Creating Legal Pathways to a Zero-Carbon Future

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Summary

An essential part of the decarbonization challenge is proposing, analyzing, and comparing various legal pathways to that result in each individual country. Those legal pathways should be capable of reducing greenhouse gas emissions at a speed and scale needed to give the world its best chance of keeping the global average temperature increase below 2°C while also producing as many economic, social, environmental, and security benefits as possible. This Article, adapted from Chapter 2 of Contemporary Issues in Climate Change Law & Policy (ELI Press 2016), provides an overview of the challenge of achieving a zero-carbon future, as well as the way in which sustainable development would frame the decisionmaking process for doing so.

What do we need to do to have a decent chance of preventing large and growing emissions and atmospheric concentrations of greenhouse gases from dangerously interfering with the climate system? The answer, according to the Intergovernmental Panel on Climate Change (IPCC), is that the world needs to reduce greenhouse gas emissions by at least 40% to 70% by 2050, and to zero or below by 2100.[1] Other scientific reports would say we must proceed faster.[2] The IPCC and others indicate that the many paths to this reduction should all be guided by sustainable development.[3] That is, nations must find ways to dramatically reduce greenhouse gas emissions that also foster equitable economic and social development and promote security.

The task, then, can be succinctly stated as follows: starting now, we must rapidly reduce greenhouse gas emissions to zero or below, creating as much social, environmental, economic, and security benefit as we can, and on an equitable basis. The IPCC reports don't say so as succinctly or directly, but that is among the most essential tasks of our time.

This Article provides an overview of the challenge of achieving a zero-carbon future, as well as the way in which sustainable development would frame the decisionmaking process for doing so. It then reviews two major reports that describe overall approaches at the global and national levels for meeting the zero-carbon objective. Finally, it describes ways to identify and create legal pathways to that objective, building on the insights of these two reports. Creating legal pathways could help accelerate the transition to a sustainable energy future.

I. The Challenge of the Carbon Budget

The challenge posed by climate change is both urgent and enormous. It is also daunting: it requires that the world, as a whole, move as soon as possible from the current situation of increasing greenhouse gas emissions to rapid reductions in greenhouse gas emissions. A recently developed concept—the carbon budget[4]—provides a way of under-

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1. Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis 13 (2013), *available at* https://www.ipcc.ch/report/ar5/wg1/ [hereinafter 2013 IPCC Physical Science Report].
2. *See infra* notes 16-19 and accompanying text.
3. Intergovernmental Panel on Climate Change, Climate Change 2014: Mitigation of Climate Change, ch. 4 (2014), *available at* https://www.ipcc.ch/report/ar5/wg3/ [hereinafter 2014 IPCC Mitigation Report].
4. Fred Pearce, *What Is the Carbon Limit? That Depends Who You Ask*, ENVIRONMENT360, Nov. 6, 2014, http://e360.yale.edu/feature/what_is_the_carbon_limit_that_depends_who_you_ask/2825/.

standing both the magnitude of this challenge and possible pathways for an effective response.

The objective of the U.N. Framework Convention on Climate Change is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[5] In 2010, the Conference of the Parties to the Convention translated the stabilization objective into a maximum permissible surface temperature increase—2 degrees Celsius (C) (or 3.6 degrees Fahrenheit) above preindustrial levels.[6] Parties, it said, "should take urgent action to meet this long-term goal, consistent with science and on the basis of equity."[7] In addition, it stated the importance of "strengthening the long-term global goal on the basis of the best available scientific knowledge, including in relation to a global average temperature rise of 1.5°C."[8] The Paris Agreement, which was adopted unanimously by the Conference of the Parties in December 2015, stated the objective in terms of both temperatures—to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels," and to "pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[9]

The IPCC has translated the 2°C limit into a carbon "budget"—a numerical limit on all additional emissions, cumulatively, for the rest of the century. It concluded that this budget is between 630 and 1,180 gigatons of carbon dioxide equivalent.[10] That range represents the cumulative total of all new emissions of carbon dioxide equivalent between 2011 and 2100.[11] If cumulative emissions do not exceed the figures in that range, the IPCC states, it is "likely" that global average temperatures will stay below a 2°C increase.[12] To have a "likely" chance of staying within this budget, IPCC says, global greenhouse gas emissions need to be 40% to 70% lower by 2050 and "near zero" gigatons of carbon dioxide equivalent or "below" by 2100.[13]

Several points of caution are needed to understand this carbon budget. First, there is a one in three chance that, on its own terms, the budget will not succeed. The term "likely"—as used by both the Conference of the Parties and the IPCC—means that the chance of a particular outcome is greater than 66%,[14] or two out of three. To put this probability in perspective, it helps to recall that the U.S. Environmental Protection Agency (EPA) has traditionally regulated chemicals under its major statutes when they create a risk of cancer of between one in 10,000 and one in 10 million.[15] Cancer risks from chemicals are different from the risks of climate change, of course, but the contrasting probabilities are striking nonetheless. Even in Russian roulette, a player has only a one-in-six chance of dying.

Second, other calculations of a carbon budget provide even less time to reduce emissions that low. The writers of a frequently cited 2009 paper in *Nature*, for example, focused on the time period between 2000 and 2050, not 2000 and 2100, and calculated carbon budgets to avoid exceeding a 2°C increase based on cumulative emissions in the first half of this century.[16] Given past and projected emissions, they conclude, "we would exhaust the CO_2 emission budget by 2024, 2027 or 2039, depending on the probability accepted for exceeding 2°C (respectively 20%, 25% or 50%)."[17] The International Energy Agency states that, with business-as-usual emissions, the remaining carbon budget (based on a 50% chance of keeping the temperature increase below 2°C) will be exhausted around 2040.[18] Others, including James Hansen, are less certain that the world can increase global temperatures by 2°C without severe adverse consequences. They argue that 1.5°C, or an even lower temperature limit, would be even better.[19] The

5. United Nations Framework Convention on Climate Change, art. 2, May 29, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 107. U.N. Doc. A/AC.237/18 (Part II)/Add.1; 31 I.L.M. 849 [hereinafter Framework Convention].
6. Conference of the Parties, United Nations Framework Convention on Climate Change, Decision 1/CP.16 (The Cancun Agreements: Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action Under the Convention) ¶ 4, *in* Report of the Conference of the Parties on Its Sixteenth Session, Held in Cancun From 29 November to 10 December 2010, Addendum, Part Two: Action Taken by the Conference of the Parties at Its Sixteenth Session, FCCC/CP/2010/7/Add.1 (2011), *available at* http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf.
7. *Id.*
8. *Id.* That translates to 2.7 degrees Fahrenheit.
9. United Nations Framework Convention on Climate Change, Conference of the Parties, Paris Agreement, art. 2.1(a), *in* Decision 1/CP.21 (Adoption of the Paris Agreement) (2015), U.N. Doc. FCCC/CP/2015/L.9/Rev.1, *available at* https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf [hereinafter Paris Agreement].
10. 2014 IPCC Mitigation Report, *supra* note 3, at 431. A gigaton is one billion tons. Carbon dioxide equivalent includes all greenhouses gases measured according to the warming potential of carbon dioxide.
11. *Id.*
12. *Id.* at 441. Working Group I reached a slightly different estimate about the budget—1,010 additional gigatons of carbon dioxide equivalent. 2013 IPCC Physical Science Report, *supra* note 1, at 27. Working Group I used a slightly different methodology and did not use ranges. 2014 IPCC Mitigation Report, *supra* note 3, at 441.
13. 2014 IPCC Mitigation Report, *supra* note 3, at 13.
14. *Id.* at 4, note 2.
15. John D. Graham, The Legacy of One in a Million, Risk in Perspective 1-2 (1993) (Harvard Center for Risk Analysis), *available at* http://www.hsph.harvard.edu/wp-content/uploads/sites/1273/2013/06/The-Legacy-of-One-in-a-Million-March-1993.pdf.
16. Malte Meinshausen et al., *Greenhouse-Gas Emission Targets for Limiting Global Warming to 2°C*, 458 Nature 1158 (2009).
17. *Id.* at 1159.
18. International Energy Agency, Energy and Climate Change: World Energy Outlook Special Report, Executive Summary 2 (2015), *available at* http://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChangeExecutiveSummaryUKversionWEB.PDF.
19. James Hansen et al., *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Na-*

Paris Agreement appears to be based on a recognition of these concerns, aiming to keep the temperature increase "well below 2°C" and indicating the desirability of holding the increase to 1.5°C. Of course, the carbon budget to stay below a 1.5°C increase is even smaller, and hence it is more likely that the world will exceed it.

Third, operationalizing this budget requires that it be allocated by nation based on population, historical contribution to global atmospheric greenhouse gas concentrations, development status (developed vs. developing), equity, and other factors. The question of each nation's "fair share" of the budget is both essential and highly contested.[20]

At the same time, if business as usual continues, and the growth of greenhouse gas emissions continues to accelerate, the world will simply blow by the budget and considerably exceed global average temperature increases of 2°C. According to the IPCC, emissions of carbon dioxide equivalent are increasing by about 1 gigaton annually, were the highest in human history between 2000 and 2010, and in 2010 alone reached 49 gigatons.[21] Half of cumulative anthropogenic (human-caused) carbon dioxide emissions have occurred in the last 40 years.[22] These increases are occurring in spite of the efforts that have been made thus far to reduce greenhouse gas emissions.[23] The IPCC thus concludes:

> Without additional efforts to reduce GHG [greenhouse gas] emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7°C to 4.8°C compared to pre-industrial levels. . . .[24]

A variety of other projections based on business-as-usual emissions growth also put the world on track for a temperature increase of at least 4°C.[25]

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.[26] Such a world, the report said, would be "one of unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on ecosystems and associated services."[27] The report adds:

> [G]iven that uncertainty remains about the full nature and scale of impacts, there is also no certainty that adaptation to a 4°C world is possible. A 4°C world is likely to be one in which communities, cities and countries would experience severe disruptions, damage, and dislocation, with many of these risks spread unequally. It is likely that the poor will suffer most and the global community could become more fractured, and unequal than today.[28]

In the 2015 Paris Agreement, "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 . . . ."[29] This "balance" means that net greenhouse gas emissions should be zero by that time. Serious efforts to address the carbon budget must begin as soon as possible. As economist Nicholas Stern summarizes the available scientific literature, the window for keeping temperatures under 2°C "is still open, but is closing rapidly."[30]

II. Sustainable Development as a Framework for Addressing the Carbon Budget

Sustainable development is a decisionmaking framework to foster human well-being by ensuring that societies achieve development and environment goals at the same time.[31] It is not simply an academic or policy idea; it is the internationally accepted framework[32] for maintaining and improving human quality of life and well-being

ture, 8 PLOS One e81648 (2013). *See also* Jeff Tollefson, *Global-Warming Limit of 2°C Hangs in the Balance*, 520 Nature 14 (Apr. 2, 2015).

20. Donald A. Brown, Climate Change Ethics: Navigating the Perfect Moral Storm (2012); Fred Pearce, *The Trillion-Ton Cap: Allocating The World's Carbon Emissions*, ENVIRONMENT360, Oct. 23, 2013, *at* http://e360.yale.edu/feature/the_trillion-ton_cap_allocating_the_worlds_carbon_emissions/2703/.
21. 2013 IPCC Physical Science Report, *supra* note 1, at 6.
22. *Id.* at 7.
23. *Id.* at 6.
24. *Id.* at 8.
25. Sustainable Development Solutions Network & Institute for Sustainable Development and International Relations, Pathways to Deep Decarbonization 4 (2014), *available at* http://unsdsn.org/wp-content/uploads/2014/09/DDPP_Digit_updated.pdf.
26. International Bank for Reconstruction and Development/World Bank, Turn Down the Heat: Why a 4°C Warmer World Must Be Avoided (2012), *available at* http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/07/17/090224b0828c33e7/1_0/Rendered/PDF/Turn0down0the00orld0must0be0avoided.pdf.
27. *Id.* at ix.
28. *Id.* at xviii.
29. Paris Agreement, *supra* note 9, art. 4.1.
30. Nicholas Stern, Why Are We Waiting? The Logic, Urgency, and Promise of Tackling Climate Change 32 (2015).
31. John C. Dernbach & Federico Cheever, *Sustainable Development and Its Discontents*, 4 Transnat'l Envtl. L. 247 (2015); John C. Dernbach, *Sustainable Development as a Framework for National Governance*, 49 Case W. Res. L. Rev. 1 (1998).
32. G.A. Res. 70/1, Transforming Our World: The 2030 Agenda for Sustainable Development, preamble & ¶ 2, U.N. Doc. A/RES/70/1 (Oct. 21, 2015) ("We are determined to ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature."); ("We are committed to achieving sustainable development in its three dimensions—economic, social and environmental—in a balanced and integrated manner."). *See also* U.N. Conference on Sustainable Development, *The Future We Want*, U.N. Doc. A/66/L.56, July 24, 2012, ¶ 1, *available at* http://daccess-dds-ny.un.org/doc/UNDOC/LTD/N12/436/88/PDF/N1243688.pdf?OpenElement (in which world's nations agreed to "renew our commitment to sustainable development and to ensuring the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations."). The 2012 conference renewed the commitment originally made at the U.N. Conference on Environment and Development in 1992—to a "global partnership for sustainable development." U.N. Conference on Environment and Development (UNCED), Agenda 21, U.N. Doc. A/CONF.151.26, 1992, ¶ 1.1, *available at* http://www.un.org/esa/dsd/agenda21/.

for the present generation as well as future generations.[33] The United Nations Framework Convention on Climate Change specifically provides: "The Parties have a right to, and should, promote sustainable development."[34] Sustainable development provides an essential decisionmaking framework for addressing the carbon budget and is superior to conventional development.

A. A Decisionmaking Framework

Sustainable development is a framework for making decisions; it is not a mere goal or sentiment, and it is not simply another word for green. The key action principle of sustainable development is integrated decisionmaking.[35] Essentially, decisionmakers must consider and advance environmental protection at the same time as they consider and advance their economic and social development goals.[36] By contrast, in conventional development, the environment tends to be an afterthought in a decisionmaking process in which economic development is the primary if not sole objective.[37] Sustainable development is thus not just about environmental law; it is about how the entire development process is conducted. This matters in three ways.

First, for developing countries, sustainable development provides a way of reconciling their equally daunting and otherwise irreconcilable objectives of economic development and reduction and elimination of carbon emissions. As recently as 2000, developed countries consumed more energy overall than developing countries.[38] By 2040, however, developing country energy consumption is projected to be more than twice as much as that in developed countries.[39] In fact, more than 85% of the growth in energy consumption over that period will come from developing countries.[40] Given the rising demand for energy in those countries, sustainable development of energy, including the greatest possible use of energy efficiency and renewable energy, provides the only realistic way of keeping temperatures "well below 2°C."

For developed countries, where there already tends to be a significant fossil-fuel-based energy infrastructure, the challenge is more one of converting that infrastructure to sustainable energy. However, for all countries, the challenge is to build "a new energy-industrial revolution."[41] This job requires a decisionmaking framework for integrating development and environmental considerations and goals; mere environmental goals will not get the job done. Thus, the parties to the Framework Convention agreed to integrate climate change mitigation and adaptation into their national development plans and processes.[42] Sustainable development requires public and private decisions that, taken together, actually keep global average temperature increases within 2°C.

Second, sustainable development is based on an understanding that problems have multiple dimensions and need to be understood as such. Thus, climate change has environmental, economic, social, and security dimensions—all of which need to be taken seriously. In a conventional development setting, environmental problems tend to be undervalued because there is less certainty about the likelihood and significance of adverse environmental impacts than there is about the economic and perhaps social benefits of a project. Thus, the precautionary approach, in which "cost-effective measures to prevent environmental degradation" can and should proceed in spite of the lack of complete scientific certainty about environmental problems,[43] is intended to help ensure that environmental impacts are not undervalued. The precautionary approach is also embedded in the Framework Convention.[44]

The precautionary approach provides a way of resolving uncertainties about the size of the budget and what actions should be taken to avoid exceeding 2°C. Quite simply, as the Paris Agreement suggests, governmental, business, and nongovernmental actors should take all possible actions to keep the temperature increase as far below that level as they can.

Third, the effectiveness of sustainable development actions is not measured simply by their contribution to Gross Domestic Product (GDP), as tends to be the case with conventional development. Instead, the effectiveness of sustainable development actions is measured by their economic, environmental, security, and social benefits.[45] More broadly, they are measured by their contribution to human well-being or quality of life. For the carbon budget challenge, these measures of sustainable development make it possible for nations to consider and achieve a range of benefits beyond reduction of greenhouse gas emissions. Because greenhouse gases are distributed fairly evenly

33. At the U.N. Conference on Environment and Development in 1992, countries agreed to a statement of 27 principles for sustainable development called the Rio Declaration on Environment and Development. U.N. Conference on Environment and Development, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. I), June 14, 1992, *available at* http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm [hereinafter Rio Declaration]. These principles have proven to have enduring significance in understanding what sustainable development means for law. *See* The Rio Declaration on Environment and Development: A Commentary (Jorge E. Viñuales ed., 2015) (detailed explanation of each principle of Rio Declaration). One provides: "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature." Rio Declaration, prin. 1. According to another: "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations." *Id.* prin. 3.
34. Framework Convention, *supra* note 5, art. 3.4.
35. John C. Dernbach, *Achieving Sustainable Development: The Centrality and Multiple Facets of Integrated Decisionmaking*, 10 Ind. J. Global Leg. Stud. 247 (2003); Rio Declaration, *supra* note 33, prin. 4 ("In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.").
36. *Id.*
37. World Commission on Environment and Development, Our Common Future 28-29 (1987).
38. U.S. Energy Information Administration, International Energy Outlook 2013, at 9 (2013).
39. *Id.*
40. *Id.*
41. Stern, *supra* note 30, at 30.
42. Framework Convention, *supra* note 5, art. 4.1(f).
43. Rio Declaration, *supra* note 33, prin. 15.
44. Framework Convention, *supra* note 5, art. 3.3.
45. 2014 IPCC Mitigation Report, *supra* note 3, at 292-93, 296-97.

through the global atmosphere, the greenhouse gas benefits of reductions are also distributed globally.

As U.S. states discovered more than a decade ago, the other benefits (called co-benefits) of addressing climate change—including new jobs; growing businesses; greater stability in energy production; reduced emissions of sulfur dioxide, mercury, and other air pollutants; and reduced energy costs for businesses and the poor—produced more immediate and tangible improvements *in those states* than the greenhouse gas emission reductions that accompanied these benefits.[46] Recent laws requiring greater use of renewable energy and energy efficiency, in fact, can be fairly characterized as economic development laws for those industries; their economic development benefits are a major reason they were adopted.[47] The effect of renewable energy portfolio standards and feed-in-tariffs for renewable energy has been to build the renewable energy industry in jurisdictions where these laws have been adopted.[48] Similarly, the IPCC has found "significant co-benefits for human health, ecosystem impacts, and sufficiency of resources and resilience of the energy system" in mitigation scenarios that are consistent with keeping temperatures under 2°C.[49]

B. *A More Attractive Approach Than Conventional Development*

Sustainable development is more fair and equitable than conventional development. It also can produce more benefits and fewer costs. It is thus an essential framework for making decisions to keep the temperature increase "well below 2°C."

Sustainable development is based on a critique of conventional development as not only environmentally damaging, but also unfair and inequitable.[50] Conventional development works by producing economic and, to a lesser degree, social benefits for certain individuals or companies.[51] At the same time, it occurs at the expense of the environment as well as people who depend on that environment. These people tend not to be the same as those benefited. The adversely affected people could exist in the present generation, or in future generations, or both. That is exactly how conventional fossil-fuel based energy development is working now and, as explained earlier, will only makes things worse if business as usual continues. Sustainable development—low-carbon or zero-carbon development—gives us our best chance (not a certainty) of keeping the global average temperature increase under 2°C; would produce obvious benefits; and should not make people less well off than they were originally. Articulating the equitable or moral basis for sustainable development approaches to climate change also enhances the likelihood that nations and communities will agree to and implement these approaches.[52]

In addition, sustainable development should produce more benefits than conventional development, with fewer costs. In fact, one of the most important features of sustainable development is that it sidesteps the binary "development *or* environment" thought structure that constrains conventional development decisionmaking. By providing a third choice—"development *and* environment"—sustainable development changes the decisionmaking structure and opens up a policy space that is capable of producing more benefits and fewer costs.

Sustainable development thus reframes the policy debate about how to decarbonize the global economy. As Nicholas Stern explains, the "prevailing assumption" is that decarbonization involves "higher cost substitutes" and "burden sharing" among countries.[53] However, in the last decade or two, there have been substantial improvements in energy efficiency technology and management systems, and renewable energy "has advanced far quicker and a greater scale" than anyone anticipated.[54] In addition, the policy space of "development and environment" is now being filled by a variety of new or modified laws that foster renewable energy; energy efficiency and conservation in buildings, transportation, and industry; and distributed energy, among other things.[55] There is also a "better understanding of the potential attractiveness of alternative, low-carbon paths for more durable and better-quality growth, development, and poverty reduction."[56] Instead of the prevailing gloomy assumption about decarbonization, then, the question should be "how to reduce emissions in ways that provide very widespread benefits to people over time."[57]

III. Deep Decarbonization Scenarios

Two major international reports outline approaches to decarbonization. They provide a way of understanding what it would mean to make genuine progress toward keeping the atmospheric temperature increase from greenhouse gas emissions below 2°C. One describes basic elements, and the other includes both basic elements and technically feasible country-specific outcomes. Nevertheless, they do not provide country-specific *legal* pathways to those outcomes.

One of these reports, *Decarbonizing Development: Three Steps to a Zero-Carbon Future*, was issued by the World

46. John Dernbach and the 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).
47. John C. Dernbach, *Creating the Law of Environmentally Sustainable Economic Development*, 28 Pace Envtl. L. Rev. 614 (2011).
48. Jonas Meckling et al., *Winning Coalitions for Climate Policy*, 349 Science 1170 (Sept. 11, 2015).
49. 2014 IPCC Mitigation Report, *supra* note 3, at 17.
50. Our Common Future, *supra* note 37, at 28-37 (explaining how conventional development has contributed to poverty and environmental degradation).
51. *Id.*
52. 2014 IPCC Mitigation Report, *supra* note 3, at 290-91.
53. Stern, *supra* note 30, at 298.
54. *Id.* at 86.
55. *See, e.g.*, John C. Dernbach et al., Acting as if Tomorrow Matters: Accelerating the Transition to Sustainability (Envtl. L. Inst. 2012).
56. Stern, *supra* note 30, at 298.
57. *Id.*

Bank in 2015.[58] The report focuses on carbon dioxide, and not other greenhouse gases, because carbon dioxide is the most important greenhouse gas and because it can stay in the atmosphere for hundreds of years.[59] It includes not only actions to reduce carbon dioxide emissions but also to remove carbon dioxide from the atmosphere; "achieving the 2°C target will necessitate negative emissions . . . in the second part of this century."[60]

A key to effective action, the report says, is "early action."[61] Early action is prudent, cost-effective, and cheaper, and avoids technological lock-in (e.g., construction of fossil-fuel-based power plants that will likely be in service for 40 or more years).[62] It is also more likely to work. The more time passes before carbon dioxide emissions peak and then decline, the steeper the annual reductions must be—from 4-5% (peaking date of 2015) to 8% (peaking date of 2025).[63] Excluding situations where economic collapse has occurred, there is only one example of a country that achieved annual greenhouse gas reductions of more than 4%.[64]

According to the report, "three broad principles must guide countries' low-carbon efforts."[65] First, "every country needs to define a long-term target—say, for 2050—that is consistent with decarbonization and to build short-term, sector-specific plans that contribute to that target and are adapted to the country's wealth, endowments, and capacity."[66] Countries should also "favor measures with high emission-reduction potential" even if these measures are more costly and will take longer to implement than other measures.[67]

Second, every country needs to get "prices right" for carbon, not just as good climate policy, but also as "good economic and fiscal policy."[68] The core problem is that the price of carbon-based energy does not reflect its many social, environmental, and economic costs.[69] Getting the prices right includes elimination of fossil fuel subsidies.[70] However, because prices alone don't necessarily induce desired behavior or achieve specified emissions reductions, they must be supplemented with other measures, including "targeted investment subsidies, performance standards and mandates, or communication campaigns that trigger the required changes. . . ."[71]

Finally, countries must put together policy packages that are not only attractive to most voters, but also "avoid impacts that appear unfair or that are concentrated in a region, sector, or community."[72] Policies thus must be designed to protect the poor and vulnerable.[73] In addition, for pragmatic reasons, governments must find ways to address adversely affected economic sectors by providing compensation, helping sectors that would otherwise lose to become part of the solution, and enacting measures to address competitiveness.[74]

The other major report is based on the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations.[75] 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.[76] The project focuses on carbon dioxide "emissions from the burning of fossil fuels and industrial processes,"[77] not on all greenhouse gas emissions. In addition, it assumes a century-long effort divided in two parts, 2011-2050 and 2051-2100; the bulk of the emissions reduction will occur in the first period, and the rest will occur in the second period as emissions reach zero.[78] Working from the overall IPCC budget for greenhouse gases, and analyzing various IPCC scenarios for future emissions, the project's authors conclude that annual global carbon dioxide emissions from fossil fuel combustion and industrial processes would need to be reduced to "close to" 11 gigatons by 2050 to have a "likely" chance of keeping emissions within the 2-degree limit.[79] In 2011, emissions from the same sources totaled 34 gigatons.[80] The required reduction is thus almost 68%.

The first stage of the project was completed in 2014.[81] It consists of "preliminary findings on technically feasible pathways to deep decarbonization" for 15 countries representing 70% of global greenhouse gas emissions—Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, the United Kingdom, and the United States.[82] Research teams in each of these countries used a "backcasting" approach that assumes the 2°C goal based on the IPCC carbon budget has been met, and then describes the changes that were needed to achieve that goal.[83] They

58. Marianne Fay et al., International Bank for Reconstruction and Development/The World Bank, Decarbonizing Development: Three Steps to a Zero-Carbon Future (2015), *available at* http://www.worldbank.org/content/dam/Worldbank/document/Climate/dd/decarbonizing-development-report.pdf.
59. *Id.* at 25.
60. *Id.* at 26.
61. *Id.* at 39.
62. *Id.*
63. *Id.* at 40.
64. *Id.* (citing France when it was developing nuclear power).
65. *Id.* at 2.
66. *Id.*
67. *Id.*
68. *Id.* at 79.
69. National Research Council, Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use (2010).
70. Decarbonizing Development, *supra* note 58, at 79.
71. *Id.* at 3.
72. *Id.*
73. *Id.* at 139-51.
74. *Id.* at 153-64.
75. Pathways to Deep Decarbonization, *supra* note 25.
76. *Id.* at iii.
77. *Id.* at 7-8.
78. *Id.* at 8.
79. *Id.* at viii.
80. *Id.*
81. The second stage, which was to be completed in 2015, "will refine the analysis of the technical decarbonization potential, exploring options for even deeper decarbonization." *Id.* at iii. *See also infra* note 107 and accompanying text.
82. Pathways to Deep Decarbonization, *supra* note 25, at iii-iv.
83. *Id.* at x. For an explanation of the use of backcasting in achieving sustainability, see Philip Vergragt & Jaco Quist, *Backcasting for Sustainability: Introduction to the Special Issue*, 78 Technological Forecasting & Social Change 747 (2011).

Key Elements of National Decarbonization Strategies

World Bank	Deep Decarbonization Project
• Decarbonized electricity production. • Electrification (to include reliance on that clean electricity), and where that is not possible, a switch to cleaner fuels. • Improved efficiency and reduced waste in all sectors. • Preservation and increase of carbon sinks such as forests and other vegetation and soils.[a]	• Energy efficiency and conservation across all sectors of the economy, including power generation, transportation, buildings, industry, and urban design. • Low-carbon electricity from replacement of fossil fuel-based generation with renewable energy or the use of carbon capture and storage at fossil fuel-based generating facilities. • Switching from more carbon-intensive fuels to less carbon-intensive fuels in all economic sectors.[b]

a. Decarbonizing Development, *supra* note 58, at 27-28.
b. Pathways to Deep Decarbonization, *supra* note 25, at xii.

used 1.6 tons of carbon dioxide emissions per capita by 2050 as a benchmark, which is much lower than the current global average of 5.2 tons.[84] Because per capita emissions tend to be higher in developed countries than developing countries, the needed emissions reductions in developed countries are greater. The research teams, which worked independently of their governments, appear to have been comprised primarily of technology, energy, and economic analysts; the U.S. research team drew from a consulting firm, Energy and Environmental Economics (E3), and two government laboratories, Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory.[85]

Significantly, the two reports reach similar conclusions about the overall approach that each country should take to decarbonization. Both make clear the need to use sustainable development to create economic, social, environmental, and other benefits.[86] As the table on page 34 shows, energy efficiency, decarbonizing the electricity sector, and switching to low-carbon or zero-carbon fuels are common elements in both. The World Bank adds carbon sinks, which remove carbon dioxide from the atmosphere.

Unlike the World Bank report, however, the Deep Decarbonization project also describes country-specific pathways to decarbonization. The United States and China are perhaps the two countries whose decarbonization pathways matter the most. In 2013, the world's two largest emitters of carbon dioxide from fossil fuel combustion and industrial processes were China and the United States.[87] China replaced the United States as the world's largest emitter of carbon dioxide in 2006.[88] Remarkably, China's total carbon dioxide emissions in 2013, only seven years later, were nearly double those of the United States (29% of the global total compared to 15%).[89] U.S. per capita carbon dioxide emissions were 16.6 tons, compared to 7.4 tons for China (and 7.3 tons per capita for the European Union).[90] In that same year, China's population was more than four times that of the United States (1.357 billion compared to 316 million).[91]

The United States and China decarbonization pathways are illustrative of what the researchers learned. For the United States, the most important finding "is that it is technically feasible for the U.S. to reduce [carbon dioxide] emissions from fossil fuel combustion" by 85% from 1990 levels by 2050, which is "an order of magnitude decrease in per capita emissions compared to 2010."[92] If the U.S. did that, it could reduce its overall greenhouse gas emissions by 80% below 1990 levels by 2050.[93] Moreover, the United States could meet that longer term objective by meeting a shorter term objective it has already established, the report said.[94] The shorter term objective, stated by the United States in 2015, is "to achieve an economy-wide target of reducing its greenhouse gas emissions by 26%-28% below its 2005 level in 2025."[95]

Enormous changes would be required in the U.S. energy system to make those reductions happen. Because it is difficult to decarbonize gas and liquid fuels, the researchers said, meeting the 2050 objective would require almost complete decarbonization of electricity and, among other

84. Pathways to Deep Decarbonization, *supra* note 25, at viii, 24-26. For current per capita emission levels in the United States, China, and the European Union, see *infra* note 92 and accompanying text.
85. James H. Williams et al., Energy and Environmental Economics (E3), Lawrence Berkeley National Laboratory, & Pacific Northwest National Laboratory, Pathways to Deep Decarbonization in the United States (2014), *available at* http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf.
86. Pathways to Deep Decarbonization, *supra* note 25, at vii; Decarbonizing Development, *supra* note 58, at 55.
87. Jos G.J. Olivier et al., PBL Netherlands Environmental Assessment Agency & European Commission Joint Research Centre, Trends in Global CO_2 Emissions: 2014 Report 4 (2014), *available at* http://edgar.jrc.ec.europa.eu/news_docs/jrc-2014-trends-in-global-co2-emissions-2014-report-93171.pdf.
88. Jos G.J. Olivier et al., PBL Netherlands Environmental Assessment Agency & European Commission Joint Research Centre, Trends in Global CO_2 Emissions: 2012 Report 28 (2012), *available at* http://edgar.jrc.ec.europa.eu/CO2REPORT2012.pdf.
89. Trends in Global CO_2 Emissions: 2014 Report, *supra* note 87, at 4.
90. *Id.* at 24.
91. Population Reference Bureau, 2013 World Population Data Sheet 2 (2013), *available at* http://www.prb.org/pdf13/2013-population-data-sheet_eng.pdf.
92. Pathways to Deep Decarbonization, *supra* note 25, at 204.
93. Pathways to Deep Decarbonization in the United States, *supra* note 85, at xiii.
94. *Id.* at xv.
95. United States, Cover Note, INDC [Intended Nationally Determined Contribution], and Accompanying Information (2015), *available at* http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf.

things, switching a "large share" of end uses that require gasoline and liquid fuels over to electricity (such as electric cars).[96] It would also be necessary to produce fuel from electricity itself, they said, citing the production of hydrogen from hydrolysis as an example.[97] That would double electricity generation but reduce its carbon intensity to 3% to 10% of current levels, requiring a vast increase in either renewable energy (as much as "2,500 gigawatts (GW) of wind and solar generation (30 times present capacity))" or carbon capture and sequestration.[98] The average fuel economy for light duty vehicles such as cars would need to be over 100 miles per gallon, and these vehicles would need to be fueled almost entirely by electricity and hydrogen.[99] The overall cost of this effort would be roughly 1% of GDP, the researchers say.[100]

Unlike the United States, which has significant emissions of carbon dioxide from electricity generation, industry, transportation, and buildings,[101] the great bulk of Chinese carbon dioxide emissions are from electricity generation and industry, with most of the electricity used by industry.[102] Indeed, half of the energy use in the industrial sector is from a handful of energy-intensive industries (including iron and steel as well as cement).[103] China's stated greenhouse gas emission goals are also quite different from those of the United States. China's objectives are to "achieve the peaking of carbon dioxide emissions around 2030" and make "best efforts" to peak earlier, to "lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level" by 2030, and to "increase the share of non-fossil fuels in primary energy consumption to around 20%."[104]

In the report's "illustrative" decarbonization pathway, China's energy-related carbon dioxide emissions decrease by 34% between 2010 and 2050.[105] This reduction is achieved through large-scale use of nuclear power (25% of electricity generation by 2050), wind and solar energy (35%), and hydroelectricity (18%). While fossil fuel plants provide the remaining electricity, many are either natural gas plants that back up renewable energy or are based on highly efficient coal burning technologies coupled with carbon capture and sequestration.[106] For industry, final energy consumption grows only 28%, mostly because of energy efficiency improvements through technological innovation and carbon sequestration.[107] Carbon dioxide emissions from transportation and buildings grow to 49% of total emissions, but energy efficiency, rail transportation, and decarbonized electricity keep emissions much lower than they would otherwise be.[108]

These, of course, represent dramatic changes from our current situation. As previously explained, this first stage of the Deep Decarbonization project analyzes only the technical feasibility of achieving these outcomes. The second stage of the project, which was not yet published as this Article was completed, is to systemically analyze costs and benefits, finance requirements, and "domestic and global policy frameworks" for achieving these outcomes, and explain in greater detail how deep decarbonization and sustainable development can be met at the same time.[109] As helpful as this second stage of work is likely to be in explaining possible pathways, it will still be necessary to translate those pathways into effective laws that are capable of being adopted.

IV. Translating Decarbonization Scenarios Into Law

Decarbonization is highly unlikely to happen at the national level unless it is translated into a supportive legal structure. At least two elements are needed to translate such decarbonization scenarios into law. The U.S. scenario is illustrative.

A. Incorporation of Backcasting Into Law and Policymaking

Most legal and policy approaches to reducing greenhouse gas emissions move from the present toward some point in the future and are bounded by the technical and economic feasibility of achieving a particular result. For example, the Energy Policy and Conservation Act of 1975 directs the U.S. Department of Transportation (DOT) to adopt corporate average fuel economy (CAFE) standards for automobiles.[110] Each standard is to be based on "maximum feasible fuel economy" that the Secretary of Transportation determines can be achieved for a particular year.[111] Under the Clean Air Act, standards for emissions of air pollutants for new motor vehicles "shall take effect after such period as the [EPA] Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period."[112]

In 2012, exercising their authority under both acts, EPA and DOT issued combined fuel economy standards/green-

96. Pathways to Deep Decarbonization in the United States, *supra* note 85, at xiii.
97. *Id.*
98. *Id.*
99. *Id.*
100. *Id.* at xii.
101. Pathways to Deep Decarbonization, *supra* note 25, at 203.
102. *Id.* at 85.
103. *Id.* at 84.
104. People's Republic of China, Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions (June 20, 2015), *available at* http://www4.unfccc.int/submissions/INDC/Published%20Documents/China/1/China's%20INDC%20-%20on%2030%20June%202015.pdf. China also intends, by 2030, to "increase the forest stock volume by around 4.5 billion cubic meters on [from?] the 2005 level." *Id.*
105. Pathways to Deep Decarbonization, *supra* note 25, at 87.
106. *Id.* at 88.
107. *Id.* "If CCS is deployed appropriately on a commercialized scale after 2030 in key industry sectors, it is expected to sequester 28% of total CO_2 emissions in the industry sector in 2050. . . ." *Id.*
108. *Id.* at 87-89.
109. *Id.* at x.
110. 42 U.S.C. §§32901-19.
111. *Id.* §32902(a).
112. 42 U.S.C. §7521(a)(2).

house gas emission limits for passenger cars, light-duty trucks and medium-duty passenger vehicles for model years 2017-2025.[113] The final standards are projected to result in an average industry fleetwide level of 163 grams/mile of carbon dioxide in model year 2025, which is equivalent to 54.5 miles per gallon if achieved exclusively through fuel economy improvements.[114] The 54.5 miles per gallon requirement, in turn, is built on previous fuel economy standards that, taken together, have moved fuel economy standards in steps toward higher and higher levels. According to EPA, this regulation will have significant greenhouse gas reduction and economic benefits.[115] From today's perspective, in which average U.S. fuel economy is in the neighborhood of 25 miles per gallon,[116] an average fleetwide fuel efficiency level of 54.5 miles per gallon for new vehicles is a fairly impressive achievement.

Backcasting, by contrast, looks at a desired future state and asks what it would take to achieve that future state.[117] Under the deep decarbonization future described earlier for the United States, the average fuel economy for light duty vehicles in 2050 would be more than 100 miles per gallon. In addition, those vehicles would be fueled not by gasoline or diesel fuel but by electricity or hydrogen.[118] Moreover, those vehicles would need to be powered by an electricity generation system that is both twice the size of today's system and based almost entirely on renewable energy and, where fossil fuels are still used, carbon sequestration.[119]

Assuming that the United States can achieve 54.5 miles per gallon as a fleetwide average for *new* vehicles by 2025, how does it achieve a fleetwide average of more than 100 miles per gallon for *all* vehicles by 2050? As the deep decarbonization report for the U.S. explained, "[t]his would require the deployment of roughly 300 million alternative fuel vehicles by 2050."[120] Backcasting would oblige policymakers to consider that question and develop credible and workable laws and policies that answer it, at the same time as they develop shorter-term laws and policies. It seems likely that the United States will require a much higher level of ambition regarding motor vehicles' fuel efficiency between 2025 and 2050 to achieve the outcome described in the deep decarbonization report. It also seems possible that a more ambitious 2025 standard or goal would have better positioned the United States to achieve the required reductions.[121]

Similarly, EPA's Clean Power Plan, finalized in August 2015, would reduce greenhouse gases from electric generating facilities by 32% from 2005 levels by 2030.[122] As ambitious as that goal is, the pathway from that result in 2030 to the Deep Decarbonization Project's virtually decarbonized and expanded electrical generation system in 2050 is even more ambitious.

The value of backcasting as a reality check on the ambitiousness of plans to reduce greenhouse gas emissions also applies at the international level. The objective of keeping the global average temperature increase from greenhouse gas emissions under 2°C, within the emissions reduction timetables set by the IPCC (40% to 70% reduction by 2050; zero or negative emissions by 2100), provides a framework for backcasting. In the run-up to the December 2015 Paris Conference of the Parties to the Convention on Climate Change, countries submitted their Intended Nationally Determined Contributions (INDCs).[123] The INDCs reflect the level of emissions reduction that each country intends to achieve. The objectives stated earlier for both the United States and China are the INDCs that each country submitted under the Convention.[124] The question is whether the sum of each national INDC will actually put the world on track to keep the increase in world temperatures under 2°C. In the summer of 2015, the International Energy Agency released a report stating that the answer is no:

> 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.[125]

The Paris Agreement acknowledges this "emissions gap"—between what has been submitted and what needs to be done—and creates a process for addressing it. Every five years beginning in 2015, every country is to submit nationally determined contributions that "represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition."[126] Every five years beginning in 2023, the Conference of the Parties

113. 77 Fed. Reg. 62624 (Oct. 15, 2012) (codified at 40 C.F.R. Parts 85, 86, and 600).
114. 77 Fed. Reg. at 62627.
115. U.S. Environmental Protection Agency, *Transportation and Climate—Regulations & Standards: Light-Duty*, http://www.epa.gov/oms/climate/regs-light-duty.htm (last visited Sept. 10, 2015) (estimating that it will reduce greenhouse gas emissions by two billion metric tons and provide "net benefits up to $451 billion").
116. Michael Sivak & Brandon Schoettle, University of Michigan Transportation Research Institute, Benefits of Recent Improvements in Vehicle Fuel Economy 1-2 (2014).
117. *See supra* note 83 and accompanying text.
118. Pathways to Deep Decarbonization in the United States, *supra* note 85, at xiii.
119. *Id.*
120. *Id.*
121. *Cf.* Howard A. Latin, *Climate Change Mitigation and Decarbonization*, 25 Vill. Envtl. L.J. 1, 82 (2014) ("[T]he fundamental climate change policy choice for America is between a decarbonization strategy that will be 'difficult to accomplish' and the conventional multi-decade emissions-reduction approaches that are 'certain to fail.'").
122. U.S. Environmental Protection Agency, Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units (2015), *available at* http://www2.epa.gov/sites/production/files/2015-08/documents/cpp-final-rule.pdf.
123. United Nations Framework Convention on Climate Change, Intended Nationally Determined Contributions (INDCs), http://unfccc.int/focus/indc_portal/items/8766.php (last visited Sept. 19, 2015) (explaining INDCs and containing links to national INDC submissions).
124. *See supra* notes 95 (United States) and 104 (China) and accompanying text.
125. International Energy Agency, Energy and Climate Change, *supra* note 18, at 2.
126. Paris Agreement, *supra* note 9, art. 4.3.

is to "take stock of the implementation of this Agreement to assess the collective progress towards achieving" its purpose.[127] These requirements should encourage or prod governments to be more ambitious over time, without being prescriptive about what they should do.

One way to meld forward-looking emission limits with backcasting is for each nation to prepare nonbinding deep decarbonization plans that extend into the future past 2020, 2025, or 2030, toward 2050 and even 2100. Unlike the deep decarbonization plans prepared as part of this project, they would be prepared by the governments themselves. Such plans would enable governments to see farther into the future than 2025 or 2030 (the end dates of the United States and China INDCs), and give governments a sense of whether the nationally determined contributions they submit every five years are ambitious enough to enable achievement of deep decarbonization.[128]

B. Use of Legal Scenarios

Scenarios are a commonplace part of the discussion concerning climate change and sustainability. "A scenario is essentially a story about the future."[129] Scenarios are not predictions; they are narrative descriptions of possible futures if events unfold in a certain way.[130] They involve four elements—a description of the current state of things, an explanation of "driving forces" that propel the system, a description of other forces that can change the trajectory of the system, and "sideswipes, major surprises that can alter an otherwise straightforward outcome."[131] The IPCC reports and Deep Decarbonization reports use scenarios extensively. Scenarios add value by making it possible to understand possible futures, in somewhat concrete terms, if events unfold in a certain way. However, in those reports, the scenarios tend to focus on science, policy, and technology.

The use of legal scenarios—either stand-alone legal scenarios or multidisciplinary scenarios with a distinct legal component—would likely help decide how to achieve deep decarbonization at the national and subnational levels. Laws are one of the "driving forces" that propel action in any country and could, if changed, propel a country in a different direction. Legal scenarios could illuminate the ways in which different kinds of laws could affect emissions reductions most effectively and fairly. They could also show different legal pathways and illustrate how to design laws to maximize economic, social, and environmental benefits.

One of the signal contributions of the Deep Decarbonization scenarios for individual countries is that they particularize the 2°C goal to the circumstances of individual countries. However, they do not take the additional step of describing the particular laws or types of laws that would be needed to get to those outcomes. What legal framework, for example, would be needed to get from 54.5 miles per gallon for new vehicles in the United States in 2025 to 300 million alternative fuel vehicles by 2050? Legal scenarios about different laws or combinations of laws would make it possible for decisionmakers and the public to visualize what the choices are.

Many possible legal and policy approaches to decarbonization are available, including government supported research and development, carbon taxation, regulation, public information, and land use and transportation law changes. They can be used singly or in combination, and they can be sequenced in different ways over time. Legal scenarios could illuminate trade offs among and between different approaches and identify ways in which various tools could be mutually reinforcing or mutually antagonistic. Scenarios could also make clear what approaches are indispensable—or at least highly valuable—in keeping the temperature increase well below 2°C. It appears, for example, that laws and policies that foster clean energy development help build a counterweight to the fossil fuel industry and thus make it more politically possible to adopt laws setting a price on carbon. Nearly two-thirds of the countries and subnational jurisdictions that had adopted a carbon pricing scheme by 2013 had previously adopted renewable energy portfolio standards or feed-in tariffs for renewable energy.[132] Carbon pricing, as previously indicated, is likely an essential element of any deep decarbonization strategy.

Legal scenarios could also be of use in assessing the role of negative emissions in any decarbonization strategy. In contrast to emissions reductions, which are about preventing additional carbon dioxide from entering the atmosphere, negative emissions occur when carbon dioxide already in the atmosphere is removed. Negative emissions can be increased by enhancing the capacity of carbon sinks such as soil and trees to absorb carbon dioxide; they could also be achieved through a variety of technologies.[133] Overall carbon dioxide concentrations in the atmosphere are already very high. Concentrations of greenhouse gases are at levels that have not been seen for at least 800,000 years.[134] That fact suggests the value of removing carbon dioxide from the atmosphere for precautionary reasons. In addition, the 2°C goal will require a remarkable and in many ways unprecedented level of international cooperation to achieve, and there is a significant likelihood of laggards. Negative emissions provide a way of obtaining protection from the effects of laggards.

Still, a considerable effort will need to be made to develop technologies for negative emissions. Although the

127. *Id.* arts. 14.1 & 14.2.
128. Pathways to Deep Decarbonization, *supra* note 25, at xiv.
129. Gilberto C. Gallopin & Paul Raskin, *Windows on the Future: Global Scenarios and Sustainability*, Env't, Apr. 1998, at 7, 8.
130. *Id.*
131. *Id.*
132. Meckling et al., *supra* note 48.
133. *See, e.g.*, Ben Caldecott et al., University of Oxford Smith School of Enterprise and the Environment, Stranded Carbon Assets and Negative Emissions Technologies (2015), *available at* http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/Stranded%20Carbon%20Assets%20and%20NETs %20-%2006.02.15.pdf.
134. 2013 IPCC Physical Science Report, *supra* note 1, at 11.

Deep Decarbonization project includes carbon capture and sequestration from fossil fuel plants, it does not address the use of biomass to produce energy followed by the capture and sequestration of resulting carbon, because that technology is regarded as too uncertain at present.[135] To be sure, law and policy at the national level, coupled with international cooperation efforts, can help foster the development of such technologies. But what kinds of other laws and policies are needed—in industry, agriculture, forestry, electricity generation, and other sectors—to produce negative emissions? What are the most cost-effective, equitable, and permanent ways of accomplishing that result, and with the most benefits? The development of legal scenarios—based on different tools and combinations of tools—could assist in answering those questions.

The sustainable development frame, which would maximize the social, economic, environmental, and security benefits of legal measures taken to decarbonize the economy, also indicates the value of legal scenarios. Reductions in greenhouse gas emissions do not produce local benefits; the co-benefits of those measures do, and designing legal measures that maximize these co-benefits is a key element in getting these measures adopted. National laws that allow subnational governments such as states and municipalities to particularize implementation to local circumstances, for example, may lead to greater co-benefits than more uniform laws.[136] Similarly, what role could a properly motivated public play in individual efforts to reduce greenhouse gas emissions? If such efforts had a greater impact, perhaps other and less attractive measures would be unnecessary.[137] Similarly, what are the best measures to protect the poor and manage the impact of the transition on the fossil-fuel industry? By helping answer these and other questions, legal scenarios based on sustainable development could identify the most attractive and politically achievable legal pathways for keeping the temperature increase well below 2°C.

V. Conclusion

An essential part of the decarbonization challenge is proposing, analyzing, and comparing various legal pathways to that result in each individual country. Those legal pathways should be capable of reducing greenhouse gas emissions at a speed and scale needed to give the world its best chance of keeping the global average temperature increase below 2°C while also producing as many economic, social, environmental, and security benefits as possible. In the face of a daunting challenge, there exists a real possibility that law and lawyers can help improve human quality of life throughout the world by facilitating zero-carbon development.

135. Pathways to Deep Decarbonization, *supra* note 25, at 8-9. For an overview of one proposal, see Graciela Chichilnisky & Peter Eisenberger, *Carbon Negative Power Plants*, CryoGas Int'l, May 2011, at 36, *available at* http://www.chichilnisky.com/wp-content/uploads/2011/04/Carbon-Negative-Power-Plants.pdf.

136. John C. Dernbach et al., *Making the States Full Partners in a National Climate Change Effort: A Necessary Element for Sustainable Economic Development*, 40 ELR 10597 (June 2010).

137. Thomas Dietz et al., *Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions*, 106 Proc. Nat'l Acad. Sci. 18452 (2009).