & Analysis* concludes our year-long series of excerpts from *Legal Pathways to Deep Decarbonization in the United States*, forthcoming from ELI Press. We believe the urgency and importance of this topic, coupled with the book's original, policy-oriented treatment of it, warranted extensive advance coverage. Previous installments examined an array of specific sectors across the entire U.S. economy, with many more included in the published volume. In this final excerpt, one of the book's co-editors reflects on the deep decarbonization project, its extension and application through the "legal pathways" described by the contributing authors, and its significance for the future.

Over the past year, readers of *ELR News & Analysis* have seen advance excerpts from *Legal Pathways to Deep Decarbonization in the United States* (available in late 2018 or early 2019 from ELI Press), a playbook of legal pathways for enabling the United States to address what is perhaps the greatest problem facing this country and the rest of humanity. That book identifies more than 1,000 legal options for reducing U.S. greenhouse gas (GHG) emissions by at least 80% from 1990 levels by 2050. This "80x50" target and similarly aggressive carbon abatement goals are often referred to as deep decarbonization, "deep" because it requires systemic changes to the energy economy.[1]

In North American football, a playbook is a comprehensive listing of all of the plays that can be employed by a particular team. In any one game, some of these plays will be used, and some will not, depending on the circumstances. But coaches for the team draw from the playbook to employ an appropriate combination of plays in order to win. Similarly, *Legal Pathways* attempts to provide a comprehensive description and explanation of legal pathways to deeply decarbonize the U.S. economy. It is likely that not all of them will be used, but public and private decisionmakers can employ various combinations of these pathways to achieve the needed reductions in U.S. GHG emissions.

The book, and the chapters excerpted in *News & Analysis*, grew out of the deep conviction that an analysis and comprehensive description of the large number and diversity of legal tools available for deep decarbonization in the United States will better enable governments as well as businesses, nongovernmental organizations (NGOs), and other private actors to accelerate the transition to a decarbonized

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1. Deep decarbonization applies not only to reductions in carbon dioxide, but also other GHG pollutants, such as methane and nitrous oxide. "'Deep decarbonization' refers to the reduction of greenhouse gas (GHG) emissions over time to a level consistent with limiting global warming to 2°C or less, based on the scientific consensus that higher levels of warming pose an unacceptable risk of dangerous climate change." James H. Williams et al., Pathways to Deep Decarbonization in the United States, U.S. 2050 Report, Volume 2: Policy Implications of Deep Decarbonization in the United States 8 (Deep Decarbonization Pathways Project & Energy and Environmental Economics, Inc., 2015), http://deepdecarbonization.org/wp-content/uploads/2015/11/US_Deep_Decarbonization_Policy_Report.pdf [hereinafter DDPP U.S. Policy Report].

economy.[2] The chapters are written by legal scholars and practicing attorneys who have expertise in the particular topics they are addressing. The legal pathways identified include federal, state, and local actions. The legal pathways also include certification, auditing, labeling, and reporting programs, which tend to be enforced through a variety of contractual and related arrangements that are perhaps best described as private environmental governance.[3]

For all four types of actors—federal, state, local, and private—the legal pathways articulated fall into a wide variety of categories. Some involve additional regulation, but the great majority do not. A key premise is that, while a number of technologies and other methods are available to achieve radical reductions in GHG emissions (most but not all involving energy efficiency, fuel switching, or decarbonized electricity), there are numerous legal impediments to implementing these technologies and methods at the necessary scale and speed. The work is aimed at identifying these impediments and devising ways to surmount them. By adopting these methods, policymakers and lawyers can allow clean technology and other methods to achieve their potential as rapidly as possible. Beyond additional regulation (for some issues) and reduction or removal of legal barriers (for different issues), other types or categories of legal pathways described and analyzed include market-leveraging approaches, tradable permits or allowances, information/persuasion, infrastructure development, research and development, property rights, facilities and operations, insurance, and social equity.

The authors' objective is not to identify one best legal approach or set of approaches for the United States to reduce GHG emissions. Nor are we directing these at a particular political party or particular decisionmaker. Our objective instead is to identify the broadest possible range of plausible legal approaches to deep decarbonization, so that public and private decisionmakers can better understand the wide range of available choices and can choose those legal pathways that they believe are appropriate or feasible.

As the book goes to press, the United States is in a precarious position on climate change. On one hand, there is already significant observed evidence of climate change, and the adverse effects of climate change are almost certain to grow in scale and cost in coming decades. In consequence, some state and local governments, as well as many corporations and businesses, have taken steps to reduce GHG emissions and adapt to climate change.[4] At the federal level, the United States has begun to take similar steps. These efforts intensified during the Barack Obama Administration, and perhaps the most publicly visible and politically controversial manifestation of that was the Clean Power Plan, which was intended to reduce GHGs from electric power-generating facilities by 32% from 2005 levels by 2030.[5]

On the other hand, the Donald Trump Administration, seeing the climate change issue through the lenses of reducing government regulation and trying to revive the coal industry, has expressed skepticism about the basic science of climate change and initiated proceedings to roll back many Obama Administration initiatives on climate change,[6] including the Clean Power Plan.[7] By showing there are well over 1,000 other legal pathways to decarbonizing the U.S. economy, we will hopefully provide more opportunity for decisionmakers of all political persuasions to find common ground on a way forward.

This Postscript to our series, and introduction to the book, first explains the urgency of climate change and describes the significance of the Paris Agreement. It then summarizes U.S. technical and policy pathways to deep decarbonization, as set out in two reports by the Deep Decarbonization Pathways Project (DDPP) and in other studies. It explains why deep decarbonization is in the best interests of the United States, and describes the value of understanding legal pathways to deep decarbonization.

I. The Paris Agreement and the Urgency of Climate Change

The legal pathways are intended to achieve, at a minimum, an 80% reduction in U.S. GHG emissions from 1990 levels by 2050. While the Paris Agreement provides an orderly process for all countries to reduce their GHG emissions, the commitments made to date under the Agreement by the United States and other countries are not sufficient to achieve that level of reduction—and this was true even before President Trump announced that the United States would withdraw from the Agreement. Yet, it is increasingly clear that the United States and other countries must accelerate the reduction of GHG emissions.

Two DDPP reports for the United States provide the foundation for our legal analysis. These reports are based on the target of achieving an 80% reduction in U.S. GHG

2. John C. Dernbach et al., Acting as if Tomorrow Matters: Accelerating the Transition to Sustainability (ELI Press 2012).
3. Michael P. Vandenbergh, *Private Environmental Governance*, 99 Cornell L. Rev. 129 (2013); Errol Meidinger, *Environmental Certification Systems and U.S. Environmental Law: Closer Than You May Think*, 31 ELR 10162 (Feb. 2001).
4. *See generally* Global Climate Change and U.S. Law (Michael B. Gerrard & Jody Freeman eds., 2d ed. 2014).
5. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64661, 64736 n.384 (Oct. 23, 2015) (to be codified at 40 C.F.R. pt. 60).
6. *See* Columbia Law School, Sabin Center for Climate Change Law, *Climate Deregulation Tracker*, http://columbiaclimatelaw.com/resources/climate-deregulation-tracker/ (last visited June 7, 2018).
7. Emission Guidelines for Greenhouse Gas Emissions From Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review Program, 83 Fed. Reg. 44746 (Aug. 31, 2018) (to be codified at 40 C.F.R. pts. 51, 52, and 60); Repeal of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 82 Fed. Reg. 48035, 48035 (Oct. 16, 2017) (to be codified at 40 C.F.R. pt. 52), https://www.federalregister.gov/documents/2017/10/16/2017-22349/repeal-of-carbon-pollution-emission-guidelines-for-existing-stationary-sources-electric-utility. Prior to this, the U.S. Supreme Court enjoined implementation of the Clean Power Plan until all legal challenges are resolved. West Virginia v. Environmental Prot. Agency, 136 S. Ct. 1000, 1000 (2016).

emissions from 1990 levels by 2050.[8] That target was effectively created in 2009, when the United States joined the "Group of Eight," or G8 nations, in agreeing on a "global long-term goal of reducing global emissions by at least 50% by 2050 and, as part of this, on an 80% or more reduction goal for developed countries by 2050."[9] The G8, in turn, appears to have taken the 80% goal from the 2007 climate change mitigation report of the Intergovernmental Panel on Climate Change (IPCC). The IPCC indicated that an 80% to 95% reduction in GHG emissions by 2050 by developed countries, and substantial but less drastic reductions by developing countries, are needed to keep atmospheric concentrations of carbon dioxide (CO_2) below 450 parts per million (ppm).[10] Subsequent events and analysis support the urgency of this level of reduction, and indicate that greater and more rapid reductions may be needed.

In 2017, average surface temperatures around the world were 1.62 degrees Fahrenheit (°F) (0.90 degrees Celsius (°C)) warmer than they were in the middle of the 20th century.[11] According to the National Aeronautics and Space Administration, "Earth's global surface temperatures in 2017 ranked as the second warmest since 1880."[12] Increased atmospheric concentrations of GHGs, the IPCC concluded in 2014, "are extremely likely to have been the dominant cause of the observed warming since the mid-20th century."[13] The IPCC also concluded that further emission increases will have significant adverse effects: "Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems."[14]

On December 12, 2015, in Paris, France, the Parties to the United Nations Framework Convention on Climate Change[15]—a total of 196 countries[16]—agreed to a goal of net-zero GHG emissions by the second half of this century.[17] The Paris Agreement, as it is called, marks the first time since the Framework Convention was opened for signature in 1992 that all Parties have agreed to such a goal. It was also the first time that all Parties agreed to take actions to reduce their GHG emissions.[18] The only prior agreement even remotely comparable to the Paris Agreement—the Kyoto Protocol—did not contain an overall emissions reduction goal, and only limited developed countries' emissions.[19]

In June 2017, President Trump nonetheless announced his intention to withdraw the United States from the Paris Agreement.[20] Under the Paris Agreement, no country can withdraw from the agreement for a period of three years after the agreement enters into force.[21] That withdrawal, in turn, is effective one year later.[22] Because the Paris Agreement achieved a sufficient number of ratifications and other approvals to enter into force on November 4, 2016, the earliest that the United States can actually withdraw is November 4, 2020,[23] which is one day after the U.S. presidential election.

Even without the announced U.S. withdrawal from the Paris Agreement, the challenge of achieving its goals is enormous. While GHG emissions in the United States in 2016 were 11% lower than their peak in 2007,[24] the United States is the second-largest emitter of GHGs in the world

8. James H. Williams et al., Pathways to Deep Decarbonization in the United States, U.S. 2050 Report, Volume 1: Technical Report xii (Deep Decarbonization Pathways Project & Energy and Environmental Economics, Inc., 2015), http://deepdecarbonization.org/wp-content/uploads/2015/11/US_Deep_Decarbonization_Technical_Report.pdf [hereinafter DDPP U.S. Technical Report];DDPP U.S. Policy Report, *supra* note 1, at 8.
9. G8, Chair's Summary, L'Aquila, 10 July 2009, at 4 (2009), http://ec.europa.eu/economy_finance/publications/pages/publication15572_en.pdf; The White House, United States Mid-Century Strategy for Deep Decarbonization 8 (2016), http://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf; DDPP U.S. Policy Report, *supra* note 1, at 8.
10. IPCC, Climate Change Mitigation 775-76 (2007).
11. Press Release, National Aeronautics and Space Administration, Long-Term Warming Trend Continued in 2017: NASA, NOAA (Jan. 18, 2018), https://www.nasa.gov/press-release/long-term-warming-trend-continued-in-2017-nasa-noaa.
12. *Id*.
13. IPCC, Climate Change 2014 Synthesis Report: Summary for Policymakers 4 (2014), https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.
14. *Id*. at 8.
15. United Nations Framework Convention on Climate Change, *opened for signature* May 9, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 107 (entered into force Mar. 21, 1994) [hereinafter Framework Convention], https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.
16. United Nations Framework Convention on Climate Change, *Status of Ratification of the Convention*, http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php (last visited June 7, 2018). There are actually 197 Parties—196 countries and an economic integration organization, the European Union. *Id*.
17. The Agreement states:

    > Parties aim to reach global peaking of greenhouse gas emissions as soon as possible . . . and to undertake rapid reductions thereafter . . . so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.

    Adoption of the Paris Agreement, U.N. Framework Convention on Climate Change Conference of the Parties, 21st Sess., Agenda Item 4(b), art. 4.1 (in Decision 1/CP.21), U.N. Doc. FCCC/CP/2015/L.9/Rev.1 (2015) [hereinafter, to avoid confusion with the Paris Agreement, citations to the decision will refer to Decision 1/CP.21, and citations to the Paris Agreement itself will refer to the Paris Agreement], https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf. The "balance" of emissions and removals means net-zero emissions. Kelly Levin et al., *INSIDER: Understanding the Paris Agreement's Long-Term Goal to Limit Global Warming*, World Resources Inst., Dec. 15, 2015, http://www.wri.org/blog/2015/12/insider-understanding-paris-agreement%E2%80%99s-long-term-goal-limit-global-warming.
18. Joby Warrick & Chris Mooney, *196 Countries Approve Historic Climate Agreement*, Wash. Post, Dec. 12, 2015, https://www.washingtonpost.com/news/energy-environment/wp/2015/12/12/proposed-historic-climate-pact-nears-final-vote/.
19. Kyoto Protocol to the United Nations Framework Convention on Climate Change, art. 3.1 & Annex B, U.N. Doc. FCCC/CP/197/L.7/Add. (1998), http://unfccc.int/resource/docs/convkp/kpeng.pdf.
20. *See* Remarks Announcing United States Withdrawal From the United Nations Framework Convention on Climate Change Paris Agreement, 2017 Daily Comp. Pres. Doc. 00373 (June 1, 2017), https://www.gpo.gov/fdsys/pkg/DCPD-201700373/pdf/DCPD-201700373.pdf.
21. Paris Agreement, *supra* note 17, art. 28.1.
22. *Id*. art. 28.2.
23. United Nations Framework Convention on Climate Change, *Paris Agreement—Status of Ratification*, https://unfccc.int/process/the-paris-agreement/status-of-ratification (last visited June 7, 2018).
24. U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, at ES-4 fig. ES-1 (2018) (EPA 430-R-18-003), https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf.

Table 1
Deadline for Achieving Net-Zero Emissions With Greater Than a 50% Probability of Success[a]

	1.5°C Increase	2°C Increase
Total CO_2 emissions[b]	2045-2050	2060-2075
Total GHG emissions covered under Kyoto Protocol[c]	2060-2080	2080-2090

a. United Nations Environment Programme, The Emissions Gap Report 2015: A UNEP Synthesis Report 6 (2015), https://uneplive.unep.org/media/docs/theme/13/EGR_2015_301115_lores.pdf.
b. From energy and industry, as well as land use, land use change, and forestry.
c. Not only CO_2 but also methane, nitrous oxide, and fluorinated compounds.

(after China).[25] U.S. CO_2 emissions per capita are among the highest in the world.[26] The U.S. energy sector is now heavily dependent on coal, oil, and natural gas—which together are responsible for the bulk of U.S. GHG emissions, mostly in the form of CO_2.[27] Any comprehensive effort to address climate pollutants must also address methane, nitrous oxide, fluorinated gases, and black carbon.[28]

Though some states had begun to address GHG emissions by 2000,[29] federal efforts began in earnest with the inauguration of President Obama in 2009. In the run-up to the Paris climate conference, every country was asked to submit an intended nationally determined contribution (INDC) to reduce its GHG emissions.[30] In its 2015 INDC, the U.S. State Department said that the United States' short-term objective is "to achieve an economy-wide target of reducing its greenhouse gas emissions by 26-28 per cent below its 2005 level in 2025."[31] This objective, the United States said, "is consistent with a straight line emission reduction pathway from 2020 to deep, economy-wide emission reductions of 80% or more [from 2005 levels] by 2050."[32]

The United States also explained that the short-term objective is based on actions that had already been taken, or were about to be finalized, including strengthened efficiency standards for motor vehicles, household appliances, and industrial equipment; methane emission standards for landfills as well as oil and gas facilities; and the U.S. Environmental Protection Agency's (EPA's) Clean Power Plan.[33] Even if the Clean Power Plan had gone into effect, the United States would still need to double its pace in reducing carbon intensity to reach the 2025 goal.[34] However, the Trump Administration has been working to systematically dismantle federal efforts to reduce GHG emissions, and has been encouraging the extraction and use of fossil fuels.

The Paris Agreement was designed to achieve the objective of the Framework Convention on Climate Change, which is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[35] The world's understanding of what that level means is evolving in the direction of lower concentrations of GHGs and thus lower emissions. Prior to Paris, the most frequently stated goal was to hold the global increase in temperatures to 2°C (or 3.6°F) above pre-industrial levels.[36] The Paris Agreement, however, aims to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C [3.7°F] above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[37]

25. U.S. Environmental Protection Agency, *Global Greenhouse Gas Emissions Data*, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (last updated Apr. 13, 2017).
26. World Bank, *CO_2 Emissions (Metric Tons Per Capita)* (showing U.S. per capita emissions to be 17.0 tons in 2011, which is exceeded only by Aruba, Bahrain, Brunei Darussalam, Kuwait, Luxembourg, Oman, Qatar, Trinidad and Tobago, and United Arab Emirates), http://data.worldbank.org/indicator/EN.ATM.CO2E.PC (last visited June 7, 2018).
27. U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015, at ES-5 to ES-8 (2016) (EPA 430-P-17-001) (showing CO_2 emissions from fossil fuel combustion to constitute the great majority of overall GHG emissions), https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf.
28. *See id*. at ES-5 to ES-9 (showing U.S. emissions of those pollutants) and 1-4, 1-6, 1-8 (explaining importance of black carbon).
29. John Dernbach & Widener University Law School Seminar on Global Warming, *Moving the Climate Debate From Models to Proposed Legislation: Lessons From State Experience*, 30 ELR 10933 (Nov. 2000).
30. Daniel Bodansky & Lavanya Rajamani, Center for Climate and Energy Solutions, Key Legal Issues in the 2015 Climate Negotiations 3 (2015), https://www.c2es.org/site/assets/uploads/2015/06/key-legal-issues-2015-climate-agreement.pdf. The legal status of these INDCs depended on whether the subsequent Paris Agreement required them to be achieved or included measures for formally implementing them. *Id.* The Paris Agreement did not do that.
31. United States, Cover Note INDC and Accompanying Information (2015), http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf.
32. *Id.*
33. *Id.*
34. Cristina Maza, *Climate Deal to Be Signed Amid "Faster" Global Progress, Moniz Says*, Christian Sci. Monitor, Apr. 20, 2016, http://www.csmonitor.com/Environment/2016/0420/Climate-deal-to-be-signed-amid-faster-global-progress-Moniz-says.
35. Framework Convention, *supra* note 15, art. 2.
36. *Report of the Conference of the Parties on Its Sixteenth Session, Held in Cancun From 29 November to 10 December 2010*, U.N. Framework Convention on Climate Change, Decision 1/CP.16, ¶ 4, U.N. Doc. FCCC/CP/2010/7/Add.1 (2011), http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf.
37. Paris Agreement, *supra* note 17, art. 2.1(a).

Table 1 shows the global deadlines calculated by the United Nations Environment Programme (UNEP)[38] in 2016 for achieving net-zero emissions in order to hold temperatures below both 1.5°C and 2°C, respectively.

As Table 1 makes clear, the entire world must get to net-zero CO_2 emissions in roughly three decades in order to hold the temperature increase below 1.5°C. Two extra decades are allowed to get to net zero if the goal is to hold temperatures below a 2°C increase. Under the 1.5°C scenarios, all other GHG emissions must be net zero well before century's end, while the 2°C scenario permits the achievement of net-zero GHG emissions shortly before 2100. Some analysts conclude that we have even less time. A 2017 report by Carbon Tracker, the Climate Action Tracker consortium, the Potsdam Institute for Climate Impact Research, and Yale University concludes that the Paris Agreement goals will become out of reach if global GHG emissions do not peak by 2020 and decline sharply thereafter.[39]

The differences between a 1.5°C outcome and a 2°C outcome appear to be considerable. "[W]eather extremes, hydrological impacts and vulnerability to food insecurity" will be significantly greater with 2°C of warming than with 1.5°C of warming.[40] Human exposure to such risks as drought intensity, water stress, heat event exposure, habitat degradation, and lower crop yield doubles between 1.5°C and 2°C of warming, and is an order of magnitude greater under either scenario for "populations vulnerable to poverty."[41]

Sea-level rise will also be less with 1.5°C of warming than with 2°C of warming.[42] This conclusion gains particular significance when coupled with a report that loss of the Antarctic ice sheet quadrupled between 1992-1997 and 2012-2017.[43] The Antarctic ice sheet holds enough water to increase sea levels around the world by more than 150 feet.[44] "When warming is limited to 1.5°C as compared with 2°C," a study published in *Science* has concluded, the number of plants and vertebrates expected to lose more than 50% of their range would be cut in half, while the number of insects projected to lose more than 50% of their range would be reduced by two-thirds.[45]

Three additional observations clarify both the daunting nature of this challenge and its urgency. *First*, growth in energy use and, consequently, CO_2 emissions, is projected to be very high in coming decades, particularly in developing countries. Energy-related GHG emissions are responsible for the great majority of total GHG emissions.[46] In addition, 78% of the total global GHG emissions increase between 1970 and 2010 was due to CO_2 emissions for energy and industrial production.[47] As recently as 2000, developed countries consumed more energy overall than developing countries.[48] By 2040, however, developing country energy consumption is projected to be more than double that in developed countries.[49] More than 85% of the growth in energy consumption over that period will come from developing countries.[50] China and India alone are expected to account for one-half of the global increase in energy consumption,[51] and China's energy consumption is projected to be more than double that of the United States by 2040.[52] While our focus is the United States, which could serve as a model for developing countries' decarbonization efforts, the growth of emissions from developing countries underscores the need for the United States and other developed countries to intensify their decarbonization efforts to become such models.

Second, the probability of success given in Table 1 for meeting either scenario is low for an event of this enormity. That probability—only more than 50%—is three times worse than the odds in Russian roulette. To have a higher probability of success, net-zero or even negative emissions, would have to be achieved even earlier. A variety of projections based on business-as-usual emissions growth put the world on track for a temperature increase of at least 3.7°C to 4.8°C (6.7°F to 8.6°F) by 2100.[53] A 2012 report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics describes the impact of a 4°C temperature increase by 2100 as disastrous.[54] Such a world, the report said, "would be one of unprecedented

38. UNEP provides extensive scientific, technical, and policy analysis in support of global efforts to address climate change. *See* UNEP, *Climate Change*, http://www.unep.org/climatechange/ (last visited June 7, 2018).
39. Carbon Tracker Initiative et al., 2020: The Climate Turning Point (2017), http://www.mission2020.global/wp-content/uploads/2020-The-Climate-Turning-Point.pdf.
40. Richard A. Betts et al., *Changes in Climate Extremes, Fresh Water Availability and Vulnerability to Food Insecurity Projected at 1.5°C and 2°C Global Warming With a Higher-Resolution Global Climate Model*, 376 Phil.Transactions of the Royal Soc'y A: Mathematical, Physical & Engineering Sci. 2119 (2018).
41. Edward Byars et al., *Global Exposure and Vulnerability to Multi-Sector Development and Climate Change Hotspots*, 13 Envtl. Res. Letters 055012 (2018).
42. Carl-Friedrich Schleussner, *Differential Climate Impacts for Policy-Relevant Limits to Global Warming: The Case of 1.5 °C and 2 °C*, 7 Earth Syst. Dynam. 327(2016).
43. The IMBIE Team, *Mass Balance of the Antarctic Ice Sheet Between 1992 and 2017*, 558 Nature 219 (2018).
44. *Id.* at 219.
45. Rachel Warren et al., *The Projected Effect on Insects, Vertebrates, and Plants of Limiting Global Warming to 1.5°C Rather Than 2°C*, 360 Science 791 (2018).
46. IPCC, Climate Change 2014: Mitigation of Climate Change 354-55 (2014).
47. *Id.* at 6.
48. U.S. Energy Information Administration, International Energy Outlook 2013, at 9 fig. 12 (2013) (DOE/EIA-0484(2013)), http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf.
49. *Id.*
50. *Id.* at 9.
51. *Id.* at 9-10.
52. *Id.* at 10.
53. Sustainable Development Solutions Network & Institute for Sustainable Development and International Relations, Pathways to Deep Decarbonization: 2014 Report 4 (2014) [hereinafter DDPP 2014 Report], http://unsdsn.org/wp-content/uploads/2014/09/DDPP_Digit_updated.pdf.
54. World Bank, Turn Down the Heat: Why a 4°C Warmer World Must Be Avoided xiii-xviii (2012), http://www.worldbank.org/content/dam/Worldbank/document/Full_Report_Vol_2_Turn_Down_The_Heat_%20Climate_Extremes_Regional_Impacts_Case_for_Resilience_Print%20version_FINAL.pdf.

heat waves, severe drought, and major floods in many regions, with serious impacts on ecosystems and associated services," and no certainty that adaptation would even be possible.[55] Climate change is also occurring with growing speed and intensity, as indicated by the fact that 2014, 2015, and 2016 each set a record for highest recorded temperature, and that 2017 was the second warmest year on record.[56] All of this, of course, underscores the importance of reducing GHG emissions as rapidly as possible.

Third, it may not be enough to bring the level of emissions to zero. CO_2, the most prominent GHG, stays in the atmosphere for hundreds of years.[57] Given the magnitude of the risks involved, and the strong possibility—some would say the certainty—that some nations will not significantly reduce their emissions, it is likely that finding ways to remove CO_2 from the atmosphere, and thus getting net emissions below zero in other countries, will be necessary.[58]

A major problem—known to the Parties before Paris—is that their INDCs, taken together, are not sufficient to put countries on a trajectory toward keeping the average temperature increase below 2°C. The INDCs submitted by all countries prior to Paris "present[ed] a real increase in the ambition level compared to a projection of current policies," according to UNEP in 2015.[59] As its report explains, however, the INDCs represent only about one-half of the reduction required by 2030 if the world is to have a greater than 66% chance of keeping the global temperature increase below 2°C.[60] Similarly, both the Organisation for Economic Co-operation and Development and the International Energy Agency issued reports prior to the Paris conference saying that the total emissions reductions from all countries that had thus far been submitted would barely change the world's GHG emissions trajectory.[61] The Conference of the Parties in Paris noted this emissions gap—between what is needed and what was promised—"with concern."[62] Moreover, as a legal matter, the INDCs are non-binding and unenforceable, and it is not clear how many countries will actually fulfill their pledges.

To meet the zero-emissions goal, the Paris Agreement establishes a process for ratcheting up national emissions reduction commitments over time. Beginning in 2020, and every five years afterwards, each country is to "prepare, communicate and maintain successive nationally determined contributions that it intends to achieve."[63] These, of course, are in addition to those that countries already submitted. Each "successive nationally determined contribution" is to "represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition."[64]

Beginning in 2023, and every five years afterwards, the Conference of the Parties is to "take stock of the implementation of this Agreement to assess the collective progress towards achieving [its] purpose."[65] "The outcome of th[is] global stocktake" is to "inform Parties in updating and enhancing, in a nationally determined manner, their actions," including "enhanc[ed] international cooperation for climate action."[66] The Paris Agreement also states that "[a]ll Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies. . . ."[67] The Parties were also invited "to communicate, by 2020, to the secretariat mid-century, long-term low greenhouse gas emission development strategies" that would then be published on the secretariat's website.[68] Again, the overall objective is net-zero GHG emissions by the second half of the century.[69]

Another significant challenge for the United States is the expectation stated in the Framework Convention that developed countries will take a leadership position in reducing their GHG emissions. As the preamble states, developed countries have contributed "the largest share of historical and current global emissions of greenhouse gases."[70] They also, by definition, have greater financial and technological resources. Thus, in ratifying the Framework Convention, developed countries agreed to adopt policies and measures that will demonstrate that they "are taking the lead" in addressing climate change.[71] That means that

55. *Id*. at xiii-xiv, xviii.
56. *See* Press Release, National Aeronautics and Space Administration, *supra* note 11.
57. *See* Mason Inman, *Carbon Is Forever*, 2 Nature Rep. Climate Change 156 (2008), https://www.researchgate.net/publication/232782348_Carbon_is_forever.
58. *See* James Hansen et al., *Young People's Burden: Requirement of Negative CO_2 Emissions*, 8 Earth Sys. Dynamics 577 (2017); Bobby Magill, *Michigan Scientists See Urgency for Negative Emissions*, Climate Cent., Aug. 8, 2016, http://www.climatecentral.org/news/scientists-see-urgency-for-negative-emissions-20588. Still, there appear to be serious economic and technological limits to employing various carbon removal methods at scale. *See* Pete Smith et al., *Biophysical and Economic Limits to Negative CO_2 Emissions*, 6 Nature Climate Change 42 (2015).
59. UNEP, The Emissions Gap Report 2015: A UNEP Synthesis Report xvii (2015) (advance report), https://uneplive.unep.org/media/docs/theme/13/EGR_2015_301115_lores.pdf.
60. Press Release, UNEP, INDCs Signal Unprecedented Momentum for Climate Agreement in Paris, but Achieving 2 Degree Objective Contingent Upon Enhanced Ambition in Future Years (Nov. 6, 2015), https://www.unenvironment.org/news-and-stories/press-release/indcs-signal-unprecedented-momentum-climate-agreement-paris.
61. Organisation for Economic Co-operation and Development, Climate Change Mitigation: Policies and Progress 16 (2015) ("Even if the INDCs and national targets announced to date are fully achieved, the remaining global carbon budget (consistent with a below 2 °C world) will be exhausted by around 2040 unless stronger action is taken."), https://read.oecd-ilibrary.org/environment/climate-change-mitigation_9789264238787-en#page1; International Energy Agency, Energy and Climate Change: World Energy Outlook Special Report 12 (2015):

> With INDCs submitted so far, and the planned energy policies in countries that have yet to submit, the world's estimated remaining carbon budget consistent with a 50% chance of keeping the rise in temperature below 2 °C is consumed by around 2040—eight months later than is projected in the absence of INDCs.

https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf.
62. Paris Agreement, *supra* note 17, ¶ 17.
63. *Id*. arts. 4.2, 4.9; *see also* Decision 1/CP.21, *supra* note 17, ¶¶ 23, 24.
64. Paris Agreement, *supra* note 17, art. 4.3.
65. *Id*. arts. 14.1, 14.2.
66. *Id*. art. 14.3.
67. *Id*. art. 4.19. The agreement adds that these strategies should take "into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." *Id*.
68. Decision 1/CP.21, *supra* note 17, ¶ 36.
69. Paris Agreement, *supra* note 17, art. 4.1.
70. Framework Convention, *supra* note 15, pmbl.
71. *Id*. art. 4.2(a).

the United States, among other developed countries, should strive to reduce its GHG emissions as rapidly as possible. In other words, the emissions reduction curves for developed countries should be steeper than those for developing countries. Such a leadership position, for example, would require that the United States reduce the CO_2 emissions intensity of the economy (CO_2 emissions per dollar of gross domestic product (GDP)) by an annual rate of 8% between now and 2050.[72] By contrast, the currently projected *total* reduction in U.S. CO_2 emissions intensity between 2016 and 2040 is 10%.[73]

Nor is the United States alone among developed countries. According to a 2017 analysis published in *Nature*, "[e]mission rates are falling in almost all advanced industrialized countries. But the declines are too slow to meet the pledges that governments made in Paris."[74] One commentator has observed that, at the current rate, the clean energy transition will take nearly 400 years.[75] The challenge for the United States and other countries, then, is not simply to make some progress toward decarbonization. The challenge, rather, is to accelerate progress.

II. U.S. Technical and Policy Pathways to Deep Decarbonization

As previously noted, the legal pathways are based on the technical and policy pathways shown in two DDPP reports on U.S. decarbonization.[76] These two reports are the earliest comprehensive studies about decarbonizing the U.S. economy of which we are aware. The legal pathways are also guided, to a somewhat lesser extent, by two additional studies on U.S. decarbonization that were issued in November 2016. These more recent reports draw substantially the same conclusions on major issues as the DDPP reports because they share many of the same methodologies and authors.[77]

Until recently, a basic problem with long-term emissions reduction goals was that there had been "little physically realistic modeling of the energy and economic transformations required" to substantially reduce GHG emissions by 2050.[78] Using California's goal of reducing GHG emissions by 80% from 1990 levels by 2050 as a focal point, energy analyst Jim Williams and others concluded in a widely read 2012 paper that technically feasible energy efficiency and renewable electricity by themselves are not sufficient to achieve California's goals.[79] It is also necessary, they concluded, that the transportation and building sectors move from fossil fuels to decarbonized electricity.[80] This analysis, which shows the value of sophisticated long-term thinking and modeling on the necessary long-term changes, marks the beginning of the DDPP, a global collaboration of research teams developing pathways to deeply reduce GHG emissions.[81] The modeling and analysis exemplified by the DDPP provides a way to envision the major technological and other changes that are needed to achieve the Paris Agreement's objectives, and to understand the basic policy options that exist and the decisions that must be made.

The DDPP, which is led by the Sustainable Development Solutions Network[82] and the Institute for Sustainable Development and International Relations (IDDRI),[83] is the principal international effort to devise pathways to decarbonize the global economy.[84] The DDPP appears to be the only effort to systematically and comprehensively analyze decarbonization pathways in many countries at the same time.

The DDPP is based on the work of research teams in 16 countries that are responsible for 74% of the world's GHG emissions: Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, the United Kingdom, and the United States.[85] The project was undertaken "to understand and show how individual countries can transition to a low-carbon economy" based on the limit of 2°C.[86] Prior to this project, most of these countries "had never developed pathways consistent with a global 2°C limit, nor were they actively considering this question."[87]

72. DDPP U.S. Policy Report, *supra* note 1, at 10.
73. U.S. Energy Information Administration, Annual Energy Outlook 2017 With Projections to 2050, at 24 (2017), https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf.
74. David G. Victor et al., *Prove Paris Was More Than Paper Promises*, 548 Nature 25 (2017).
75. James Temple, *At This Rate, It's Going to Take Nearly 400 Years to Transform the Energy System*, MIT Tech. Rev., Mar. 14, 2018, https://www.technologyreview.com/s/610457/at-this-rate-its-going-to-take-nearly-400-years-to-transform-the-energy-system/.
76. *See* DDPP U.S. Technical Report, *supra* note 8; DDPP U.S. Policy Report, *supra* note 1.
77. Tim Duane et al., Risky Business, From Risk to Return: Investing in a Clean Energy Economy 70 (2016), https://riskybusiness.org/site/assets/uploads/sites/5/2016/10/RiskyBusiness_FromRiskToReturn.pdf (acknowledging substantial research assistance from the DDPP and the DDPP authors); Ben Haley, *DDPP Informs US Climate Strategy*, Evolved Energy Res., Nov. 16, 2016, https://www.evolved.energy/single-post/2016/11/16/Deep-Decarboniation-Pathways-Project-Informs-US-Climate-Strategy.
78. James H. Williams et al., *The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity*, 335 Science 53, 53 (2012). Jim Williams now directs the DDPP project and is an associate professor at the University of San Francisco. *See* University of San Francisco, *Jim Williams, Associate Professor*, https://www.usfca.edu/faculty/jim-williams (last visited June 7, 2018).
79. Williams et al., *supra* note 78, at 53.
80. *Id*. at 53-54.
81. *See* Jim Williams et al., Pathways to Deep Decarbonization in the United States, PowerPoint Presentation 5 (May 10, 2016) (on file with author).
82. Sustainable Development Solutions Network, *Vision and Organization*, http://unsdsn.org/about-us/vision-and-organization/ (last visited June 7, 2018); *see also* DDPP, *About* (explaining the relationship between the Sustainable Development Solutions Network and the DDPP), http://deepdecarbonization.org/about/ (last visited June 7, 2018).
83. DDPP, *supra* note 82; *see also* IDDRI, https://www.iddri.org/en (last visited June 20, 2018).
84. DDPP 2014 Report, *supra* note 53, at 4.
85. Deep Decarbonization Pathways Project, Pathways to Deep Decarbonization: 2015 Report 3 (Sustainable Development Solutions Network & Institute for Sustainable Development and International Relations 2015) [hereinafter DDPP 2015 Synthesis Report], http://deepdecarbonization.org/wp-content/uploads/2016/03/DDPP_2015_REPORT.pdf.
86. DDPP 2014 Report, *supra* note 53, at III.
87. DDPP 2015 Synthesis Report, *supra* note 85, at 42.

The overall objective of the project is to devise pathways that will "ensure a better-than-even chance of remaining below a 2°C temperature rise."[88] Effectively addressing climate change, the DDPP says, will require, "more than any other factor, the profound transformation of energy systems through steeply reducing carbon intensity in all sectors of the economy."[89] The project also assumes a century-long effort divided in two parts, 2011-2050 and 2051-2100; most of the emissions reduction would occur prior to 2050, with the rest occurring afterwards as emissions reach zero.[90]

The DDPP concludes that it is technically feasible to limit warming to 2°C in spite of assumptions of global population growth of 17% between 2010 and 2050 and global GDP growth of 250% in the same period.[91] Research teams in each of the 16 countries used a "backcasting" approach that assumed the 2°C goal based on the IPCC carbon budget had been met, and then described the changes that were needed to achieve that goal.[92] The research teams, which worked independently of their governments, consisted primarily of technology, energy, and economic analysts.[93] The most ambitious pathways in these reports reduced emissions intensity per unit of GDP by 87% from 2010 levels by 2050, and emissions intensity per capita by 62%.[94] Nearly all of the reports showed pathways to reducing CO_2 emissions to two tons or less per capita by 2050,[95] which is much lower than the current global average of 5.2 tons per capita.[96] Because per capita emissions tend to be higher in developed countries than in developing countries, the needed emissions reductions in developed countries are greater.

All pathways are based on "three pillars of energy system transformation."[97] These are: (1) energy efficiency and conservation across all sectors of the economy, including electricity generation, transportation, buildings, industry, and urban design; (2) low-carbon electricity from replacement of fossil fuel-based generation with combinations of renewable energy, nuclear energy, and the use of carbon capture and storage (CCS) at fossil fuel-based generating facilities; and (3) switching from more carbon-intensive fuels to less carbon-intensive fuels, and eventually switching from fossil fuel use to decarbonized energy carriers, principally electricity, in all sectors.[98] Deep decarbonization requires that all three be achieved at scale in all countries.[99] The first pillar, energy efficiency and conservation, plays the dominant role in the DDPP scenarios prior to 2030, while the second and third pillars become the primary drivers of decarbonization after that.[100]

The tipping point to decarbonization occurs, according to the DDPP, when "costs decline at a rate and speed sufficient to drive their global deployment based solely on their favorable economics."[101] Getting to that point requires enormous new investment in low-carbon technologies, though gross energy investment will be only modestly greater than it is at present.[102] That level of new and redirected investment requires "that policymakers establish investment market rules and institutions to direct investments towards low-carbon options."[103] One approach is for developed countries to "take the lead in developing, deploying, and buying down the cost of low-carbon technologies so they become affordable earlier in developing countries, relative to the cost of conventional technologies."[104]

According to the DDPP, these pathways have enormous practical value for all stakeholders: "By describing the full extent of the transformation required over a longer time frame, [deep decarbonization pathways] provide a unique context for understanding the ambition of the current INDCs, and what further measures deep decarbonization will entail."[105] These pathways allow decisionmakers to see how the next thing that ostensibly needs to be done, or how the climate-related issue now in front of them, fits into an overall effort to decarbonize a nation's entire economy. This is particularly true because, as noted earlier, most of the 16 DDPP countries had not previously engaged in this effort.[106] And these decisionmakers include not only of governmental leaders, but also business and other nongovernmental leaders.

In addition to the DDPP reports, our work also relies to a lesser degree on two reports issued in 2016. The U.S. government under the Obama Administration issued the first of these reports, *United States Mid-Century Strategy for Deep Decarbonization*; it sets out a deep decarbonization strategy for 2050 based on three primary components.[107] This report centers on the transition to a low-carbon energy system, and incorporates the DDPP pillars previously described: energy efficiency, low-carbon electricity generation, and fuel switching. The additional two components of the strategy it puts forth, however, focus on mitigation approaches largely excluded from the DDPP analysis: (1) forest and land use management for carbon sequestration, and (2) reduction of non-CO_2 GHG emissions. (As of

88. *Id*. at 3.
89. *Id*. Some of the individual country reports, however, address other GHGs. *Id*. at 18 n.10.
90. DDPP 2014 Report, *supra* note 53, at 8.
91. *Id*. at 5-6.
92. *Id*. at x. Nearly all of the reports for the 16 countries are available at DDPP, *Country Reports*, http://deepdecarbonization.org/countries/ (last visited June 7, 2018). For an explanation of the use of backcasting in achieving sustainability, see Philip J. Vergragt & Jaco Quist, *Backcasting for Sustainability: Introduction to the Special Issue*, 78 Technological Forecasting & Soc. Change 747 (2011).
93. The U.S. research team, for example, drew from a consulting firm and two U.S. government laboratories, DDPP U.S. Technical Report, *supra* note 8, at iii.
94. DDPP 2015 Synthesis Report, *supra* note 85, at 6.
95. *Id*. at 6-7. The two exceptions are China and South Africa, which are reduced to about three tons per capita by 2050. *Id*. at 7 tbl. 4a.
96. DDPP 2014 Report, *supra* note 53, at VIII, 24-26.
97. DDPP 2015 Synthesis Report, *supra* note 85, at 8.
98. *Id*.
99. *Id*.
100. *Id*. at 10-11.
101. *Id*. at 30.
102. *Id*. at 32.
103. *Id*. at 34.
104. *Id*. at 30.
105. *Id*. at 35.
106. *Id*. at 42.
107. *See* The White House, *supra* note 9.

this writing, a handful of other countries have also developed mid-century decarbonization strategies, including Benin, Canada, the Czech Republic, France, Germany, Mexico, Ukraine, and the United Kingdom.[108])

The second non-DDPP report influencing the legal pathways book grew out of the Risky Business Project, which was founded by former New York City Mayor Michael Bloomberg, former U.S. Secretary of the Treasury Hank Paulson, and businessman and philanthropist Tom Steyer.[109] Entitled *From Risk to Return, Investing in a Clean Energy Economy*,[110] this report hinges on the three DDPP pillars without adding significant additional components. Its analysis of decarbonization is distinguished by its stronger economic lens, focusing on capital investment needs, expected monetary returns, and impacts on American jobs.

Taken together, the U.S. government's *Mid-Century Strategy* and Risky Business' *From Risk to Return* effectively complement the DDPP reports, providing a thorough understanding of what it would take to decarbonize the U.S. economy. However, a widening assemblage of decarbonization pathway reports also provide valuable—and often variable—insights into what a desirable decarbonized society would look like, as well as the collective actions that would most effectively navigate us toward that vision. A select number of these reports illustrate the diversity of these pathways, both on a national and global scale. The pathways are scattered across spectrums of ambition, specificity, and feasibility, exposing a vast range of imagined futures and ways to achieve them. Many of the U.S. decarbonization reports are depicted in Table 2.

Perhaps the most ambitious U.S. approach was developed by Stanford University Professor Mark Jacobson and his team.[111] Their decarbonization concept relies exclusively on the use of wind, water, and sunlight (WWS) to provide energy for every sector in the United States. Without any reliance on nuclear, geothermal, or CCS technologies, they propose that a 100% reduction in GHG emissions from energy is conceivably attainable by 2050. Remarkably, they call for 100% of end-use energy to be derived from electricity or fuels produced from electricity by 2050, a goal that vastly eclipses that of most other pathways, including the DDPP, which project closer to a 50% share.

While Jacobson's WWS pathway has served as a cornerstone for many environmental groups advocating for clean energy reform, it has drawn controversy within the academic realm. In 2017, mathematician and research scholar Chris Clack, along with 20 other scientists, published a study[112] in the *Proceedings of the National Academy of Sciences* that strongly questions the feasibility of the WWS pathway. In response, Jacobson and his team issued a rebuttal that reaffirmed their original conclusions.[113]

A broader spectrum of decarbonization studies exist for the global level. (See Table 3.) On the high end of the ambition spectrum, a comparably optimistic pathway, presented by a team led by Johan Rockström, director of the Stockholm Resilience Centre and a professor of environmental science at Stockholm University, envisions net-zero emissions on a global scale by 2050.[114] The report also calls for using technologies to remove CO_2 from the atmosphere to sustain global net negative emissions between 2050 and 2100, so as to restore atmospheric CO_2 concentrations to levels last seen in the early 2000s (380 ppm) by the end of the century.

Other ambitious global reports take a shorter-term approach, focusing on rapidly approaching deadlines rather than ones decades away. The already-mentioned 2017 report by Carbon Tracker and others states an objective of reaching peak global GHG emissions by 2020 and global net-zero emissions by 2040, primarily through reform in electricity generation, transport, land use, and industry.[115] A 2016 report by the C40 initiative, a network of global megacities collaborating to address climate change, similarly calls for peak global emissions by 2020.[116] The C40 report distinguishes itself in that it targets action at the city level, specifically outlining decarbonization actions within mayoral jurisdiction.

Some scenarios were prepared by major oil companies. Perhaps the most interesting and ambitious, *Sky: Meeting the Goals of the Paris Agreement*, was issued by Shell International B.V. in 2018.[117] The Shell scenario, which is heavily dependent on CCS from fossil fuel-burning facilities and removal of CO_2 from the atmosphere, has the world reaching net-zero GHG emissions by 2070.[118] The report has been criticized for, among other things, overly optimistic assumptions about the scale and cost at which CCS and CO_2 removal can occur.[119] Still, the report does describe a net-zero emissions world, albeit one reliant on one-half of the fossil fuels currently in use.[120] While Shell says it has no

108. United Nations Framework Convention on Climate Change, *Communication of Long-Term Strategies*, http://unfccc.int/focus/long-term_strategies/items/9971.php (last visited Aug. 17, 2018). The European Union has also published several deep decarbonization roadmaps. Claire Dupont & Sebastian Oberthür, *Decarbonization in the EU: Setting the Scene*, *in* Decarbonization in the European Union: Internal Policies and External Strategies 1, 7-8 (Claire Dupont & Sebastian Oberthür eds., Palgrave Macmillan 2015).

109. Risky Business, *About Us*, https://riskybusiness.org/about/ (last visited June 7, 2018).

110. Risky Business, From Risk to Return, *supra* note 77 (links to report, four appendices, and case study).

111. Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States*, 8 Energy & Envtl. Sci. 2093 (2015).

112. Christopher T.M. Clack et al., *Evaluation of a Proposal for Reliable Low-Cost Grid Power With 100% Wind, Water, and Solar*, 114 Proc. Nat'l Acad. Sci. 6722 (2017).

113. Mark Z. Jacobson et al., *The United States Can Keep the Grid Stable at Low Cost With 100% Clean, Renewable Energy in All Sectors Despite Inaccurate Claims*, 114 Proc. Nat'l Acad. Sci. E5021 (2017).

114. Johan Rockström et al., *A Roadmap for Rapid Decarbonization*, 355 Science 1269 (2017).

115. Carbon Tracker Initiative et al., *supra* note 39.

116. C40 & Arup, Deadline 2020: How Cities Will Get the Job Done (2016), http://www.c40.org/researches/deadline-2020.

117. Shell International B.V., Sky: Meeting the Goals of the Paris Agreement (2018).

118. *Id*. at 60.

119. *See, e.g.*, Greg Muttitt, *Shell Game: What Shell Gets Wrong in Its New Climate Report*, Oil Change Int'l, Mar. 28, 2018, http://priceofoil.org/2018/03/28/shell-game-oil-company-says-climate-future-is-fossil-fuelled/.

120. *Id*.

Table 2
National Decarbonization Pathways

Publication	Decarbonization Pathway Targets			
	Reduction of Net GHG Emissions	Reduction of GHG Emissions Per Capita	Year to Achieve Net-Zero Emissions	Includes Periods of Net Negative Emissions
The White House, *United States Mid-Century Strategy for Deep Decarbonization* (2016)[a]	80% (2005 levels) by 2050[b]	*Not specified*	2060-2070	No
Risky Business Project, *From Risk to Return: Investing in a Clean Energy Economy* (2016)[c]	80% (1990 levels) by 2050[d]	89% (2015 levels) by 2050 [1.8 tons CO_2 (tCO_2) by 2050][e]	*Not specified*	No
Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States* (2015)[f]	100% (2015 levels) by 2050	*Not specified*	2050	No
International Renewable Energy Agency, *Renewable Energy Prospects: United States of America* (2015)[g]	33% (2005 levels) by 2030	*Not specified*	*Not specified*	No
DDPP, *Pathways to Deep Decarbonization in the United States* (2015)[h]	80% (1990 levels) by 2050	89% (2014 levels) by 2050 [1.7 tCO_2 by 2050][i]	*Not specified*	No
Leon E. Clark et al., *Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise* (2014)[j]	**50% Scenario**: 50% (2005 levels) by 2050	*Not specified*	*Not specified*	No
	80% Scenario: 80% (2005 levels) by 2050	*Not specified*	*Not specified*	No

a. The White House, United States Mid-Century Strategy for Deep Decarbonization (2016).
b. Three different scenarios would achieve reductions ranging from 74%-86% net GHG emissions reduction by 2050. *Id*. at 7.
c. Tim Duane et al., Risky Business, From Risk to Return: Investing in a Clean Energy Economy 70 (2016).
d. *Id*. at 21.
e. Tim Duane et al., Risky Business, From Risk to Return: Investing in a Clean Energy Economy, App. 1: A-1 Model, Methodology, Key Results 19 (2016), https://riskybusiness.org/site/assets/uploads/sites/5/2016/10/A-1-Appendix-Model-Meth-Results.pdf. The 89% reduction from 2015 levels assumes 2015 per capita emissions of 16.2 tons of CO_2 (tCO_2) per person. *Id*. at 17 tbl. A-1-2.
f. Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States*, 8 Energy & Envtl. Sci. 2093 (2015).
g. International Renewable Energy Agency, Renewable Energy Prospects: United States of America (2015).
h. James H. Williams et al., Pathways to Deep Decarbonization in the United States, U.S. 2050 Report, Volume 1: Technical Report xii (Deep Decarbonization Pathways Project & Energy and Environmental Economics, Inc., 2015).
i. *Id*. at 5. An 89% reduction from 2014 levels assumes 2014 per capita emissions of 16.0 tCO_2 per person (from *id*. at 20 tbl. 7).
j. Leon E. Clark et al., *Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise*, 35 Energy J. 9 (2014).

immediate plans to change its investments to move toward zero emissions, it says it made a commitment in 2017 to reduce its GHG emissions in accordance with "society's implementation of the Paris Agreement's goal."[121]

Many global decarbonization pathway reports fall midline on the ambition spectrum, but low on the scale of specificity, providing a bird's-eye analysis of what the

121. Shell explained:

> Although, we have no immediate plans to move to a net-zero emissions portfolio, in November of 2017, we announced our ambition to reduce our net carbon footprint in accordance with society's implementation of the Paris Agreement's goal of holding global average temperature to well below 2°C above pre-industrial levels. Accordingly, assuming society aligns itself with the Paris Agreement's goals, we aim to reduce our net carbon footprint, which includes not only our direct and indirect carbon emissions, associated with producing the energy products which we sell, but also our customers' emissions from their use of the energy products that we sell, by 20% in 2035 and by 50% in 2050.

Shell International B.V., *supra* note 117, at 66.

Table 3
Global Decarbonization Pathways

Publication	Decarbonization Pathway Targets			
	Reduction of Net GHG Emissions	Reduction of GHG Emissions Per Capita	Year to Achieve Net-Zero Emissions	Includes Periods of Net Negative Emissions
Johan Rockström et al., *A Roadmap for Rapid Decarbonization* (2017)[a]	380 ppm by 2100	*Not specified*	2050	Yes
International Energy Agency & International Renewable Energy Agency, *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System* (2017)[b]	70% or more (2017 levels) by 2050[c]	78% (2017 levels) by 2050 [<1.0 tCO_2 by 2050][d]	2060	No
International Energy Agency, *Tracking Clean Energy Progress: Informing Energy Sector Transformations* (2017)[e]	**2°C Scenario**: 70% (2017 levels) by 2060	*Not specified*	Before 2100	No
	Beyond 2°C Scenario: 100% by 2060	*Not specified*	2060	No
Climate Tracker Initiative et al., *2020: The Climate Turning Point* (2017)[f]	Peak by 2020	*Not specified*	2040	No
ExxonMobil, *2017 Outlook for Energy: A View to 2040* (2017)[g]	Peak at 10% above 2015 levels by 2030-2040	*Not specified*	*Not specified*	No
Shell International B.V., *Sky: Meeting the Goals of the Paris Agreement* (2018)[h]	**Well Below 2**°C **Scenario**: 100% by 2070	100 gigajoules per year[i]	2070	Yes
C40 & Arup, *Deadline 2020: How Cities Will Get the Job Done* (2016)[j]	**2°C Scenario**: Peak at 5% above 2016 levels by 2020	42% (2016 levels) by 2030 [2.9 tCO_2 by 2030]	2100	No
	1.5°C Scenario: Peak at 5% above 2016 levels by 2020	42% (2016 levels) by 2030 [2.9 tCO_2 by 2030][k]	2050	Yes
World Bank, *Decarbonizing Development: Three Steps to a Zero-Carbon Future* (2015)[l]	*Not specified*	*Not specified*	2100	No
DDPP, *Pathways to Deep Decarbonization* (2015)[m]	51% (2010 levels) by 2050[n]	[2.1 tCO_2 by 2050][o]	2050-2070[p]	No
LIMITS Consortium, *Limiting Global Warming to 2°C: Policy Findings From Durban Platform Scenario Analyses* (2014)[q]	450 ppm by 2100	*Not specified*	2075	Yes
International Energy Agency, *Energy Technology Perspectives: Pathways to a Clean Energy System* (2012)[r]	50% or more (2009 levels) by 2050	*Not specified*	2075	No

a. Johan Rockström et al., *A Roadmap for Rapid Decarbonization*, 355 Science 1269 (2017).
b. International Energy Agency & International Renewable Energy Agency, Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (2017).
c. *Id*. at 7.
d. *Id*. at 62. The 78% reduction from 2017 levels assumes 2017 per capita emissions of 4.4 tCO_2 per person. *Id*. at 62.
e. International Energy Agency, Tracking Clean Energy Progress: Informing Energy Sector Transformations (2017).
f. Carbon Tracker Initiative et al., 2020: The Climate Turning Point (2017), http://www.mission2020.global/wp-content/uploads/2020-The-Climate-Turning-Point.pdf.

g. ExxonMobil, 2017 Outlook for Energy: A View to 2040 (2017), http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2017/2017-outlook-for-energy.pdf.
h. Shell International B.V., Sky: Meeting the Goals of the Paris Agreement (2018). Two years earlier, the company issued another scenario based on meeting the 2°C limit. Shell International B.V., Better Life With a Healthy Planet (2016).
i. Shell International B.V., Sky: Meeting the Goals of the Paris Agreement 27 (2018).
j. C40 & Arup, Deadline 2020: How Cities Will Get the Job Done (2016), http://www.c40.org/researches/deadline-2020.
k. *Id*. at 9. A 42% reduction from 2016 levels assumes 2016 per capita emissions of 5.0 tCO_2 per person. The report notes that this reduction "would keep cities on a trajectory consistent with either 1.5 or 2 degrees of warming; it is only after 2030 that these trajectories diverge."
l. World Bank, Decarbonizing Development: Three Steps to a Zero-Carbon Future (2015).
m. Deep Decarbonization Pathways Project, Pathways to Deep Decarbonization: 2015 Report 3 (Sustainable Development Solutions Network & Institute for Sustainable Development and International Relations 2015), http://deepdecarbonization.org/wp-content/uploads/2016/03/DDPP_2015_REPORT.pdf.
n. An average over modeled pathway scenarios ranging from 46%-56% net GHG emissions reduction below 2010 levels by 2050. *Id*. at 5.
o. *Id*. at 6.
p. *Id*. at 3. The precise year for net zero is not specified, but the report notes that limiting anthropogenic warming to less than 2°C of warming "requires that the world cut global net emissions of greenhouse gases so that they approach zero between 2050 and 2075." *Id*.
q. LIMITS Consortium, Limiting Global Warming to 2°C: Policy Findings From Durban Platform Scenario Analyses (2014), http://www.feem-project.net/limits/docs/limits_pb.pdf.
r. International Energy Agency, Energy Technology Perspectives: Pathways to a Clean Energy System (2012).

global energy transition will look like. For example, the World Bank put forth a 2015 report[122] that restates the importance of transitioning to a net-zero emissions world as soon as possible. It echoes the DDPP's call for electricity decarbonization, energy efficiency, and fuel switching, while adding a focus on preservation of natural carbon sinks. It does not, however, provide specific targets to guide decarbonization on a national or local scale. The International Energy Agency's 2012[123] and 2017[124] reports are similarly high-level, describing overarching energy trends and tracking clean energy technology and innovation over a wide range of global sectors, including industry, buildings, and transport. Such reports offer valuable insights, but on a broader scale than may be directly applicable to decarbonization pathways in the United States.

On the high end of the specificity spectrum, several reports (global and U.S.) focus in greater detail on a single sector. For example, the International Renewable Energy Agency's 2015 report[125] and a collaborative 2017 report by the International Energy Agency and the International Renewable Energy Agency[126] offer comprehensive descriptions of pathways to decarbonize the electricity sector. These reports are useful for better understanding the role of renewable electricity, but do not offer a holistic vision for decarbonization of all sectors.

While a diverse collection of reports enhances our understanding of the range of decarbonization possibilities, the DDPP analysis falls relatively midline in terms of ambition, feasibility, and specificity, making it especially useful for a balanced analysis. Still, while the legal pathways in our book are guided by a range of reports, the legal pathways are not in all cases limited by the assumptions that these reports make. Achieving the outcomes in the DDPP and other reports will be challenging, to say the least, and some recommended approaches may falter for economic, technological, or political reasons. Therefore, we identify legal pathways that are in addition to or supplement the pathways that the DDPP identifies.

For example, chapters on "Behavior,"[127] "Transportation Demand and Mode Shifting," and "Phasing Out Fossil Fuels in the Electricity Sector" all supplement approaches taken in the DDPP reports by providing additional legal options for achieving decarbonization. It may be possible to get to decarbonization without these things, but maybe not. A chapter on "Negative Emissions Technologies and Direct Air Capture" provides another example.[128] Specific legal pathways can make the availability of negative emissions technologies more likely than the DDPP envisioned because these options overcome obstacles to scaling up those technologies. These analyses are illustrative, but not exhaustive, of the ways in which the work supplements the pathways described in the DDPP reports.

Expanding the range of legal options has other values as well. It helps enable policymakers to choose options that have the lowest costs, the greatest co-benefits (economic, social, and environmental benefits other than the benefit of reducing climate pollutants), or those that are most politically feasible. Expanding the range of legal options thus provides ways of accomplishing decarbonization more quickly.

III. Why Deep Decarbonization Is in America's Interest

Deep decarbonization is in America's interest for a great many reasons. Perhaps the most important are public health and welfare, national security, food security, and consistency with American values.

122. World Bank, Decarbonizing Development: Three Steps to a Zero-Carbon Future (2015).
123. International Energy Agency, Energy Technology Perspectives: Pathways to a Clean Energy System (2012).
124. International Energy Agency, Tracking Clean Energy Progress: Informing Energy Sector Transformations (2017).
125. International Renewable Energy Agency, Renewable Energy Prospects: United States of America (2015).
126. International Energy Agency & International Renewable Energy Agency, Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (2017).
127. An excerpt was published in Michael P. Vandenbergh & Paul C. Stern, *The Role of Individual and Household Behavior in Decarbonization*, 47 ELR 10941 (Nov. 2017).
128. An excerpt was published in Tracy Hester, *Legal Pathways to the Broad Use of Negative Emissions Technologies and Direct Air Capture of Greenhouse Gases*, 48 ELR 10413 (May 2018).

A. Public Health and Welfare

Deep decarbonization is needed to protect human health and well-being in the United States. In 2009, after detailed analysis of the science and consideration of extensive public comment, EPA made a formal finding that "six greenhouse gases taken in combination endanger both the public health and the public welfare of current and future generations."[129] For public health, EPA found, the greatest increased risks from climate change are "associated with changes in air quality, increases in temperatures, changes in extreme weather events, increases in food- and water-borne pathogens, and changes in aeroallergens."[130] For public welfare, a term defined under the Clean Air Act (CAA) to include a wide variety of non-health-related impacts,[131] EPA found "numerous and far-ranging risks to food production and agriculture, forestry, water resources, sea level rise and coastal areas, energy, infrastructure, and settlements, and ecosystems and wildlife."[132]

The endangerment finding was then challenged before the U.S. Court of Appeals for the District of Columbia (D.C.) Circuit, which unanimously upheld the finding.[133] The U.S. Supreme Court took jurisdiction over another part of this case, and reversed the D.C. Circuit's decision on that part of the case, but did not take jurisdiction over the endangerment finding decision.[134]

The endangerment finding is not the last word on the actual and likely impacts of climate change on the United States. The U.S. Global Change Research Program, which was authorized by the U.S. Congress in 1990, issued the first portion of its fourth climate change assessment in 2017.[135] Concentrations of CO_2 in the atmosphere, the report said, are now more than 400 ppm, "a level that last occurred about 3 million years ago, when both global average temperature and sea level were significantly higher than today."[136] Average global surface temperatures are about 1.8°F (1.0°C) warmer than they were 115 years ago, are likely to increase by another 2.5°F in the United States by 2050, and "could reach 9°F (5°C) or more by the end of this century" if the world continues on a business-as-usual pathway.[137] It projected sea-level rise by 2100 at one to four feet, and said that a rise of eight feet "cannot be ruled out."[138] Already, it explained, rainfall intensity is increasing, there are a growing number of heat waves, the incidence of forest fires is greater, the ocean is acidifying, and glaciers are melting.[139]

Three aspects of climate change impacts on the United States merit some additional explanation: public health risks of a changing climate, the public health benefits of climate change action, and the economic effects of action and inaction.

1. Public Health Risks of Climate Change

Climate change intensifies existing health threats and creates new ones. These are some of the most important health impacts[140]:

Heat waves. Heat waves are highly likely to increase in intensity.[141] Extreme heat events have long been a source of high mortality, especially in the elderly, people who work outdoors, and people who cannot afford air-conditioning.[142]

Outdoor air quality. Rising temperatures and wildfires and decreasing precipitation will lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.[143]

Heavy precipitation. The frequency of heavy precipitation events has already increased and is projected to increase much more throughout the United States.[144] Floods are the second deadliest of all weather-related hazards (behind extreme heat). Flash floods and flooding associated with tropical storms result in the highest numbers of deaths, mostly from drowning. After storms pass, waterborne disease outbreaks frequently occur.[145]

Drought. Some parts of the United States have experienced prolonged droughts, and these are projected to

129. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66496, 66496 (Dec. 15, 2009) (codified at 40 C.F.R. ch. I). EPA also found that "the combined emissions of these greenhouse gases from new motor vehicles and new motor vehicle engines contribute to the greenhouse gas air pollution that endangers public health and welfare" under §202(a) of the CAA, 42 U.S.C. §7521(a). *Id*. The six gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. *Id*. at 66497. In a similarly well-documented notice, EPA denied petitions for reconsideration of that finding. EPA's Denial of the Petitions to Reconsider the Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 75 Fed. Reg. 49556 (Aug. 13, 2010).

130. 74 Fed. Reg. at 66497.

131. 42 U.S.C. §7602(h):

> All language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants.

132. 74 Fed. Reg. at 66498.

133. Coalition for Responsible Regulation v. Environmental Prot. Agency, 684 F.3d 102 (D.C. Cir. 2012), *rev'd in part on other grounds sub nom*. Utility Air Regulatory Group v. Environmental Prot. Agency, 134 S. Ct. 2427, 44 ELR 20132 (2014).

134. *Id*.

135. U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment (Vol. 1) (2017) [hereinafter Climate Science Special Report], https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf.

136. *Id*. at 11.

137. *Id*. at 10-11.

138. *Id*. at 10.

139. *Id*. at 10-11.

140. *See generally* Climate Change, Public Health, and the Law (Michael Burger & Justin Gundlach eds., Cambridge Univ. Press, forthcoming 2018).

141. *Id*. at 21.

142. U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment 44 (2016) [hereinafter Impacts of Climate Change on Human Health].

143. *Id*. at 44, 70.

144. Climate Science Special Report, *supra* note 135, at 20-22.

145. American Public Health Association & U.S. Department of Health and Human Services, Extreme Rainfall and Drought (n.d.), https://www.cdc.gov/climateandhealth/pubs/precip-final_508.pdf.

grow considerably worse.[146] This leads to dust storms, flash flooding, degraded water quality, reduced water quantity, and (especially when combined with extreme heat) wildfires that can destroy large areas and endanger populations, both directly and through smoke that can carry long distances.[147] A "25% to 100% increase in extreme dry-to-wet precipitation events is projected" for California, "despite only modest changes" in average precipitation, and this increase in extreme events "would seriously challenge California's existing water storage, conveyance and flood control infrastructure."[148]

Diseases caused by vectors. Climate affects the distribution of diseases borne by fleas, ticks, and mosquitoes.[149] Among the diseases spread by these vectors in the United States are Lyme, dengue fever, West Nile virus, and Rocky Mountain spotted fever. Climate change alters the geographic and seasonal occurrence of these diseases.[150]

Higher pollen concentrations. Climate change leads to more frost-free days and warmer air temperatures, which can, in turn, cause greater production of plant-based allergens.[151]

Water availability. According to the U.S. Global Change Research Program, "[i]ncreases in some extreme weather events and storm surges will increase the risk that infrastructure for drinking water, wastewater, and stormwater will fail due to either damage or exceedance of system capacity, especially in areas with aging infrastructure."[152] In addition, the ongoing reductions in "surface and groundwater supplies in many areas are expected to continue, increasing the likelihood of water shortages for many uses."[153]

Finally, it needs to be recognized that the adverse health consequences to people in other countries, particularly those in low-lying island countries and those in already hot regions, could potentially be catastrophic. For example, it may not be possible to even survive without air-conditioning in some very hot regions during the hottest months as temperatures increase.[154]

2. Public Health Benefits of Reducing GHG Emissions

In addition to avoiding or minimizing adverse effects from climate change, actions to reduce GHG emissions can also have beneficial public health impacts. Efforts in the United States to fight climate change are focused on the two principal sources of GHGs: coal-fired power plants and motor vehicles. Though inhalation of GHGs in the relevant concentrations is not especially harmful, these sources also emit harmful air pollutants whose quantities would be greatly reduced as a co-benefit of GHG reductions.

Coal-fired power plants emit numerous air pollutants. Fine particulate matter ($PM_{2.5}$) causes cardiac death, damaged respiratory systems, blood clots, high blood pressure, asthma, and is a contributing factor in other disorders, such as Alzheimer's disease. Sulfur dioxide causes nasal inflammation, shortness of breath, and other problems. Mercury (which coal plants emit into the air) falls back to earth in precipitation, becomes embedded in fish tissue, and is consumed by humans; it harms fetuses and small children and leads to many neurological problems.[155]

Several studies have quantified the economic damages (mostly mortality and morbidity) in the United States caused by the air pollution from coal-fired power plants. A study from the National Research Council estimated the economic costs at $62 billion/year (in 2007 dollars).[156] Another published in the *American Economic Review* estimated damages of $53.4 billion/year (in 2000 dollars).[157]

Gasoline engines, mainly used in passenger automobiles and small trucks, emit carbon monoxide, nitrogen oxides (NO_x), and hydrocarbons. Diesel engines, used widely in heavy-duty vehicles like trucks and buses, emit all of these (though more NO_x and less carbon monoxide), and also significant amounts of $PM_{2.5}$ (much of which is black carbon, a significant contributor to climate change). More ambitious Corporate Average Fuel Economy standards, in addition to yielding major savings in fuel costs and reductions in GHG emissions, lead to greatly reduced emissions of these unhealthful pollutants. So would tighter GHG emission standards for heavy-duty vehicles.[158]

3. Economic Opportunities and Economic/Property Risks

The economic opportunities of accelerating the transition to renewable energy and energy efficiency are considerable, while the costs of business as usual are almost certain to be enormous. The economic and job creation benefits of action on climate change, for example, are already significant, and are virtually certain to grow in the future. Taken together, energy productivity (energy efficiency, energy conservation, and better energy management) and renew-

146. Climate Science Special Report, *supra* note 135, at 113.
147. *Id*. at 108-10.
148. Daniel L. Swain et al., *Increasing Precipitation Volatility in Twenty-First Century California*, 8 Nature Climate Change 427, 427 (2018).
149. Impacts of Climate Change on Human Health, *supra* note 142, at 130.
150. *Id*. at 130-43.
151. *Id*. at 77-79.
152. *Id*. at 158.
153. *Id*. at 28.
154. Jeremy S. Pal & Elfatih A.B. Eltahir, *Future Temperature in Southwest Asia Projected to Exceed a Threshold for Human Adaptability*, 6 Nature Climate Change 197 (2016).
155. Erica Burt et al., University of Illinois at Chicago School of Public Health, Scientific Evidence of Health Effects From Coal Use in Energy Generation (2013), https://noharm-uscanada.org/sites/default/files/documents-files/828/Health_Effects_Coal_Use_Energy_Generation.pdf; National Research Council, Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use 82-99 (2010), https://www.nap.edu/catalog/12794/hidden-costs-of-energy-unpriced-consequences-of-energy-production-and,
156. *Id*. at 6.
157. Nicholas Z. Muller et al., *Environmental Accounting for Pollution in the United States Economy*, 101 Am. Econ. Rev. 1649 (2011), *available at* https://www.aeaweb.org/articles?id=10.1257/aer.101.5.1649.
158. Jonathan J. Buonocore et al., *Health and Climate Benefits of Different Energy-Efficiency and Renewable Energy Choices*, 6 Nature Climate Change 100 (2016), *available at* http://www.nature.com/nclimate/journal/v6/n1/full/nclimate2771.html#supplementary-information.

able energy "are now the largest source of new energy services to the American economy."[159]

Some 2.2 million workers are employed in energy efficiency.[160] California's various energy-efficiency programs, which have kept per capita electricity consumption in that state relatively flat for decades, have saved consumers billions of dollars, reduced air pollution from fossil fuels, created jobs, and helped low-income families.[161] Doubling energy productivity would save the U.S. economy $327 billion annually after subtracting investment costs, and generate an additional 1.3 million jobs.[162]

Job creation in the wind and solar industries is also growing very rapidly. Even though coal provides a much greater share of U.S. electricity than solar, the number of solar workers is double that in the coal industry.[163] Between 2010 and 2017, solar employment grew from about 93,000 to roughly 250,000 jobs, an increase of 168%.[164] Wind industry employment grew to 102,000 jobs in 2016, a 32% increase over 2015.[165] In 2018, the U.S. Bureau of Labor Statistics projected that solar photovoltaic installers and wind turbine service technicians would be the two fastest-growing occupations in the United States over the next decade.[166]

Indeed, a driving force behind state and local renewable energy and energy-efficiency efforts for two decades has been the desire to increase jobs and businesses, foster the development of new technologies, and reduce the costs of energy for both homes and businesses.[167] Growth in energy productivity and renewable energy is likely to increase in the future, with attendant growth in jobs and economic development, thanks to three key trends. Costs per unit of energy service are declining, performance is increasing, and the functions they can serve are diverse and increasing.[168]

By contrast, the projected economic costs of climate change to the United States are enormous. A 2017 study published in *Science* integrated climate science and econometric analysis to estimate damage from climate change to the United States.[169] The authors concluded that "[t]he combined value of market and nonmarket damage across analyzed sectors—agriculture, crime, coastal storms, energy, human mortality, and labor"—is likely to be about "1.2% of gross domestic product" for every additional 1°C of temperature increase. They also found a 90% likelihood that, by "the late 21st century, the poorest third of counties are projected to experience damages between 2 and 20% of county income . . . under business-as-usual emissions."[170]

In 2018, the Union of Concerned Scientists used data on chronic coastal flooding as well as data from Zillow, the online real estate company, to project that sea-level rise in the contiguous United States will put 300,000 homes and business properties worth $236 billion at risk of "chronic, disruptive flooding" by 2045. It also projected that 2.5 million properties worth more than $1 trillion in today's dollars will be at risk of such flooding by 2100.[171] In many coastal and noncoastal areas, property values are already declining because of the effects of climate change.[172]

B. National Security

Since the 1990s, the U.S. Department of Defense (DOD) and the intelligence community have been concerned about climate change.[173] In 2008, under President George W. Bush, DOD's National Defense Strategy identified climate change as a national security concern.[174] DOD's 2014 Quadrennial Defense Review described the effects of climate change as "threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions—conditions that can enable terrorist activity and other forms of violence."[175]

In 2015, DOD identified four national security risks raised by climate change: (1) "[p]ersistently recurring conditions such as flooding, drought, and higher temperature" that contribute to conflict and instability; (2) "[m]ore frequent and/or more severe extreme weather events that may require" substantial DOD "humanitarian assistance and disaster relief"; (3) "[s]ea level rise and temperature

159. John Byrne & John Dernbach, *Consumers Prefer Clean Energy*, Balt. Sun, May 9, 2017, http://www.baltimoresun.com/news/opinion/oped/bs-ed-efficient-energy-20170509-story.html.
160. U.S. Department of Energy, U.S. Energy and Employment Report 8-9 (2017), https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf; Environmental Entrepreneurs (E2) & E4TheFuture, Energy Efficiency Jobs in America: A Comprehensive Analysis of Energy Efficiency Employment Across All 50 States 4 (2016), https://www.e2.org/wp-content/uploads/2016/12/EnergyEfficiencyJobsInAmerica_FINAL.pdf.
161. Natural Resources Defense Council, California's Energy Efficiency Success Story: Saving Billions of Dollars and Curbing Tons of Pollution 2 (2013), https://www.nrdc.org/sites/default/files/ca-success-story-FS.pdf.
162. Alliance to Save Energy, American Energy Productivity: The Economic, Environmental, and Security Benefits of Unlocking Energy Efficiency 9-10, 13-14 (2013), http://www.ase.org/sites/ase.org/files/rhg_americanenergyproductivity_0.pdf.
163. International Renewable Energy Agency, Renewable Energy and Jobs: Annual Review 2017, at 6 (2017).
164. The Solar Foundation, National Solar Jobs Census 2017, at 4 (2018), https://www.thesolarfoundation.org/national/.
165. U.S. Department of Energy, *supra* note 160, at 8.
166. U.S. Department of Labor, Bureau of Labor Statistics, *Fastest Growing Occupations*, https://www.bls.gov/emp/tables/fastest-growing-occupations.htm (last modified Apr. 11, 2018).
167. John Byrne et al., *American Policy Conflict in the Greenhouse: Divergent Trends in Federal, Regional, State, and Local Green Energy and Climate Change Policy*, 35 Energy Pol'y 4555 (2007).
168. Byrne & Dernbach, *supra* note 159.
169. Solomon Hsiang et al., *Estimating Economic Damage From Climate Change in the United States*, 356 Science 1362 (2017).
170. *Id. See also* Trevor Houser et al., Economic Risks of Climate Change: An American Perspective (2015).
171. Kristina Dahl et al., Union of Concerned Scientists, Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate 2 (2018), https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf.
172. John Nolon, *Land Use and Climate Change Bubbles: Resilience, Retreat, and Due Diligence*, 39 Wm. & Mary Envtl. L. & Pol'y Rev. 321 (2015).
173. The Center for Climate & Security, *Chronology of Military and Intelligence Concerns About Climate Change*, https://climateandsecurity.org/2017/01/12/chronology-of-the-u-s-military-and-intelligence-communitys-concern-about-climate-change/ (last visited June 7, 2018).
174. DOD, National Defense Strategy 5 (2008).
175. DOD, Quadrennial Defense Review 2014, at 8 (2014), http://archive.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf.

changes" that can adversely affect navigation, port facilities, and coastal communities; and (4) "[d]ecreases in Arctic ice cover, type, and thickness" that raise a variety of security and operational issues.[176] The National Defense Authorization Act enacted by Congress and signed by President Trump in December 2017 stated that "[c]limate change is a direct threat to the national security of the United States and is impacting stability in areas of the world both where the United States Armed Forces are operating today, and where strategic implications for future conflict exist."[177]

While President Trump's 2018 National Defense Strategy omitted any reference to climate change,[178] Dan Coats, director of national intelligence, issued a "worldwide threat assessment" on behalf of U.S. intelligence agencies in early 2018 that included an assessment of the risks of climate change.[179] The assessment stated: "The impacts of the long-term trends toward a warming climate, more air pollution, biodiversity loss, and water scarcity are likely to fuel economic and social discontent—and possibly upheaval—through 2018."[180] After explaining that the "past 115 years have been the warmest period in the history of modern civilization, and the past few years have been the warmest years on record," the Coats assessment added a blunt warning: "Research has not identified indicators of tipping points in climate-linked earth systems, suggesting a possibility of abrupt climate change."[181]

Climate change adaptation is also becoming important for DOD. A three-foot sea-level rise by 2100 could put at risk 128 coastal bases in the United States.[182] Some installations, including the large naval station in Norfolk, Virginia, have already experienced flooding and power outages due to flooding and storm surge.[183] The U.S. Government Accountability Office recommended in 2014 that DOD "develop a project plan and milestones for completing" its vulnerability assessment for various DOD facilities, and develop a plan for using that information "in support of climate change adaptation planning."[184] In that same year, DOD issued a climate change adaptation "roadmap" to guide its adaptation activities.[185] In 2018, a DOD study found that in the latter part of the 21st century, certain key military installations on atolls in the Pacific may be flooded annually.[186]

C. Food Security

Greater temperatures and weather extremes will likely "increase the exposure of food to certain pathogens and toxins."[187] In addition, a changing climate will "alter incidence and distribution of pests, parasites, and microbes" in agriculture, "leading to increases in the use of pesticides and veterinary drugs."[188] Increasing CO_2 levels reduce the "nutritional value of agriculturally important food crops, such as wheat and rice," and "reduce the concentrations of protein and essential minerals in most plant species."[189] Increases in extreme weather events will also disrupt "food distribution by damaging existing infrastructure or slowing food shipments," limiting the availability of food because of "food damage, spoilage, or contamination."[190] Climate change is also likely to damage global patterns of food production, transportation, and distribution in ways that will adversely affect U.S. producers and consumers, and these adverse effects will grow as temperatures increase.[191]

D. American Values

The reasons for addressing climate change that are discussed above—protection of human health and welfare, national security, and food security—are pragmatic. And they are also consistent with, and based on, values deeply held by a great many Americans. These include self-interest; a desire for freedom, opportunity, and quality of life; recognition that our actions should not harm others, including those in other countries as well as those in future generations; and an understanding that a growing economy should bring greater prosperity and well-being to all. They are also con-

176. DOD, National Security Implications of Climate-Related Risks and a Changing Climate 4-5 (2015), http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf.
177. Pub. L. No. 115-91, §335(b)(1), 131 Stat. 1283.
178. DOD, Summary of the 2018 National Defense Strategy of the United States of America (2018).
179. Daniel R. Coats, Statement for the Record, Worldwide Threat Assessment of the U.S. Intelligence Community 16 (2018), https://www.dni.gov/files/documents/Newsroom/Testimonies/2018-ATA---Unclassified-SSCI.pdf.
180. *Id.*
181. *Id.* As a National Research Council report states:

> Abrupt climate change is generally defined as occurring when some part of the climate system passes a threshold or tipping point resulting in a rapid change that produces a new state lasting decades or longer. . . . In this case "rapid" refers to timelines of a few years to decades.

National Research Council, Climate and Social Stress: Implications for Security Analysis 58 (2012). "A key characteristic of these changes is that they can unfold faster than expected, planned for, or budgeted for, forcing a reactive, rather than proactive mode of behavior. These changes can propagate systemically, rapidly affecting multiple interconnected areas of concern." National Research Council, Abrupt Impacts of Climate Change: Anticipating Surprises 27 (2013).

182. Laura Parker, *Who's Still Fighting Climate Change? The U.S. Military*, Nat'l Geographic, Feb. 7, 2017, http://news.nationalgeographic.com/2017/02/pentagon-fights-climate-change-sea-level-rise-defense-department-military/.
183. William J. Hennigan, *Climate Change Is Real: Just Ask the Pentagon*, L.A. Times, Nov. 11, 2016, http://www.latimes.com/nation/la-na-military-climate-change-20161103-story.html.
184. U.S. Government Accountability Office, Climate Change Adaptation: DOD Can Improve Infrastructure Planning and Processes to Better Account for Potential Impacts 45 (2014) (GAO-14-446), https://www.gao.gov/assets/670/663734.pdf.
185. DOD, 2014 Climate Change Adaptation Roadmap (2014), https://www.acq.osd.mil/eie/Downloads/CCARprint_wForward_e.pdf.
186. DOD, Strategic Environmental Research and Development Program, *The Impact of Sea-Level Rise and Climate Change on Department of Defense Installations on Atolls in the Pacific Ocean (RC-2334)*, https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Infrastructure-Resiliency/Vulnerability-and-Impact-Assessment/RC-2334/ (last visited June 7, 2018).
187. Impacts of Climate Change on Human Health, *supra* note 142, at 190.
188. *Id.*
189. *Id.*
190. *Id.*
191. U.S. Global Change Research Program, Climate Change, Global Food Security, and the U.S. Food System 2-3 (2015), http://www.usda.gov/oce/climate_change/FoodSecurity2015Assessment/FullAssessment.pdf.

sistent with the preamble to the U.S. Constitution, which is intended to "provide for the common defence, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our Posterity."[192]

The recognition, at least in the abstract, that a healthy environment is also necessary for human well-being and a healthy economy is also widely held.[193] So are the moral qualities on which virtuous personal behavior is based, including prudence, humility, responsibility, and self-discipline.[194] These and other values—applied not just personally, but also on a societal level—could provide a shared space for government, business, nongovernmental and other private-sector leaders to consider legal pathways to deep decarbonization that promote sustainable development—economic growth, job creation, human health and well-being, security, and environmental protection.

IV. The Importance of Identifying U.S. Legal Pathways to Deep Decarbonization

As the preceding parts have shown, there is abundant evidence that the United States needs to accelerate its decarbonization effort. But how? While the DDPP reports for the United States illuminate key technical and policy approaches required for deep decarbonization,[195] they do not identify in any detail the legal options or pathways that would need to be adopted for the United States to reduce its GHG emissions by at least 80% from 1990 levels by 2050. Ultimately, deep decarbonization is not likely to occur unless general policies are translated into specific draft laws, enacted, and then implemented. Particular tools (e.g., the Clean Power Plan, fuel economy standards for motor vehicles) and the actions of particular jurisdictions (e.g., California) are prominent, but a detailed and comprehensive analysis of the many legal options for deep decarbonization has not previously been available.

The seven major sections of the book, which include a total of 34 chapters, indicate its breadth. It begins with a section on cross-cutting issues—issues that apply to multiple sectors. This section includes chapters on carbon pricing, behavior, law for technological innovation, financing utility-scale facilities, financing "at the grid edge," materials consumption and solid waste, and international trade.

Two sections address energy efficiency, conservation, and fuel switching. One of these focuses on buildings and industry, and includes chapters on lighting, appliances, and other equipment; new buildings; existing buildings; and the industrial sector. The other addresses transportation, and includes chapters on transportation demand and mode shifting, light-duty vehicles, heavy-duty vehicles and freight, aviation, and shipping.

There is a large section on electricity decarbonization. It includes chapters on utility-scale renewable generating capacity; distributed renewable energy facilities; transmission, distribution, storage, and grid integration; nuclear energy; hydropower; electricity charges, mandates, and subsidies; and phasing out fossil fuels in the electricity sector. There is also a section on fuel decarbonization. It has chapters on bioenergy feedstock, the production and delivery of non-carbon gaseous fuels, and the production and delivery of bioenergy fuels.

An additional section addresses carbon capture and negative emissions. It includes chapters on carbon capture and sequestration, negative emissions technologies and direct air capture, agriculture, and forestry. While the agriculture chapter also includes recommendations on reducing emissions, it seemed appropriate to include it in this section because of agriculture's potential to remove carbon dioxide from the atmosphere. The final section focuses on non-carbon dioxide climate pollutants and has chapters on black carbon, methane, fluorinated gases, and nitrous oxide.

The breadth of topics addressed is somewhat similar to the breadth of approaches addressed in other works. A 2004 paper by Stephen Pacala and Robert Socolow,[196] for example, suggests that the problem of growing GHG emissions be addressed by dividing the growth curve into smaller parts or wedges, and addressing these wedges through 15 different strategies, each of which can achieve significant carbon dioxide reductions. These strategies range from efficient vehicles and buildings to nuclear power, CCS, the substitution of solar and wind energy for coal, and conservation tillage.[197] A 2017 book edited by Paul Hawken, *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*, describes 80 different policy options or solutions that can be employed around the world to reduce GHG emissions.[198] These options range from wind turbines and microgrids to a plant-rich diet, family planning, net-zero energy buildings, forest protection, mass transit, and household recycling. For each option, his book quantifies the reduction in GHG emissions that can be achieved, net costs, and net savings.[199]

What makes *Legal Pathways for Deep Decarbonization in the United States* distinctive is its focus on the United States, the much greater detail with which policy and legal options are analyzed, and, perhaps most importantly, the translation of the policy analysis into more than 1,000 specific *legal* recommendations. Each chapter identifies the main legal issues involved in decarbonization, and describes and explains the main legal options or pathways

192. U.S. Const. pmbl.

193. Frederic C. Rich, Getting to Green—Saving Nature: A Bipartisan Solution 179 (2016).

194. *Id.* at 183-84.

195. *See* DDPP U.S. Policy Report, *supra* note 1; DDPP U.S. Technical Report, *supra* note 8.

196. Stephen Pacala & Robert Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years With Current Technologies*, 305 Science 968 (2004).

197. *Id.*

198. Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming (Paul Hawken ed. 2017).

199. *Id.* at 222-23 (ranking options by amount of greenhouse gas reduction that can be achieved).

for successfully addressing these legal issues. These options or pathways, as indicated earlier, involve federal, state, and local law, as well as private governance. Authors were asked to include options even if they do not now seem politically realistic or likely; the idea was to identify all significant legal pathways for deep decarbonization in the United States, recognizing that they hopefully should have not just immediate value, but value over time. Authors were also asked, where information is available, to identify environmental, social, and economic co-benefits of their suggested legal pathways.

Comprehensive identification and analysis of the many possible public and private laws that can be used to decarbonize the United States should make it possible for government officials, business leaders, NGOs, and the public to visualize what the legal choices are, enabling them to understand specifically how decarbonization could work. It should help close the gap between the emissions reduction goal and the specific legal actions that are needed to achieve it.

Three of the four types of actors on which our book focuses—federal, state, and local governments—are no doubt familiar to *News & Analysis* readers. The fourth—often called private environmental governance or private climate governance—may not be as familiar. As previously excerpted here, private environmental governance includes a variety of legal approaches that are enforced by nongovernmental entities.[200] Significantly, nearly every major form of public environmental regulation has parallels in private environmental governance.[201] Many public environmental laws, for example, mandate or prohibit specified activities. In private environmental governance, corporations and other private organizations impose limits on themselves and their suppliers, participate in private associations "or multi-stakeholder groups" that "both set environmental standards for their members and have the power to monitor compliance," or participate in certification programs overseen by NGOs.[202] Similarly, while governments can impose carbon taxes or fees, companies can (and often do) adopt "internal carbon fees to reduce greenhouse gas emissions."[203]

The function of many other public climate change mitigation tools can be served—at least to some degree—by some form of private governance.[204] This does not mean that private governance is necessarily of equal effectiveness to public governance, but it does mean "that there are more options available to decisionmakers than traditionally believed."[205] While our book identifies many private governance options, readers can create their own private climate governance options by adapting public governance options to be private governance options for their clients, the organizations for which they work, or others. This is no small thing. Private corporate GHG emissions reductions could be as high as one-half billion tons of CO_2 equivalent, which is "equal to a regulatory approach that would reduce the emissions of the U.S. transportation sector by a third."[206]

The book does not contain draft laws, although it identifies a great many existing laws from one jurisdiction that could be adapted to another jurisdiction. Legal pathways or options, as described here, still need to be translated into draft legislation or regulatory or contractual language. In addition, the authors do not go into detail about most of the specific recommendations they make, which leaves to lawyers and policymakers the task of tailoring these recommendations to a particular situation or jurisdiction. Nor do they identify suites of tools that could be employed to achieve a certain percentage reduction of GHGs in a specific jurisdiction by a specific date. Legal tools can be used singly or in combination, and they can be sequenced in different ways over time. But by providing a comprehensive listing of plausible legal options, we provide the raw material for using quantitative analysis for developing such suites of tools, or deciding appropriate means of sequencing their adoption and implementation. A unique feature of the book is an index of recommendations by actor, which is intended to allow readers to find all of the recommendations that apply, say, to local governments or state public utility commissions, regardless of the chapter in which those recommendations are located.

While our overall objective was to analyze and describe legal pathways needed to achieve an 80% reduction of U.S. GHG levels from 1990 levels by 2050, the pathways described here are not precisely calibrated to achieve only that result. Because this is a playbook, the number, diversity, and ambitiousness of various legal tools described could be modified to achieve more rapid and deeper reductions, and even negative overall emissions.

V. Conclusion

While both the scale and complexity of deep decarbonization are enormous, we have a simple message: deep decarbonization is achievable in the United States using laws that exist or could be enacted. These legal tools can be employed with significant economic, social, environmental, and national security benefits.

As the book goes to press, it appears that the planet could cross a threshold that would prevent stabilization of the climate even if the global temperature increase is held below 2°C.[207] The authors of a study published in the *Proceedings of the National Academy of Sciences* in summer 2018 conclude that "the Earth System may be approach-

200. *See supra* note 3 and accompanying text.
201. Sarah E. Light & Eric W. Orts, *Parallels in Public and Private Environmental Governance*, 5 Mich. J. Envtl. & Admin. L. 1, 12-13 (2015).
202. *Id*. at 24-29. They do so in response to pressure from advocacy groups, investors, lenders, employees, and corporate and retail customers, as well as in anticipation of future government regulation. *Id*.
203. *Id*. at 33-35.
204. *Id*. at 53-71.
205. *Id*. at 53.
206. Michael P. Vandenbergh & Jonathan M. Gilligan, Beyond Politics: The Private Governance Response to Climate Change 224 (2017).
207. Will Steffen et al., *Trajectory of the Earth System in the Anthropocene*, Proc. Nat'l Acad. Sci. (2018), http://www.pnas.org/content/pnas/early/2018/07/31/1810141115.full.pdf.

ing a planetary threshold that could lock in a continuing rapid pathway toward much hotter conditions—Hothouse Earth."[208] "The impacts of a Hothouse Earth pathway on human societies would likely be massive, sometimes abrupt, and undoubtedly disruptive."[209]

But this outcome is not inevitable, they argue; "social and technological trends and decisions occurring over the next decade or two could significantly influence the trajectory of the Earth System for tens to hundreds of thousands of years"—for better or for worse.[210] With this playbook, there is now no question that the legal tools exist or can be created by which the United States, for its part, could steer away from Hothouse Earth and provide much greater human opportunity and well-being for this and future generations.

208. *Id.* at 6.
209. *Id.*
210. *Id.* at 2.