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INTRODUCTION

We live in a period of extraordinary technological change. A series of overlapping and converging emergent technologies are disrupting every industry in our economy and every aspect of our lives. These emerging technologies include synthetic biology, gene editing, nanotechnology, artificial intelligence, internet of things, 3D printing, drones, applied neurotechnologies, and blockchain and cryptocurrencies.

Each of these emerging technologies promises immense benefits, which explains why they will move forward into our economy and lives at a frantic pace. But such technologies also present concerns, including risks relating to safety, health, the environment, privacy, "playing

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God,"[1] national security, bias and discrimination, fairness, economic equality, and democratic values. These risks need to be adequately addressed and managed if the associated technology is to be successfully adopted and integrated into society.

Yet, governance of emerging technologies presents an intractable challenge. Existing regulatory agencies lack the legal authority, expertise, and resources to regulate any of the emerging technologies comprehensively, even if they wanted to. But such sweeping traditional regulation may be inadvisable given how fast the technologies are progressing, which would likely make any regulatory enactments obsolete before their ink dried. The complexity of applications, entities, issues, and stakeholders further complicates regulation. Other governance approaches, including precaution, liability, and resilience, may also have a role to play, but each is incomplete and imperfect in its own right.

Governance of emerging technologies therefore presents a conundrum. No single optimum solution exists, but rather a collection of second-best strategies intersect, coexist, and—in some ways—compete. This situation seems unsatisfactory until it is observed through the lens of the "wicked problem" framework.[2] The wicked problem concept recognizes there is often no single, optimal solution to such a problem, but rather a mix of substandard solutions that must "satisfice."[3] That is the best that can be done with a wicked problem. This also may be the best solution for the governance-of-emerging-technologies problem.

This Article discusses the advantages of using the wicked problem framework to rethink the governance-of-emerging-technologies problem. Using this framework forces the recognition that there will not be a single, effective solution to this problem. The defining

1. "Playing God" refers to the concern that humans are engaging in dangerous hubris when they try to change fundamental elements of the natural world as created by a supernatural creator. PRESIDENTIAL COMM'N FOR THE STUDY OF BIOETHICAL ISSUES, NEW DIRECTIONS: THE ETHICS OF SYNTHETIC BIOLOGY AND EMERGING TECHNOLOGIES 136, 156 (2010), https://bioethicsarchive.georgetown.edu/pcsbi/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf [https://perma.cc/3DS2-7PVX]. Ironically, the argument is made more by secular than religious technology critics. *Id.* at 156. The Presidential Commission for the Study of Bioethical Issues found such terminology to be "unhelpful at best, misleading at worst." *Id.*

2. The first definition of "wicked problems" is believed to have been offered in an editorial by Professor C. West Churchman in 1967, who cited a definition by his University of California colleague Professor Horst Rittel of this new concept of wicked problems as "that class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing." C. West Churchman, *Wicked Problems*, 14 MGMT. SCI. B-141, B-141 (1967).

3. Herbert A. Simon, *Theories of Decision-Making in Economics and Behavioral Science*, 49 AM. ECON. REV. 253, 262–64 (1959).

characteristics of a wicked problem—complexity, diversity, and uncertainty[4]—make a perfect or even satisfactory solution to emerging technologies governance beyond reach. Rather, the best strategy will be to integrate a number of imperfect tools, recognizing and trying to compensate for their particular flaws, in pursuit of moving forward with highly beneficial technologies, while exercising responsibility and care to the extent feasible.

Part I expands the argument that emerging technologies are difficult to govern, and these management challenges align with the definition of a wicked problem. Part II surveys the various approaches that have been advocated for governing emerging technologies, describing not only their advantages but also their flaws and limitations. Finally, Part III elaborates on how the wicked problem concept provides a viable framework for moving forward with a governance system that is imperfect but suffices to achieve an acceptable outcome.

I. THE WICKED PROBLEM OF EMERGING TECHNOLOGY GOVERNANCE

Emerging technologies—such as synthetic biology, gene editing, nanotechnology, artificial intelligence, internet of things, 3D printing, drones, applied neurotechnologies, and blockchain and cryptocurrencies—present a common set of governance challenges.[5] Perhaps most significant is the "pacing problem," where the pace of technology development far outstrips the capability of regulatory systems to keep up.[6] Powered by growing market demand and intense business competition, new technologies are being developed, deployed, and commercialized faster than ever before.[7] At the same time, traditional governmental processes of legislation, regulation, and judicial review have been slowed by increasing bureaucratic requirements and the increasing politicization of technological disputes.[8] The result of accelerating technology and decelerating regulatory oversight is a growing governance gap. Any new statutes or

4. Brian W. Head & John Alford, *Wicked Problems: Implications for Public Policy and Management*, 47 ADMIN. & SOC'Y 711, 716–18 (2015).

5. Gary E. Marchant, *Conclusion: Emerging Governance for Emergent Technologies*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES 254, 254 (Gary E. Marchant, Kenneth W. Abbott & Braden Allenby eds., 2013).

6. Gary E. Marchant, *The Growing Gap Between Emerging Technologies and the Law*, *in* THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT: THE PACING PROBLEM 19, 19 (Gary Marchant, Braden Allenby & Joseph Herkert eds., 2011).

7. *See id.* at 20–22 (giving examples of this phenomenon in areas such as computing power, biological technology, and internet infrastructure).

8. *Id.* at 22–28.

regulations affecting these new technologies are likely to be outdated before the ink dries. As technology governance expert David Rajeski has noted, "[i]f you think that any existing regulatory framework can keep pace with this rate of change, think again."[9] Facing such a bleak prospect, regulators often sensibly defer regulation, waiting for a more stable technology plateau that may or may not ever come.

A second regulatory challenge of many emerging technologies is that they present risks and concerns outside the scope of existing regulatory agency jurisdictions.[10] Regulatory agencies, such as the U.S. Food and Drug Administration, are restricted to regulating the safety and efficacy of products. But many applications of emerging technologies raise broader ethical and social concerns relating to human enhancement, "playing God," autonomy, dignity, fairness, equitable access, privacy, and longer-term impacts on society.[11] These issues are largely outside the safety and efficacy scope of current agency jurisdictions and thus often escape any regulatory oversight.

Yet another challenge to the regulation of emerging technologies is their breadth of application. Technologies such as artificial intelligence, nanotechnology, and blockchain span the entire industry spectrum, as well as many nonindustrial activities and sectors. They are sometimes referred to as "enabling" or "platform" technologies that, like computers or the internet, have the potential to affect virtually every industry sector.[12] There are thousands, if not tens or hundreds of thousands, of ways these core technologies are used, each with their own context of risks and benefits. These broad applications not only involve many different types of industries and businesses, but also affect many other types of stakeholders and nongovernmental organizations with particular interests in specific applications. The broad applications of these technologies also span many different regulatory agencies, each with their own organic statutes with different requirements, criteria, and goals. The end result of this multitude of applications, regulated parties, stakeholders, and regulators is tremendous regulatory diversity and complexity. Further complicating the regulatory challenge, emerging technologies are inherently

9. David Rejeski, *The Next Small Thing*, 21 ENV'T F. 42, 45 (2004).

10. Gary Marchant, Ann Meyer & Megan Scanlon, *Integrating Social and Ethical Concerns into Regulatory Decision-Making for Emerging Technologies*, 11 MINN. J.L. SCI. & TECH. 345 (2010).

11. *See* Marchant, *supra* note 5, at 255.

12. Robert Falkner & Nico Jaspers, *Regulating Nanotechnologies: Risk, Uncertainty and the Global Governance Gap*, 12 GLOB. ENV'T POL. 30, 35 (2012).

international in application, creating the need for some type of international coordination.[13]

Finally, the unprecedented uncertainty about emerging technologies also impedes effective regulation.[14] Because the technologies are so new and moving forward so quickly, there is enormous uncertainty about the trajectories, benefits, and risks of these technologies.[15] Given these uncertainties, it is possible to paint unrealistically optimistic or pessimistic visions of the technology at issue, thus fostering public controversy, conflict, and unease.[16]

In summary, the governance of emerging technologies is characterized by complexity, diversity, and uncertainty. These same characteristics—complexity, diversity, and uncertainty—are the defining characteristics of a wicked problem.[17] As a wicked problem, the governance of emerging technologies is unlikely to be solved by a single or simple solution. Traditional government regulation will not be sufficient, or many times even appropriate, for emerging technologies.[18] Rather than traditional regulation—consisting of enforceable rules unilaterally imposed by a regulatory agency—emerging technologies will require a "governance" approach that expands the categories of responsible parties beyond government to include the private sector, nongovernmental organizations, and think tanks and also expands the relevant oversight mechanism beyond enforceable government regulations.[19] Four alternative governance approaches for emerging technologies are discussed and evaluated in the next Part.

13. Marchant, *supra* note 5, at 255–56.

14. *Id.* at 254–55.

15. Falkner & Jaspers, *supra* note 12, at 33 ("Scientific uncertainty is particularly pronounced in emerging technologies, such as biotechnologies, nanotechnologies or synthetic biology.").

16. *Id.* ("[G]lobal risk governance for emerging technologies tend to be politicized where scientific uncertainty is high.").

17. Head & Alford, *supra* note 4, at 716–18.

18. Marchant, *supra* note 5, at 256 ("[T]raditional government regulation alone cannot adequately govern most emerging technologies."); Wendell Wallach & Gary Marchant, *Toward the Agile and Comprehensive International Governance of AI and Robotics*, 107 PROC. IEEE 505, 506 (2019) ("[T]here is a growing consensus that traditional government regulation is not sufficient for the oversight of emerging technologies . . . .").

19. *See* O. Renn & M.C. Roco, *Nanotechnology and the Need for Risk Governance*, 8 J. NANOPARTICLE RSCH. 153, 157–58 (2006); *see also* Orly Lobel, *The Renew Deal: The Fall of Regulation and the Rise of Governance in Contemporary Legal Thought*, 89 MINN. L. REV. 342 (2004) (arguing for a more reflexive governance approach incorporating nongovernment actors in a variety of regulatory areas).

II. ALTERNATIVE STRATEGIES FOR GOVERNING EMERGING TECHNOLOGIES

The governance of emerging technologies is unsettled. There are many competing approaches and strategies but no consensus for how to govern these technologies, except that traditional modes of regulation will not work.[20] There are four major alternative approaches to governing emerging technologies, and they can be categorized along two dimensions: ex ante versus ex post and permissive versus prohibitive. These four different approaches are typically presented as contrasting, mutually exclusive choices—policymakers must choose one or the other (a premise revisited later in this Article). The four alternatives are shown below in Table 1 and then briefly summarized in the following subsections.

TABLE 1: FOUR MAJOR ALTERNATIVE APPROACHES TO EMERGING TECHNOLOGY GOVERNANCE

	Permissive	Prohibitive
Ex ante	Soft Law	Precaution
Ex post	Resilience	Liability

A. Soft Law

The ex ante, permissive category of governance approaches involves soft law instruments. Soft law instruments set forth substantive requirements that are not directly enforceable by government regulators.[21] They can consist of private standards, codes of conduct, certification programs, principles, guidelines, and voluntary programs.[22] Soft law programs have a number of benefits for governing emerging technologies, including that they are more agile than traditional regulation because they can often be adopted or revised

20. *See supra* note 18 and accompanying text.

21. Gary E. Marchant & Brad Allenby, *Soft Law: New Tools for Governing Emerging Technologies*, 73 BULL. ATOMIC SCIENTISTS 108, 112 (2017).

22. Ryan Hagemann, Jennifer Huddleston Skees & Adam Thierer, *Soft Law for Hard Problems: The Governance of Emerging Technologies in an Uncertain Future*, 17 COLO. TECH. L.J. 37, 44–45 (2018); Kenneth W. Abbott, Gary E. Marchant & Elizabeth A. Corley, *Soft Law Oversight Mechanisms for Nanotechnology*, 52 JURIMETRICS 279, 286–96 (2012); Diana M. Bowman & Graeme A. Hodge, *Counting On Codes: An Examination of Transnational Codes as a Regulatory Governance Mechanism for Nanotechnologies*, 3 REGUL. & GOVERNANCE 145, 146–47 (2009).

relatively quickly.[23] The voluntary nature of these programs also makes them more cooperative than adversarial, which can sometimes contribute toward success.[24] Other advantages of soft law instruments are that they can address any issues ranging from health risks to ethical concerns, multiple approaches can be tried simultaneously by different stakeholders, and they can be gradually "hardened" into more formal regulatory oversight with experience. Because soft law is not tied to specific regulatory agencies, this approach is not bound to specific legal jurisdictions and is inherently international in application.[25]

Soft law approaches also have their disadvantages, however. Their biggest limitation is that—without any potential penalties for noncompliance—their voluntary nature means that some entities will choose not to comply with a soft law instrument, and some of those that do assert their intent to comply may not do so in good faith.[26] Soft law instruments are also sometimes too vague and general to have any real impact or meaning, allowing companies that support such instruments to be self-serving and engage in "greenwashing."[27] A related weakness is that unlike government regulation, where anyone who wants to comment during its enactment can do so, there is no guaranteed right of participation in the development of soft law instruments, and they are often crafted by a small group of self-selected parties.[28] Finally, a secondary benefit of regulation is to reassure the public that a problem is being addressed, but polls show that the public lacks confidence in

23. Wallach & Marchant, *supra* note 18, at 506.

24. *Id.*

25. *Id.*

26. *See* Steffen Foss Hansen & Joel A. Tickner, *The Challenges of Adopting Voluntary Health, Safety and Environment Measures for Manufactured Nanomaterials: Lessons from the Past for More Effective Adoption in the Future*, 4 NANOTECHNOLOGY L. & BUS. 341, 353–55 (2007) (noting lack of incentives for companies to participate in voluntary programs).

27. "Greenwashing" refers to the practice of a company engaging in a public relations ruse, such as signing on to a voluntary environmental program, without fundamentally changing the internal practices and external impacts of that entity. *See* Dorit Kerret & Alon Tal, *Greenwash or Green Gain? Predicting the Success and Evaluating the Effectiveness of Environmental Voluntary Agreements*, 14 PA. STATE ENV'T L. REV. 31, 35 (2005). Recently, the similar term "ethics washing" has been coined for the alleged practice of some companies to adopt ethical principles for emerging technologies, such as artificial intelligence, that are cosmetic only and have no practical effect on the company's ethical performance. *See* Elettra Bietti, *From Ethics Washing to Ethics Bashing: A View on Tech Ethics from Within Moral Philosophy* 1 (Proc. of the 2020 Conf. on Fairness, Accountability & Transparency, Jan. 2020), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3513182 [https://perma.cc/3ENP-TETN].

28. Hansen & Tickner, *supra* note 26, at 355 (critiquing lack of transparency and open participation in voluntary programs).

many soft law programs.[29] Of course, there are actions that entities supporting soft law solutions can take to enhance the effectiveness and public confidence in soft law instruments, such as involving credible nongovernmental organizations in the development and oversight of the instrument or implementing third-party certification and auditing measures. However, without a concerted effort to buttress the effectiveness and credibility of soft law programs, they will often have neither.

B. Precaution

Precaution, most often implemented in the form of the precautionary principle, seeks to "err on the side of caution" to prevent adverse effects from a human activity, such as the production or use of an emerging technology.[30] It is therefore an example of an ex ante prohibitive governance approach. The European Union is the recognized leader in applying the precautionary principle, having adopted the principle as a binding legal requirement in its foundational legislation.[31] Even though the United States has not adopted the precautionary principle per se, it does exercise precaution in many of its regulatory programs.[32] For example, risk assessments by U.S. regulatory agencies often use "conservative" assumptions that apply a plausible worst-case estimate of risk.[33] The precautionary principle has been adopted based on a historical pattern of regulators failing to take sufficient protective action against uncertain risks that eventually turned out to impose large safety risks on the population.[34] The

29. JANE MACOUBRIE, WOODROW WILSON INT'L CTR. FOR SCHOLARS, INFORMED PUBLIC PERCEPTION OF NANOTECHNOLOGIES AND TRUST IN GOVERNMENT 14 (2005) ("The majority of study participants felt that voluntary standards applied by industry would not be sufficient.").

30. *See Wingspread Conference on the Precautionary Principle*, SCI. & ENV'T HEALTH NETWORK: BLOG (Aug. 5, 2013), http://sehn.org/wingspread-conference-on-the-precautionary-principle [https://perma.cc/4S99-Z54J] ("When an activity raises threats of harm . . . precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."); PROTECTING PUBLIC HEALTH & THE ENVIRONMENT: IMPLEMENTING THE PRECAUTIONARY PRINCIPLE 59 (Carolyn Raffensperger & Joel Tickner eds., 1999) ("[E]xperience . . . tells us that we should not be so overcautious in applying the Precautionary Principle. Nine times out of ten we will not err on the side of caution, but later realize that precaution was necessary.").

31. Treaty Establishing the European Community art. 130r, Feb. 7, 1992, 1992 O.J. (C 224) 1, 52, *reprinted in* 31 I.L.M. 247, 285 (1992); *see also Communication from the Commission on the Precautionary Principle*, at 7, COM (2000) 1 final (Feb. 2, 2000).

32. Jonathan B. Wiener & Michael D. Rogers, *Comparing Precaution in the United States and Europe*, 5 J. RISK RSCH. 317, 318 (2002).

33. *See* Frank B. Cross, *Paradoxical Perils of the Precautionary Principle*, 53 WASH. & LEE L. REV. 851, 857–59 (1996) (using the Environmental Protection Agency's process as an example).

34. EUR. ENV'T AGENCY, LATE LESSONS FROM EARLY WARNINGS: THE PRECAUTIONARY PRINCIPLE 1896-2000, at 11 (Poul Harremoës, David Gee, Malcolm MacGarvin, Andy Stirling, Jane

precautionary principle flips the presumption on uncertainty—now uncertainty is used to block a technology until the uncertainties can be resolved in favor of safety, rather than being used as a barrier to taking regulatory action.[35]

The precautionary principle has been used to delay a number of emerging technologies, including biotechnology and nanotechnology, especially in Europe. The precautionary principle has a number of limitations, however, that have impeded its adoption in the United States.[36] First, there is no agreed-upon definition or meaning of the precautionary principle, even among its advocates, and, accordingly, jurisdictions that adopt the precautionary principle fail to define it.[37] There is disagreement, for example, over whether the precautionary principle applies to only serious and irreversible risks or to a much broader range of risks.[38] There are no clear criteria on how much uncertainty triggers the principle or how much data the proponent of a technology must produce to satisfy the principle.[39] A related problem is that the precautionary principle is applied selectively, and on an ad hoc basis, to appease certain groups' opposition to a particular technology.[40] At the same time, other technologies that are at least as dangerous are exempted from the precautionary principle because the principle is applied arbitrarily and subjectively rather than through application of objective criteria and scientific knowledge.[41] The precautionary principle is often justified as helping to reassure the public that a technology is safe and can be trusted, but there are studies showing

Keys, Brian Wynne & Sofia Guedes Vaz eds., 2001), https://www.eea.europa.eu/publications/environmental_issue_report_2001_22/Issue_Report_No_22.pdf/view [https://perma.cc/P58T-CP72].

35. Carl F. Cranor, *Learning from the Law to Address Uncertainty in the Precautionary Principle*, 7 SCI. & ENG'G ETHICS 313, 316 (2001).

36. Gary E. Marchant, *From General Policy to Legal Rule: Aspirations and Limitations of the Precautionary Principle*, 111 ENV'T HEALTH PERSPS. 1799, 1800–03 (2003).

37. Per Sandin, *Dimensions of the Precautionary Principle*, 5 HUM. & ECOLOGICAL RISK ASSESSMENT 889, 889–90 (1999).

38. Marchant, *supra* note 36, at 1800 ("Different versions of the [precautionary principle] vary, for example, in the level of the threat necessary to trigger the principle from 'threats of serious or irreversible damage' to 'possible risks,' a discrepancy of enormous policy importance.").

39. *Id.* at 1800–01.

40. *Id.* at 1801 ("In the absence of such criteria, the application of the [precautionary principle] appears to be governed primarily by arbitrary decisions based on individual and group self-interests and biases.").

41. *See* Jonathan B. Wiener, *Precaution*, *in* THE OXFORD HANDBOOK OF INTERNATIONAL ENVIRONMENTAL LAW 597, 600–01, 611–12 (Daniel Bodansky, Jutta Brunée & Ellen Hey eds., 2007) (comparing precaution in Europe and the United States to illustrate "precautionary particularity," which is "the selective use of precaution by different states against different risks"); Marchant, *supra* note 36, at 1801 ("The ambiguity of the [precautionary principle] invites arbitrary application, both with respect to which risks it is applied to and what it requires when it does apply.").

that implementation of the precautionary principle to a technology increases rather than decreases public anxiety.[42] Finally, the precautionary principle does not consider the health benefits of a technology—for example, some technologies such as nanotechnology may have the potential to save many lives, and thus banning such technologies under the precautionary principle would do more harm than good.[43] As Cass Sunstein has noted, the precautionary principle, applied fairly, is paralyzing because it would ban what it simultaneously mandates.[44]

C. Resilience

The approaches discussed so far are ex ante, where a governing body must anticipate and predict risks before they occur. Given the enormous uncertainties about emerging technologies, ex ante approaches can create the concern that potential risks that never manifest will receive too much focus, while the real risks that unexpectedly develop will be overlooked. Ex post approaches like resilience do not have that problem, as they respond to risks after they result in harm. Resilience is the more permissive form of ex post governance—it does not seek to punish the risk creator but rather to mitigate the harm that results from an action or technology.[45] Resilience involves measures that seek to restore the fundamental structure and functions of a system after harm occurs.

The U.S. National Academies of Sciences defines resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to actual or potential adverse events."[46] Given that some harm is likely from any human activity or technology, resilience is a prudent and necessary strategy to try to minimize those resulting harms. Resilience can be substantive—such as requirements for

42. Peter M. Wiedemann & Holger Schütz, *The Precautionary Principle and Risk Perception: Experimental Studies in the EMF Area*, 113 ENV'T HEALTH PERSPS. 402, 404 (2005); Peter M. Wiedemann, Andrea T. Thalmann, Markus A. Grutsch & Holger Schütz, *The Impacts of Precautionary Measures and the Disclosure of Scientific Uncertainty on EMF Risk Perception and Trust*, 9 J. RISK RSCH. 361, 368–70 (2006).

43. *See* Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003, 1020–24 (2003) (extrapolating this concept to areas like genetically modified foods and drug testing).

44. Cass R. Sunstein, *Throwing Precaution to the Wind: Why the 'Safe' Choice Can Be Dangerous*, BOS. GLOBE (July 13, 2008), http://archive.boston.com/bostonglobe/ideas/articles/2008/07/13/throwing_precaution_to_the_wind/?page=full [https://perma.cc/92ZV-BGHE].

45. Gary E. Marchant & Yvonne A. Stevens, *Resilience: A New Tool in the Risk Governance Toolbox for Emerging Technologies*, 51 U.C. DAVIS L. REV. 233, 244–48 (2017).

46. COMM. ON INCREASING NAT'L RESILIENCE TO HAZARDS & DISASTERS & COMM. ON SCI. ENG'G, & PUB. POL'Y, THE NAT'L ACADS. SCIS., ENG'G, & MED., DISASTER RESILIENCE: A NATIONAL IMPERATIVE 16 (2012).

insurance, remediation funds that can pay for cleanup, or "kill switches" that can deactivate a runaway genetically modified organism or AI system.[47] Resilience can also be procedural—putting in place systems for adaptive management or emergency response for prompt mitigation of harms.[48] Just as secondary prevention may be more feasible than primary prevention for some health problems,[49] resilience after harms occur may be a more effective and feasible strategy for some risks than ex ante risk assessment and risk management, which may unduly delay or block beneficial technologies.[50]

Nonetheless, resilience does have its limitations. Resilience addresses risks that are either inevitable and unpreventable, or incapable of being predicted ex ante. If the risk was not predicted, one cannot be certain that the resilience measures in place will effectively ameliorate the unanticipated hazards.[51] Another limitation of resilience approaches is that they wait until the harm occurs before trying to reduce the impacts, rather than preventing the risk in the first place. Many examples, from asbestos[52] to the Dalkon Shield[53] to global warming,[54] demonstrate that it would be much preferred and effective to have prevented the problem in the first place, rather than to try to mitigate the harm after it occurs. Finally, resilience is a relatively new

47. Marchant & Stevens, *supra* note 45, at 254, 262–70.

48. *Id.* at 255–62.

49. *See id.* at 250 (explaining that medicine relies on secondary prevention measures, such as screenings and medication, because it is impossible to prevent all illnesses and injuries).

50. Resilience is therefore consistent with the concept of permissionless innovation. *See* ADAM THIERER, PERMISSIONLESS INNOVATION: THE CONTINUING CASE FOR COMPREHENSIVE TECHNOLOGICAL FREEDOM 1–3 (2014) (defining permissionless innovation as "the general freedom to experiment and learn through ongoing trial-and-error experimentation").

51. Even though resilience applies after harm occurs, the success of the resilience measures will depend on the advance preparations for the resilience to apply. David D. Woods, *Four Concepts for Resilience and the Implications for the Future of Resilience Engineering*, 141 RELIABILITY ENG'G & SYS. SAFETY 5, 8–9 (2015).

52. Asbestos was introduced as a "miracle" fiber that could provide effective and inexpensive insulation in buildings and other applications, but it ended up killing hundreds of thousands of workers with painful mesothelioma and other lung cancers. EUR. ENV'T AGENCY, *supra* note 34, at 52.

53. The Dalkon Shield was a contraceptive device that injured tens of thousands of women and caused birth defects to many of their progeny because the device did not work as advertised. Joseph A. Page, *Asbestos and the Dalkon Shield: Corporate America on Trial*, 85 MICH. L. REV. 1324, 1324 n.1, 1326 (1987).

54. The adverse impacts of global warming from the accumulation of greenhouse gases, such as carbon dioxide, in the atmosphere are, for practical purposes, irreversible, as the resulting changes in the climate will take many centuries or even thousands of years to reverse given the long residency time of greenhouse gases in the atmosphere. *See* EDMOND A. MATHEZ, CLIMATE CHANGE: THE SCIENCE OF GLOBAL WARMING AND OUR ENERGY FUTURE 128 (2009) (noting that once "large quantities of CO2 [are injected] into the atmosphere," it may take "tens of thousands of years for the climate system to recover to its former state").

strategy for governing emerging technologies, so it is the least developed and validated approach.[55]

D. Liability

The fourth competing strategy for governing emerging technologies is liability, which is ex post and prohibitive, but can provide a powerful risk management or governance effect.[56] If an emerging technology harms people, the entities responsible for unleashing that technology could be held liable for the resultant injuries. Liability can be more effective than regulation in managing some risks, such as tobacco, because it requires corporate defendants to divulge information, has fewer barriers to action, and is less susceptible to political pressure.[57] Liability not only can compensate people for their injuries, but can also be a powerful deterrent against unreasonable risks and incentivize companies to ensure that technologies and products are developed and used safely.[58] Another advantage of liability as a governance tool is that, because it is ex post, it does not need to rely on speculation about hypothetical risks, as it only kicks in once real harm has occurred.[59] Finally, litigation relies on citizens in their roles as jurors to determine liability and damages in litigation, thus providing for democratic representation by the public in decisions about technologies.

Not surprisingly, litigation also has its disadvantages as a technology governance approach. To start, financial compensation cannot truly make up for some injuries, especially irreversible harms

55. Jeryang Park, Thomas P. Seager & P. Suresh C. Rao, *Lessons in Risk- Versus Resilience-Based Design and Management*, 7 INTEGRATED ENV'T ASSESSMENT & MGMT. 396, 398 (2011) ("[T]he development of practical methods to implement resilience in an engineering context is still in an incipient stage.").

56. *See, e.g.*, Jonathan H. Adler, *Free & Green: A New Approach to Environmental Protection*, 24 HARV. J.L. & PUB. POL'Y 653, 667–71 (2001) (detailing the effects of environmental liability on land management); Keith N. Hylton, *When Should We Prefer Tort Law to Environmental Regulation?*, 41WASHBURN L.J. 515, 520–28 (2002) (comparing tort litigation liability to a form of private enforcement); Alexandra B. Klass, *Common Law and Federalism in the Age of the Regulatory State*, 92 IOWA L. REV. 545, 582–84 (2007) (advocating for using the common law regime as a means of environmental protection).

57. Patrick Luff, *Regulating Tobacco Through Litigation*, 47 ARIZ. STATE L.J. 125, 163–73 (2015).

58. While deterrence is a frequently cited purpose of tort liability, the empirical evidence on whether liability actually deters actors is mostly inconclusive. Benjamin van Rooij & Megan Brownlee, *Does Tort Deter? Inconclusive Empirical Evidence About the Effect of Liability in Preventing Harmful Behavior*, *in* CAMBRIDGE HANDBOOK ON COMPLIANCE (forthcoming 2021), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3563452 [https://perma.cc/HV55-EZTJ].

59. *See* James A. Henderson, Jr., *Tort vs. Technology: Accommodating Disruptive Innovation*, 47 ARIZ. STATE L.J. 1145, 1147–48 (2015) (articulating how the American tort system's lack of ex ante regulation encourages innovation).

such as human deaths or permanent damage to the environment.[60] Second, many emerging technologies have highly uncertain effects and consequences, making it difficult to recognize and prove that an emerging technology caused a specific injury to a given plaintiff, which, in turn, allows some technology products or applications to escape liability.[61] Third, litigation is an expensive process, with very high administration costs to pay for lawyers, expert witnesses, and court expenses. Fourth, liability is particularly ineffective against long-tail risks, where the long lag between the time of the tortious act and the resulting damages (and litigation) dilutes the deterrent effect.[62] Many emerging technologies such as nanotechnology, synthetic biology, and artificial intelligence may have long-term hazards that would create such long-tail risks. Fifth, defendants are increasingly using mandatory arbitration and liability waivers to reduce the impacts, and hence the deterrent effect, of liability.[63] Finally, while a benefit of litigation is that it empowers citizens as jurors to decide culpability and penalties, the flip side is that lay jurors can produce irrational, inconsistent, or excessive judgments that distort risk management and impede innovation.[64]

E. Summary of the Four Alternative Governance Approaches

Given that traditional regulation is inadequate and poorly aligned to govern emerging technologies, four alternative approaches have been proposed: soft law, precaution, resilience, and liability. Each of these approaches has its advantages and strengths, but each, on their own, also has serious limitations. To date, there is competition and conflict over which of the four approaches should be adopted. The critics of each approach tend to have the upper hand, with the proponents on the defensive because each of these approaches is seriously flawed if relied on as the sole mechanism for governance. As discussed in the final section of this paper, however, the wicked problem framework may

60. *See* Marchant & Stevens, *supra* note 45, at 243.

61. *Id.* at 242–43.

62. Michael G. Faure, *The Complementary Roles of Liability, Regulation and Insurance in Safety Management: Theory and Practice*, 17 J. RISK RSCH. 689, 696 (2014).

63. Ryan Martins, Shannon Price & John Fabian Witt, *Contract's Revenge: The Waiver Society and the Death of Tort*, 41 CARDOZO L. REV. 1265, 1267–68, 1299–1300 (2020).

64. Daniel Kahneman, David Schkade & Cass R. Sunstein, *Shared Outrage and Erratic Awards: The Psychology of Punitive Damages*, 16 J. RISK & UNCERTAINTY 49, 72–73 (1998); Reid Hastie & W. Kip Viscusi, *What Juries Can't Do Well: The Jury's Performance as a Risk Manager*, 40 ARIZ. L. REV. 901, 912 (1998).

provide a more holistic and satisfying approach to break the existing deadlock on how to govern emerging technologies.

III. FRAMING EMERGING TECHNOLOGY GOVERNANCE AS A WICKED PROBLEM

The wicked problem concept provides a different, and perhaps more revealing and useful, framework for understanding the emerging technology governance challenge. The wicked problem literature provides several pertinent lessons for breaking through the emerging technology governance logjam. The first lesson is that there is no perfect solution, as each solution is a "clumsy solution."[65] The four alternative strategies proposed for governing emerging technologies are certainly "clumsy" solutions—they each have their own major imperfections. But given that governance of emerging technologies is a wicked problem, we can expect nothing more, and just because a solution is clumsy and imperfect is not a reason to reject it entirely. Rather, the way forward is to determine how to use each or any of the alternative strategies to advance governance and make progress in addressing concerns associated with an emerging technology, notwithstanding the imperfections of the chosen approach. In other words, the goal must be muddling through, not optimizing the response.[66] This accords with a second lesson from the wicked problem literature: we should not expect perfection, only partial success.[67]

The path forward may be guided by a third lesson from the wicked problems literature: a combination of strategies is needed to address the problem.[68] In other words, rather than thinking of the four alternative governance strategies as conflicting and inapposite, perhaps they can work together to compensate for each of their limitations. The four approaches could be integrated into a governing toolbox for emerging technologies, with a custom mix of the strategies being deployed for each emerging technology governance problem based on the context and circumstances of each concern.

65. Thomas Hartmann, *Wicked Problems and Clumsy Solutions: Planning as Expectation Management*, 11 PLAN. THEORY 242, 242 (2012).

66. Charles E. Lindblom, *The Science of "Muddling Through,"* 19 PUB. ADMIN. REV. 79, 80 (1959) (describing a problem-solving methodology in which the problem solver "muddles through" policy options).

67. Duco Bannink & Willem Trommel, *Intelligent Modes of Imperfect Governance*, 38 POL'Y & SOC'Y 198, 214 (2019) ("A wicked problem in itself does not allow perfect, but instead only imperfect responses.").

68. Catrien J.A.M. Termeer, Art Dewulf, Gerard Breeman & Sabrina J. Stiller, *Governance Capabilities for Dealing Wisely with Wicked Problems*, 47 ADMIN. & SOC'Y 680, 699–703 (2015).

For example, consider the use of the emerging technology of gene drives to eliminate a species of mosquito that transmits a dangerous disease such as malaria or zika virus. A gene drive is a genetic system that can be inserted into the genome of a species in nature. The gene drive is preferentially passed on in reproduction, so it can quickly spread throughout and even eliminate an entire population.[69] While this technology could potentially save thousands or even millions of human lives that might otherwise be lost to the pathogen carried by the target mosquito species, the intentional forced extinction and displacement of an existing species in an ecosystem could have all kinds of detrimental but unforeseen consequences.[70] Given the potentially serious and irreversible consequences of gene drives, this is an emerging technology application that calls for precaution.[71]

Thus, it is appropriate to apply precaution as a first governance strategy by postponing deployment of the gene drive until adequate safety demonstrations and modeling have been completed and appropriate consultations with stakeholders have taken place.[72] A second strategy, resilience, could be employed to engineer "kill switches" into any released gene drives, which would allow the gene drive to be deactivated if things started to go wrong.[73] A third strategy, soft law, could provide private, multinational standards or guidelines—developed by a consortium of different stakeholders—for the risk assessment approach used to satisfy precaution and require the kill switches suggested by resilience.[74] Finally, the fourth strategy, liability, could be used to deter anyone from deploying gene drives that do not comply with the private standards that set the standard of care and define best practices for courts to judge liability, especially when government regulations do not exist.[75]

69. COMM. ON GENE DRIVE RSCH. IN NON-HUMAN ORGANISMS: RECOMMENDATIONS FOR RESPONSIBLE CONDUCT, BD. ON LIFE SCIS., & DIV. ON EARTH & LIFE STUD., THE NAT'L ACADS. SCIS., ENG'G, & MED., GENE DRIVES ON THE HORIZON: ADVANCING SCIENCE, NAVIGATING UNCERTAINTY, AND ALIGNING RESEARCH WITH PUBLIC VALUES 14–17 (2016).

70. *Id.* at 26–39.

71. Gregory E. Kaebnick, Elizabeth Heitman, James P. Collins, Jason A. Delborne, Wayne G. Landis, Keegan Sawyer, Lisa A. Taneyhill & David E. Winickoff, *Precaution and Governance of Emerging Technologies*, 354 SCIENCE 710, 710 (2016).

72. *Id.* at 710–11.

73. *See* Michael R. Vella, Christian E. Gunning, Alun L. Lloyd & Fred Gould, *Evaluating Strategies for Reversing CRISPR-Cas9 Gene Drives*, SCI. REPS., Sept. 8, 2017, at 2, https://www.nature.com/articles/s41598-017-10633-2 [https://perma.cc/BHA7-QP95].

74. *See* Gary E. Marchant, *'Soft Law' Mechanisms for Nanotechnology: Liability and Insurance Drivers*, 17 J. RISK RSCH. 709, 710–11 (2014).

75. *See id.* at 715–17 (explaining that private standards can help determine standard of care in litigation).

This is just one example. But it is likely that most, if not all, emerging technology governance needs can be best addressed by some mix of the four governance strategies, whether it is two, three, or four strategies working together in coordination. The choice of which strategies to apply to a specific emerging technology problem, and the way those strategies should interact together, will likely be a case-by-case determination, with no generic playbook that applies across technologies and problems—at least initially. Over time and with accumulating experience, successful patterns and structures for integrating two or more governance approaches will likely emerge.

This need for ad hoc application of different strategies in a synergistic manner creates the need for coordination. This need for coordination among multiple actors is, again, a characteristic of successful schemes that deal with wicked problems.[76] This necessarily fragmented response "therefore requir[es] coordination to increase problem-solving capacity and effectively tackle wicked problems."[77] Since many of these strategies involve actors outside of government, it is unlikely that government is the appropriate entity to provide this coordination function.

Wendell Wallach and I have called for Governance Coordinating Committees to do exactly this: coordinate the various actors and strategies that need to be integrated to govern any given emerging technology.[78] More important than the specific coordinating mechanism we propose, our analysis shows the general and well-recognized need for some type of multistakeholder entity or forum for providing the necessary coordination.[79] There is a need for creation of such a coordinating entity that does not itself implement the governance strategies, but rather helps to communicate and synchronize various governance initiatives, as well as to identify governance gaps that may require additional action or initiatives. Of course, creation of such a coordinating "orchestration" entity is not easy with many complex, unresolved issues about funding, decisionmaking, participation, scope,

76. Tom Christensen, Ole Martin Lægreid & Per Lægreid, *Administrative Coordination Capacity; Does the Wickedness of Policy Areas Matter?*, 38 POL'Y & SOC'Y 237, 237 (2019).

77. Catrien J.A.M Termeer, Art Dewulf & Robbert Biesbroek, *A Critical Assessment of the Wicked Problem Concept: Relevance and Usefulness for Policy Science and Practice*, 38 POL'Y & SOC'Y 167, 175 (2019).

78. Gary E. Marchant & Wendell Wallach, *Coordinating Technology Governance*, ISSUES SCI. & TECH., Summer 2015, at 43, 43–50.

79. Gary E. Marchant & Wendell Wallach, *Governing the Governance of Emerging Technologies*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES, *supra* note 5, at 136, 142–47 (describing various attempts to create an "issue manager" to coordinate governance of various emerging technologies).

and authority.[80] But here again, the wicked problem framing helps, as wicked problems can only be managed by "messy institutions."[81]

CONCLUSION

The governance of emerging technologies has been resistant to effective solutions and strategies for some time. Traditional government regulation will not work, at least by itself, due to the pacing problem, the diversity of applications and stakeholders, and the complexity created by unprecedented uncertainties and concerns that go beyond safety and efficacy. Four alternative strategies have been proposed or attempted: soft law, precaution, resilience, and liability. Each of these approaches offers important benefits and advantages, but each is also seriously flawed as the sole mechanism for governing emerging technologies. Because the four approaches have been perceived as competitors, in which only one can "win" and be implemented, the debate over the governance of emerging technologies has been one of controversy and conflict.

The wicked problem concept and literature provides a more fruitful framing for addressing the governance of emerging technologies. Wicked problems are characterized by uncertainty, complexity, diversity, conflict, and controversy—just like the governance of emerging technologies. The wicked problem framework provides several useful insights that may be helpful for governing emerging technologies. The first is the recognition that there will be no optimal or perfect solution; thus, we must "muddle through" with imperfect solutions. Second, the most effective approach for addressing a wicked problem is to combine different strategies, which in the context of emerging technologies means combining two or more of the four governance strategies. Finally, a wicked problem needs some type of coordinating mechanism, which has been a recognized need for emerging technologies governance for some time. Combining these three lessons from the wicked problem experience may provide a more harmonized and effective integrated strategy for governing emerging technologies.

80. Kenneth W. Abbott & Duncan Snidal, *Strengthening International Regulation Through Transnational New Governance: Overcoming the Orchestration Deficit*, 42 VAND. J. TRANSNAT'L. L. 501, 563 (2009).

81. Steven Ney & Marco Verweij, *Messy Institutions for Wicked Problems: How to Generate Clumsy Solutions?*, 33 ENV'T & PLAN. C: GOV'T & POL'Y 1679, 1679–96 (2015).