PATENTS AND CLIMATE CHANGE: A SKEPTIC'S VIEW

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Climate change poses a major challenge to humanity. In order to deal with our rapidly changing environment, there is a need for a broad range of new technologies that could assist in mitigating or adapting to climate change. Unsurprisingly, intellectual property (IP) scholars and policy makers have relied extensively on patents to provide incentives for the development of climate change technologies.

This Article casts doubts over the prospect of relying on patent incentives to adequately promote innovation in this domain. It explores the manner by which patents foster innovation in a variety of settings—from upstream research to end-product development—and reveals that the patent system is far from an optimal incentive mechanism in the environmental field, and thus cannot be trusted to adequately promote the development of climate change technologies. The likely failure of patents to effectively incentivize environmental innovation stems to a large extent from the major role assigned to market demand in directing innovation under the patent system. As market demand for environmental technologies tends to underrepresent their social value, patents cannot serve as an effective mechanism in this domain.

Considering the patent system's apparent shortcomings in the environmental field, this Article recommends looking beyond IP and increasing the use of other incentive mechanisms, including prizes and research subsidies, in order to promote the development and diffusion of climate change technologies. In addition, the analysis explores the possibility of integrating into innovation policy certain measures that may increase demand for climate change technologies and thereby enhance the effectiveness of patent incentives in this domain. Such policy tools may include, for instance, command-and-control regulation, market mechanisms such as cap-and-trade programs and carbon taxes, and information dissemination to increase public awareness.

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I. INTRODUCTION

Climate change is happening here and now, and is regarded by many as the defining challenge of our time.[1] The main driver of climate change is greenhouse gas emissions from human activities.[2] The global challenge posed by climate change has occupied many scholars from different disciplines and triggered various policy measures and proposals in recent decades. Most recently, at the Paris climate conference in December 2015,

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1 *See, e.g.*, Michael A. Carrier, *An Antitrust Framework for Climate Change*, 9 NW. J. TECH. & INTELL. PROP. 513, 513 (2011) ("Climate change is one of the most important issues of the twenty-first century."); Megha Shah, Note, *Grassroots Enforcement of EISA: The Need for a Citizen Suit Provision in the Energy Independence and Security Act of 2007*, 77 GEO. WASH. L. REV. 488, 488 (2009) (noting that former U.N. Secretary General Ban Ki-moon described climate change as "the defining challenge of our age"); *see also* J.B. Ruhl & James Salzman, *Climate Change Meets the Law of the Horse*, 62 DUKE L.J. 975, 977–78 (2013) ("Climate change is here. Its impacts are present in the current landscape, and, barring miraculous developments in politics and technology, it will be a part of the future for our generation and for many to follow." (footnote omitted)); ORGANISATION FOR ECON. CO-OPERATION & DEV., ECO-INNOVATION IN INDUSTRY: ENABLING GREEN GROWTH 3 (2009) (noting that "[c]limate change has become a top priority for [Organisation for Economic Co-Operation and Development] governments").

2 *See* Letter from Alan I. Leshner, Exec. Dir., Am. Ass'n for the Advancement of Sci., et al., to all or most U.S. Senators (Oct. 21, 2009), https://perma.cc/B6ZT-2RFM [hereinafter AAAS Joint Statement]; *see also* AM. ASS'N FOR THE ADVANCEMENT OF SCI., WHAT WE KNOW: THE REALITY, RISKS, AND RESPONSE TO CLIMATE CHANGE 1–3 (2014), https://perma.cc/LGN4-U3YZ (discussing how decades of human-generated greenhouse gases are the major force driving the direction of climate change); Jonathan H. Adler, *Eyes on a Climate Prize: Rewarding Energy Innovation to Achieve Climate Stabilization*, 35 HARV. ENVTL. L. REV. 1, 5–6 (2011) (summarizing the conclusions of the United Nations Intergovernmental Panel on Climate Change (IPCC) regarding the responsibility of human activity for global warming).

representatives of 196 countries adopted an agreement in which they acknowledged the severity of this problem and undertook radical steps in order to resolve it.[3]

Among other things, there is a growing emphasis on the need to develop a broad range of technological solutions that may assist in reducing greenhouse gas emissions or otherwise mitigating or adapting to climate change (hereinafter collectively referred to as "climate change technologies"). Unsurprisingly—considering the central role that patents play in innovation law and policy as a general manner—innovation scholars and policy makers have relied extensively on patents to incentivize the development of climate change technologies.[4] Discussions of patent policy in the environmental domain generally assume that patents can provide incentives for the development of "green" technologies; thus, they focus primarily on potential restrictions on access to patented technologies and the concern that patents would inhibit the transfer of relevant technologies to developing countries.[5]

While a continued deliberation of the means to ensure broad access to green technologies is undoubtedly warranted, this Article nevertheless focuses on the incentive side of the equation and seeks to evaluate the way the patent system functions in promoting the development of climate change technologies. Although there is evidence that the number of patent applications for environmental technologies has increased significantly in recent decades,[6] this by no means indicates that environmental innovation occurs at a socially optimal level or that the patent system functions effectively in this domain. In fact, the analysis included in this Article demonstrates that patents most likely underperform—in various important

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3 *See infra* notes 43–44 and accompanying text.

4 *See, e.g.*, Joshua D. Sarnoff, *The Patent System and Climate Change*, 16 VA. J.L. & TECH. 301, 307 (2011) (noting that the world has chosen "to rely substantially on the patent system and private markets" to promote innovation of climate change technologies); *see also infra* notes 64–65 and accompanying text. *But see infra* note 227 and accompanying text (listing studies that explore the potential use of non-patent incentive mechanisms to promote innovation in the field).

5 *See, e.g.*, Lisa Larrimore Ouellette, Comment, *Addressing the Green Patent Global Deadlock Through Bayh-Dole Reform*, 119 YALE L.J. 1727, 1727 (2010) ("Intellectual property (IP) rights can provide an incentive for the development of these technologies, but they can also impede technology dissemination—any climate change treaty must balance this controversial tradeoff between innovation and access."); Peter S. Menell & Sarah M. Tran, *Introduction*, *in* INTELLECTUAL PROPERTY, INNOVATION AND THE ENVIRONMENT, at ix, xi–xii (Peter S. Menell & Sarah M. Tran eds., 2014) ("[W]hile motivating the development of better environmental technologies, the patent system potentially constrains the diffusion of technological advances that seek to ameliorate environmental harms."); Joy Y. Xiang, *Addressing Climate Change: Domestic Innovation, International Aid and Collaboration*, 5 N.Y.U. J. INTELL. PROP. & ENT. L. 196, 209 (2015) (noting that "global climate technology efforts have focused on the transfer of clean technologies from developed nations to developing nations"). For an exploration of various policy tools that may facilitate access to patented technologies, see generally Sarnoff, *supra* note 4 (proposing, among other measures, the adoption of robust "experimental use exceptions," expanding "'march-in' rights in regard to government-funded inventions" and "adopting permissive exhaustion standards . . . to permit parallel importation").

6 *See infra* note 72 and accompanying text.

ways—in fostering environmental innovation and thus cannot be trusted to adequately promote the development of climate change technologies. While the analysis focuses on climate change technologies, many of the insights have a more general applicability and could be relevant with respect to technologies designed to deal with other environmental concerns.

As demonstrated in the Article, one of the main reasons why the effectiveness of patents as an incentive mechanism in the environmental domain is limited is the reliance of patent incentives on market demand in directing innovation.[7] To start with, a market-based platform clearly cannot be relied upon to incentivize production of nonmarket goods.[8] In the environmental context, this inherent limitation of the patent system comes into effect, for instance, with respect to basic scientific research regarding various fundamental questions related to climate change.[9] Yet, even outside the realm of pure basic research, the more upstream a research and development (R&D) project is—i.e., the more removed it is from commercial applications—the higher the uncertainty regarding the market value of such project is likely to be, and the less probable it is that the patent system would provide ample incentives to pursue it.[10] Thus, for instance, R&D endeavors designed to explore methods of employing various alternative energy sources in lieu of fossil fuels—which may later serve as the foundation for a wide array of downstream innovative efforts—are not likely to be adequately incentivized by patents.[11]

Unfortunately, in the context of environmental innovation, the concern that the patent system fails to provide adequate incentives to innovate applies to downstream innovation as well, since market demand tends to underrepresent the social value of green technologies. A cleaner environment constitutes a public good; hence, positive externalities play a significant role in undercutting demand for green products and processes. In deciding whether to purchase and install a pollution-reducing scrubber, for instance, a profit-maximizing firm is likely to focus on its direct costs and benefits, while not ascribing much weight to the substantial beneficial impact on numerous third parties that such a step may yield. If businesses are not willing to pay for climate change technologies a sufficient amount of money that reflects their social value, then the patent system—in its reliance on market demand—is not likely to incentivize development of such technologies at a socially optimal level.[12]

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7 *See* Ofer Tur-Sinai, *Technological Progress and Well-Being*, 48 LOY. U. CHI. L.J. 145, 148 (2016) (noting that "a market-based platform for incentivizing innovation may fail to provide an adequate incentive to produce certain valuable innovations in a manner that could be problematic both from a distributive and utilitarian perspective").

8 *See infra* Part III.B.

9 *See infra* notes 95–98 and accompanying text.

10 *See infra* Part III.C.

11 *See infra* notes 115–120 and accompanying text.

12 *See infra* Part III.D.

While the concern that businesses' demand for green technologies underrepresents social value has been noted in innovation literature,[13] this Article highlights that this is true with respect to individual consumers as well. Due to the existence of positive externalities and a variety of other factors explored in a growing body of interdisciplinary work, it appears that consumers cannot be trusted to sufficiently account for the ramifications of their choices on the environment. This may ultimately have a significant impact on the ability of the patent system to incentivize the development of both green consumer products and more upstream technologies, the demand for which derives from the demand for end-products.[14]

One other factor that may dilute the signal of social value produced by a market-based platform for incentivizing innovation is the inability of consumers to pay for various innovative products and services. Some low-income consumers—including developing countries in their capacity as consumers—may lack the means to pay for climate change technologies, even if they were otherwise willing to do so. This may be highly problematic regarding solutions that are required to address the particular needs of poor populations—for instance, an innovative product or process that would assist a country with a significant reliance on the agricultural sector to adapt to increasing temperatures. Such solutions would never be developed if we only relied on patent incentives.[15]

One other reason explored in the Article for the inability of the patent system to adequately promote green innovation derives from its reliance on a mechanism of exclusive rights. Some types of innovations are more difficult to exclude than others, and patent incentives have limited effectiveness in promoting highly nonexcludable innovations. This may be the case, for instance, with respect to certain industrial processes that are designed to "green" production of manufactured goods. To the extent that the use of such a production process by competitors of the patent owner can be kept in secrecy and is not embedded in the final product, it might not be possible to detect and prove infringement. As a result, patents may fail to serve as an effective incentive mechanism in this context as well.[16]

Finally, the Article explores the possibility that, by focusing on technological products and processes that meet the statutory patentability criteria, the patent system may divert resources away from engaging in the development of low-tech innovations (e.g., a method to improve efficiency of water use by proper irrigation scheduling) or non-technological

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13 *See, e.g.*, Bronwyn H. Hall & Christian Helmers, *The Role of Patent Protection in (Clean/Green) Technology Transfer*, 26 SANTA CLARA COMPUTER & HIGH TECH. L.J. 487, 488–89 (2010) (noting the concern that industrial firms may not have a high demand for environmental technologies due to externalities); Adam B. Jaffe et al., *A Tale of Two Market Failures: Technology and Environmental Policy*, 54 ECOLOGICAL ECON. 164, 166 (2005); Gregory N. Mandel, *Promoting Environmental Innovation with Intellectual Property Innovation: A New Basis for Patent Rewards*, 24 TEMP. J. SCI. TECH. & ENVTL. L. 51, 57–58 (2005). For a discussion, see *infra* Part III.D.

14 *See infra* Part III.E.

15 *See infra* Part III.F.

16 *See infra* Part III.G.

innovations (e.g., creative methods to enable people to reduce consumption) that may be highly valuable in mitigating and adapting to climate change.[17]

For these reasons, this Article concludes that patent law is far from being an ideal incentive mechanism in the context of climate change innovation. Notably, the problems identified in the Article cannot be addressed by adjusting patent doctrine or revising the patenting process, because they derive from the very nature of the patent system as a market-based private property mechanism to incentivize innovation—and the market (by hypothesis) does not exist or is inefficient in ways the patent system cannot cure.

The Article explains the importance of being aware of these limitations of patent incentives and cautions against "greenwashing" in presenting the role of the patent system in this regard.[18] Beyond that, the Article explores two principal directions that may need to be pursued in order to bolster incentives to develop climate change technologies. First, in the specific contexts where patent incentives significantly underperform, the analysis supports increasing the use of other policy instruments for incentivizing innovation, including prizes and direct governmental funding via grants, cooperation agreements, or procurement.[19] As these mechanisms do not rely on market demand in incentivizing innovation, they may outperform patents in the specific domain of green innovation, where market demand so clearly fails to align with social value. The Article explores various manners by which policy makers can prioritize the need to develop climate change technologies within such schemes.[20] Second, to the extent the state continues relying on patents to incentivize environmental innovation, it must operate the patent system in tandem with other policy measures designed to increase market demand for climate change technologies. Such measures may include, for instance, command-and-control regulation, market mechanisms such as cap-and-trade programs or carbon taxes, and education and information dissemination.[21]

The main contribution of this Article to the literature is in conducting a systematic analysis of the patent system's shortcomings in promoting the development of climate change technologies. Other scholars have importantly identified certain limitations of patent incentives in the environmental domain and explored the potential benefit of employing various non-patent mechanisms to incentivize green innovation.[22] Yet, this Article takes an extra step in this direction by offering a comprehensive

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17 *See infra* Part III.H.

18 *See infra* Part IV.A.

19 *See infra* Part IV.B.

20 *See, e.g.*, *infra* note 241 and accompanying text.

21 *See infra* Part IV.C.

22 The main concern expressed by scholars in this regard has been that the demand for green technologies by the industrial sector may be reduced as a result of externalities. *See supra* note 13 and accompanying text (listing studies dealing with such concern). For general statements doubting the effectiveness of patent incentives in the environmental domain, see *infra* note 71 and accompanying text. For proposals to resort to alternative incentive mechanisms, see *infra* note 227 and accompanying text.

exploration of the factors that may undercut the ability of the patent system to serve as an effective incentive mechanism in the environmental domain. As part of the analysis, the Article reveals certain aspects that have not been sufficiently explored in studies attending to the interface between patents and the environment. Such aspects include, inter alia, the difficulty of relying on patents to incentivize upstream research in the field,[23] the likely failure of the patent system to incentivize development of "green" industrial processes that are highly nonexcludable,[24] and the potential that patent incentives will crowd out low-tech or non-technological solutions.[25]

The systematic exploration of the patent system's limitations in the environmental domain allows identifying the categories and types of innovations with respect to which the need to substitute or supplement patents with other policy measures is particularly acute. To take one important example, while the case for direct government funding of basic research is well established (both in general and in the specific context of environmental research), it is much less so with respect to applied research.[26] Yet, once we acknowledge that patents underperform even in the context of green consumer goods—as this Article's analysis reveals—it becomes apparent that in this particular domain, governments cannot rely exclusively on patents even when it comes to downstream development. Altogether, the analysis conducted in this Article provides further justifications to look beyond intellectual property (IP) in incentivizing the development and diffusion of climate change technologies. As far as the normative implications of the analysis are concerned, the Article explores a broad range of policy measures that may be instrumental in overcoming the deficiencies of the patent system—some of which are designed to directly incentivize innovation while others are intended to increase demand for climate change technologies and thereby turn patent incentives more effective.

This Article proceeds as follows: Part II sets the stage for the discussion by providing background regarding climate change and the fundamental role of technological innovation in mitigating and adapting to climate change. Part III focuses on the patent system and identifies the contexts where patents may fail to serve as an effective incentive mechanism for the development of climate change technologies. Part IV explores the potential normative implications of the analysis.

II. CLIMATE CHANGE AND TECHNOLOGICAL INNOVATION

Climate change is shaping up to be one of the defining challenges of our time.[27] The term "climate change" refers to significant changes in the properties of the global climate system, which accompany the steady rise in

23 *See infra* Part III.C.
24 *See infra* Part III.G.
25 *See infra* Part III.H.
26 *See infra* note 230 and accompanying text.
27 *See supra* note 1 and accompanying text.

Earth's average temperature over the past century.[28] Various impacts of climate change have already been observed in recent decades "on all continents and across the oceans."[29] Such impacts include alteration of hydrological systems as a result of changing precipitation or melting snow and ice; rising of sea level; changes in agricultural productivity; and greater frequency of extreme weather events, such as heat waves, droughts, floods, cyclones, and wildfires.[30] Continuing changes to weather patterns in the future are expected to cause the disturbance of biological systems, disrupt food production and water supply, damage infrastructure and displace populations, and adversely affect many individuals' physical and mental health.[31] Climate change is expected to have its most severe repercussions in developing countries.[32]

As to the causes of climate change, rigorous scientific research demonstrates that "greenhouse gases emitted [into the atmosphere] by human activities are the primary driver."[33] Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), and other gases that are capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere:

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28 *See Climate Change: Basic Information*, U.S. ENVTL. PROTECTION AGENCY, https://perma.cc/C76W-ZFDG (last updated Jan. 17, 2017) ("Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather."). According to the IPCC, the leading international scientific organization for assessing climate change, the period spanning from 1983 to 2012 was likely the warmest period of the past 1,400 years. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 40 (Rajendra K. Pachauri et al. eds., 2015), https://perma.cc/K8SC-74CW; *see also* Xiang, *supra* note 5, at 202. Recently, the World Meteorological Organization predicted that 2016 will be the hottest year on record. *See* Press Release, World Meteorological Org., Provisional WMO Statement on the Status of Global Climate in 2016 (Nov. 14, 2016), https://perma.cc/BLK8-QYXR; *see also* Damian Carrington, *2016 Will Be the Hottest Year on Record, UN Says*, GUARDIAN (Nov. 14, 2016), https://perma.cc/NTN6-HBBC.

29 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 4 (Christopher B. Field et al. eds., 2014), https://perma.cc/YKP3-2PR7 [hereinafter IPCC REPORT].

30 *See id.* at 4–6; AAAS Joint Statement, *supra* note 2; *see also* Allison C.C. Hoppe, Note, *State-Level Regulation as the Ideal Foundation for Action on Climate Change: A Localized Beginning to the Solution of a Global Problem*, 101 CORNELL L. REV. 1627, 1629 (2016) ("With global average temperatures rising, there has been a correlated increase in the frequency of certain natural disasters, including wildfires, droughts, floods, hurricanes, and others. . . . Additionally, sea level rise and ocean acidification is directly related to climate change, and many coastal areas in the United States have begun to experience the effects of the rising oceans." (footnote omitted)).

31 *See* IPCC REPORT, *supra* note 29, at 6; Sarnoff, *supra* note 4, at 302–03.

32 *See* Hall & Helmers, *supra* note 13, at 508 (noting that reliance on the agricultural sector results in "enormous inequality in the consequences of climate change between developed and developing countries"); *see also* U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, CLIMATE CHANGE: IMPACTS, VULNERABILITIES AND ADAPTATION IN DEVELOPING COUNTRIES 5 (2007) (explaining that "[d]eveloping countries are the most vulnerable to climate change impacts because they have fewer resources to adapt"); Ruhl & Salzman, *supra* note 1, at 978 ("For some people, in some places, changes will be for the better . . . while for other people in other places the prospect is dire . . . .").

33 AAAS Joint Statement, *supra* note 2.

what ultimately leads to global warming.[34] Greenhouse gases are released into the atmosphere when fossil fuels—coal, oil, and natural gas—are burned to produce energy.[35] Other human activities that emit greenhouse gas into the atmosphere include deforestation, various industrial processes, and certain agricultural practices.[36] In order to keep global warming below critical levels, it is widely agreed upon that emissions must be drastically reduced.[37]

The connection between human conduct and the state of the environment is widely acknowledged by policy makers, and the acute need to cut on greenhouse gas emissions is repeatedly addressed in global fora.[38] As early as 1992, 154 countries adopted the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio de Janeiro Earth Summit.[39] The UNFCCC's goal "is to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[40] After the signing of the UNFCCC, the parties have met at various conferences to discuss how to achieve the treaty's goal.[41] The Kyoto Protocol, adopted in 1997 and entered into force in 2005, established internationally binding emission reduction targets based on the principle of "common but differentiated responsibilities"—the burden of cutting emissions is carried by developed countries, recognizing that they are responsible for the current level of greenhouse gas in the atmosphere.[42] Most recently, at the Paris

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34 *See, e.g.*, *Climate Change: Basic Information*, *supra* note 28; Marc Lallanilla, *Greenhouse Gas Emissions: Causes & Sources*, LIVESCIENCE (Feb. 10, 2015), https://perma.cc/Q58H-FU24.

35 *See, e.g.*, Hall & Helmers, *supra* note 13, at 509 ("The most important greenhouse gas by volume is CO_2, which is emitted during the fossil fuel combustion process."); *Climate Change: Basic Information*, *supra* note 28; Lallanilla, *supra* note 34.

36 *See, e.g.*, *Climate Change: Basic Information*, *supra* note 28 ("The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere."); Lallanilla, *supra* note 34 (discussing, among other things, livestock manure management as a source of methane emissions).

37 *See, e.g.*, AAAS Joint Statement, *supra* note 2; Hall & Helmers, *supra* note 13, at 508; ORGANISATION FOR ECON. CO-OPERATION & DEV., *supra* note 1, at 3 (noting that "pressure is mounting for world leaders to come up with ambitious medium-to long-term commitments to drastically cut greenhouse gas (GHG) emissions"); *see also* Ouellette, *supra* note 5, at 1727 ("Without a global commitment to dramatically reduce greenhouse gas emissions, climate change will very likely cause catastrophic damage in this century.").

38 *See* Carolyn Abbott & David Booton, *Using Patent Law's Teaching Function to Introduce an Environmental Ethic into the Process of Technical Innovation*, 21 GEO. INT'L ENVTL. L. REV. 219, 219–20 (2009) (noting that the international community has recognized the need for "sustainable consumption and production").

39 United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter UNFCCC]. Currently, there are 197 parties to the UNFCCC. *Status of Ratification of the Convention*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/23WJ-F7UD (last visited Jan. 27, 2018).

40 UNFCCC, *supra* note 39, art. 2.

41 *Introduction to the UNFCCC and Kyoto Protocol: Brief Overview*, INT'L INST. FOR SUSTAINABLE DEV., https://perma.cc/E2PZ-QCY8 (last visited Jan. 27, 2018).

42 *Kyoto Protocol*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/7SVQ-7MRP (last visited Jan. 27, 2018). The Kyoto Protocol has had two

climate conference in December 2015, representatives of all 196 (then) parties to the UNFCCC came together and agreed to the terms of the Paris Agreement, which purports to be an important step in the continuing effort to reach a global action plan to limit global warming.[43] Under the Paris Agreement, entered into force on November 4, 2016, developed and developing countries alike are committed to limit their greenhouse gas emissions to levels that are required in order to keep the increase in global average temperature to well below 2.0°C above pre-industrial levels.[44]

The global challenge posed by climate change has triggered various policy measures and proposals in recent decades, on an international, national, and local level. Among other things, there is a wide consensus regarding the need to encourage the development and deployment of technologies that could assist in combatting climate change.[45] Technological

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commitment periods, the first of which lasted from 2008 to 2012. *Id.* The second one runs from 2013 to 2020 and is based on the Doha Amendment to the Kyoto Protocol, which has not yet entered into force. *Id.*; *Status of the Doha Amendment*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/B8BZ-X6R7 (last visited Jan. 27, 2018); *Climate: Get the Big Picture*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/MA7M-R5K7 (last visited Jan. 27, 2018).

43 *See Paris Agreement*, EUR. COMMISSION, https://perma.cc/MA7M-R5K7 (last updated Dec. 28, 2017); *see also* Fiona Harvey, *Paris Climate Change Agreement: The World's Greatest Diplomatic Success*, GUARDIAN (Dec. 14, 2015), https://perma.cc/LZF5-EZVA (describing the agreement as "historic, durable and ambitious").

44 *See Paris Agreement*, *supra* note 43; *The Paris Agreement*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/T6NR-RUUK (last visited Jan. 27, 2018). The 2.0°C objective was previously adopted by the parties to the UNFCCC in 2010, in Cancun, Mexico. *Cancun Climate Change Conference – November 2010*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/CPV3-B58G (last visited Jan. 27, 2018).

45 *See, e.g.*, Hall & Helmers, *supra* note 13, at 487 ("The worldwide challenge of climate change has led to an increased interest in mechanisms that encourage the development and adoption of new technologies."); Ouellette, *supra* note 5, at 1727 ("Carbon taxes or cap-and-trade systems are insufficient to produce the necessary emissions reduction; increased green technology research is also critical."); Margaret Taylor, *Beyond Technology-Push and Demand-Pull: Lessons from California's Solar Policy*, 30 ENERGY ECON. 2829, 2830 (2008) ("Analysts generally agree that considerable technological innovation will be necessary to reduce greenhouse gas emissions to 'safe' levels while minimizing economic impacts."); *see also* ANTOINE DECHEZLEPRÊTRE ET AL., INVENTION AND TRANSFER OF CLIMATE CHANGE MITIGATION TECHNOLOGIES ON A GLOBAL SCALE: A STUDY DRAWING ON PATENT DATA 5 (2008), https://perma.cc/7UBF-NX3F ("Accelerating the development of new low-carbon technologies and promoting their global application is a key challenge in stabilizing atmospheric [greenhouse gas] emissions."); Joshua D. Sarnoff, *Introduction*, *in* RESEARCH HANDBOOK ON INTELLECTUAL PROPERTY AND CLIMATE CHANGE 1, 1 (Joshua D. Sarnoff ed., 2016) ("Over the next few decades, tens of trillions of dollars will be needed for the development and dissemination of a wide range of new technologies to upgrade infrastructure and to mitigate and adapt to the effects of climate change."); Adler, *supra* note 2, at 9 ("Technological innovation is necessary to make climate stabilization achievable and affordable."); Gary E. Marchant, *Sustainable Energy Technologies: Ten Lessons from the History of Technology Regulation*, 18 WIDENER L.J. 831, 831 (2009) (noting that "it is increasingly clear that new sustainable technologies, particularly in the energy field and in reducing greenhouse gas emissions, will be essential to move towards a more sustainable society"); Sarah Tran, *Expediting Innovation*, 36 HARV. ENVTL. L. REV. 123, 132 (2012) ("Technology is expected to be a vital tool for reducing the world's carbon footprint."); Xiang, *supra* note 5, at 201 ("The

solutions are essential both to meet the challenge of reducing greenhouse gas emissions to "safe" levels and thereby mitigating climate change,[46] and to enable adaptation to climate change's current or expected impacts on natural and human systems.[47] The fundamental role that technological innovation is expected to play in this regard is reflected in the international instruments dealing with climate change.[48]

There is a broad range of technologies that may assist in mitigating and adapting to climate change. A few examples are in order. One class of technologies that may have great importance in mitigating climate change is technologies that improve energy efficiency—i.e., using less energy to provide the same services.[49] For example, in the field of construction, the use of new elements or materials may enable better insulation of buildings, reducing the need to use heating (or cooling) energy to maintain comfortable temperatures.[50] As another example, consider the use of compact fluorescent lamps and light-emitting diode (LED) lamps, which use much less energy than traditional incandescent light bulbs in producing the same amount of light.[51]

A different direction that has great importance in mitigating climate change is switching to alternative energy sources in lieu of fossil fuels—including, for instance, solar energy and wind power.[52] In order to facilitate this direction, there is a need to develop and further improve methods of producing energy from such alternative sources. Furthermore, there is a

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development and deployment of clean technologies are a central part of the response to climate change." (footnote omitted)).

46 Under the UNFCCC, mitigation is defined as "human intervention to reduce the sources or enhance the sinks of greenhouse gases." *Glossary of Climate Change Acronyms and Terms*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, https://perma.cc/U5XQ-KALW (last visited Jan. 27, 2018).

47 Adaptation, as defined in the UNFCCC, is the "[a]djustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." *Id.*

48 *See, e.g.*, Xiang, *supra* note 5, at 203 n.24, 204 (noting that the UNFCCC, signed in 1992, "recognized clean technologies as an important route for addressing climate change"); *Cancun Climate Change Conference – November 2010*, *supra* note 44 (specifying, among the highlights of the Cancun Agreements, signed in 2010, the agreement "to make fully operational by 2012 a technology mechanism to boost the innovation, development and spread of new climate-friendly technologies"); *see also* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 5 (noting that "technology is at the core of current discussions surrounding the post-Kyoto agreement").

49 *See* Duncan Clark, *What's Energy Efficiency and How Much Can It Help Cut Emissions?*, GUARDIAN (June 8, 2012), https://perma.cc/D6VF-8CCJ.

50 *See Insulation in Buildings*, CLIMATETECH WIKI, https://perma.cc/GZZ5-H3NY (last visited Jan. 27, 2018); *see also* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 3, 11 tbl.1 (noting energy conservation in buildings as a category of green technologies, and providing as examples "[e]lements or material used for heat insulation" as well as "energy recovery systems in air conditioning or ventilation").

51 *See, e.g.*, DECHEZLEPRÊTRE ET AL., *supra* note 45, at 11 tbl.1 (noting, in addition, that such lamps are also made to last longer); Tran, *supra* note 45, at 125.

52 Other alternative energy sources include, for example, biomass energy, geothermal energy, and hydroelectric energy. *See* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 3.

need for a vast array of technological solutions that would enable the efficient use of such alternative energy sources in various settings.[53]

Other types of mitigation technologies include "clean coal technologies" that reduce greenhouse gas emissions from fossil fuel burning;[54] methods that allow for "cleaner" production processes, reducing emissions from industrial activity;[55] "climate-friendly cement";[56] recycling and waste technologies;[57] and "technologies for capture, storage, and sequestration or disposal of greenhouse gases."[58]

As noted above, technological innovation is also called for in the adaptation front. Technological solutions that might be helpful in adjusting to the adverse effects of climate change include, for instance, genetically drought-tolerant crops;[59] "seeds that can survive flooding caused by rising sea levels";[60] early-warning systems for extreme weather events;[61] and materials and techniques allowing construction that would better withstand extreme events and other climate impacts.[62]

Needless to say, the foregoing list of examples is far from being exhaustive, and there are many other types of technologies that may be instrumental in mitigating and adapting to climate change. Notably, these various types of climate change technologies differ greatly in many ways—ranging from high-tech innovations to low-tech innovations, extending from upstream research to downstream product development, requiring different

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53 *See, e.g.*, DECHEZLEPRÊTRE ET AL., *supra* note 45, at 11 tbl.1 (listing, with respect to various renewable energy sources, certain associated types of technologies, including: in connection with biomass energy—"engines operating on such fuels"; in connection with hydroelectric energy—hydraulic turbines as well as "devices for controlling [them]"; and in connection with wind power—wind motors and "devices aimed at controlling such motors"); Hall & Helmers, *supra* note 13, at 509 (listing, among classes of green technologies, both "alternative energy resources" and "technologies employing alternative energy sources").

54 *See* Xiang, *supra* note 5, at 205; *see also* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 5.

55 *See* ORGANISATION FOR ECON. CO-OPERATION & DEV., *supra* note 1, at 25–26 (discussing the concept of "cleaner production").

56 *See* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 11 tbl.1 (providing specific examples for technological innovations in this sector); *see also* Nancy W. Stauffer, *Designing Climate-Friendly Concrete, from the Nanoscale up*, MASS. INST. TECH. NEWS (July 21, 2016), https://perma.cc/W3QD-6ACN.

57 Hall & Helmers, *supra* note 13, at 509; *see also* Michael A. Gollin, *Using Intellectual Property to Improve Environmental Protection*, 4 HARV. J.L. & TECH. 193, 196–97 (1991) (noting "recycling equipment and processes" and "waste management technologies" as types of environmental innovation).

58 Hall & Helmers, *supra* note 13, at 509–10; *see also* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 5, 11 tbl.1 (listing technologies for "extraction, transportation, storage and sequestration of CO_2" as important mitigation technologies); Anthony E. Chavez, *Exclusive Rights to Saving the Planet: The Patenting of Geoengineering Inventions*, 13 NW. J. TECH. & INTELL. PROP. 1, 5–6 (2015) (mentioning the removal of CO_2 from the atmosphere among a broader class of "climate engineering" techniques).

59 *See* Hall & Helmers, *supra* note 13, at 510.

60 Xiang, *supra* note 5, at 205.

61 *Id.*; *see also* U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE 15 box 1 (2006), https://perma.cc/X2TC-ZZX8.

62 *See, e.g.*, GER. FED. OFFICE FOR BLDG. & REG'L PLANNING, ADAPTATION TO CLIMATE CHANGE: BUILDINGS AND CONSTRUCTION IN GERMANY 7–8 (2008), https://perma.cc/Q58W-JWW8.

levels of investment in R&D, and varying in their applicability across industries and climatic zones.[63]

In order to ensure that a sufficient amount of resources is allocated to R&D of climate change technologies, there is a need to provide adequate incentives to invest in these directions. Unsurprisingly—considering the central role that patents play in innovation law and policy as a general manner[64]—policy makers and IP scholars alike have devoted much attention to the patent system as a potential mechanism to promote environmental innovation.[65] Among other things, in an effort to "green" the patent system and boost the incentives it provides for the development of environmental technologies, various patent offices around the world have implemented measures to fast-track green patent applications[66]—yet, at least in the United States, such schemes have not had a significant impact.[67] Other measures proposed by scholars in order to bolster patent incentives for green

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63 *See* Hall & Helmers, *supra* note 13, at 510.

64 Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1576 (2003) (noting patents' prominent role in innovation policy); Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents–Prizes Debate*, 92 TEX. L. REV. 303, 319 (2013); Cynthia M. Ho, *Drugged Out: How Cognitive Bias Hurts Drug Innovation*, 51 SAN DIEGO L. REV. 419, 429 (2014); Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 UCLA L. REV. 970, 975 (2012).

65 *See supra* note 4 and accompanying text (noting the substantial reliance on the patent system as an incentive mechanism in the environmental domain). For scholarly works addressing various aspects related to patents and environmental technologies, see generally Abbott & Booton, *supra* note 38; Natalie M. Derzko, *Using Intellectual Property Law and Regulatory Processes to Foster the Innovation and Diffusion of Environmental Technologies*, 20 HARV. ENVTL. L. REV. 3 (1996); Gollin, *supra* note 57; Hall & Helmers, *supra* note 13; Mandel, *supra* note 13; Sarnoff, *supra* note 4; Tran, *supra* note 45; Xiang, *supra* note 5.

66 *See, e.g.*, Hall & Helmers, *supra* note 13, at 491 (describing such initiatives launched by certain offices, and noting that "[t]he underlying assumption is that speedier grants of patents will spur the development and diffusion of green technologies"); Antoine Dechezleprêtre & Eric Lane, *Fast-Tracking Green Patent Applications*, WIPO MAG. (June 2013), https://perma.cc/5894-AAZY (providing analysis of such programs).

67 As early as 1983, U.S. patent regulations were amended to prioritize review of patent applications for inventions that, inter alia, "materially enhance the quality of the environment or materially contribute to the development or conservation of energy resources." 37 C.F.R. § 1.102(c) (1983). In addition, the United States Patent and Trademark Office implemented in 2009 a "Green Technology Pilot Program" (the "Pilot Program"), which differed in certain aspects from the arrangement under the patent regulations. *See generally* Pilot Program for Green Technologies Including Greenhouse Gas Reduction, 74 Fed. Reg. 64,666 (Dec. 8, 2009) (describing the pilot program). The Pilot Program is no longer in effect. *See Green Technology Pilot Program – CLOSED*, U.S. PAT. & TRADEMARK OFF., https://perma.cc/QM3J-3EN2 (last modified May 7, 2012). As to the limited impact of such schemes, see, e.g., Gollin, *supra* note 57, at 211–12 (noting that the "regulations have not resulted in any great shift toward more rapid issuance of patents for environmental technology"). *See also* Abbot & Booton, *supra* note 38, at 231 n.55 (discussing the limited effects of regulations); Derzko, *supra* note 65, at 12 (discussing the limited effect of the regulations as well); Mandel, *supra* note 13, at 62 (noting that the regulations "are rarely utilized"); Tran, *supra* note 45, at 126–28, 137–49 (criticizing various features of both the regulations and the Pilot Program, and noting the remarkably limited level of participation in these schemes).

innovation include reducing registration fees,[68] lengthening patent term,[69] and lowering patentability standards in order to make it easier to obtain environmental patents.[70] For the most part, the possibility of relying on patents to incentivize innovation in the field has not been questioned, and as noted above, the main focus of scholars and policy makers has been on concerns regarding restrictions on access to patented technologies.[71]

Interestingly, a recent report published by the European Patent Office (EPO) and the United Nations Environment Programme (UNEP) finds that the number of patent applications for green technologies has increased significantly in recent decades.[72] While this finding may give ground for some optimism, one needs to be cautious in interpreting it. First, a rise in patenting activity does not necessarily attest to an overall increase in the rate of inventive activity in the field, considering that the patent system is only one component of the innovation ecosystem.[73] In fact, increased patenting could represent a reallocation of resources towards R&D activity of the sort that is more likely to yield patents at the expense of other types of innovative activity.[74] Second, the fact that patents are applied for, *ex post*,

68 *See, e.g.*, Estelle Derclaye, *Should Patent Law Help Cool the Planet? An Inquiry from the Point of View of Environmental Law: Part II*, 31 EUR. INTELL. PROP. REV. 227, 230 (2009).

69 *Id. But see* Mandel, *supra* note 13, at 61 (explaining why such a reform would not significantly increase incentives to invent).

70 *See* Derzko, *supra* note 65, at 14 (proposing to remove the non-obviousness requirement as part of a *sui generis* environmental patents regime). *But see* Mandel, *supra* note 13, at 63–64 (criticizing this proposal).

71 *See supra* note 5 and accompanying text. *But see, e.g.*, Derzko, *supra* note 65, at 12 (noting the possibility that the patent system "is not an effective stimulant for environmental technology innovation"); Hall & Helmers, *supra* note 13, at 487 (arguing that "patent protection may be neither available nor useful in some settings").

72 ILJA RUDYK ET AL., U.N. ENV'T PROGRAMME & EUROPEAN PATENT OFFICE, CLIMATE CHANGE MITIGATION TECHNOLOGIES IN EUROPE – EVIDENCE FROM PATENT AND ECONOMIC DATA 9 (2015), https://perma.cc/FEN9-5BKK; *see also* DECHEZLEPRÊTRE ET AL., *supra* note 45, at 12 (showing similar findings in an earlier study).

73 For a discussion of other incentive mechanisms, see *infra* Part IV.B. For the drawbacks of using patent data as a measure of inventive activity, see, e.g., Daniel R. Cahoy, *Inverse Enclosure: Abdicating the Green Technology Landscape*, 49 AM. BUS. L.J. 805, 829 (2012) (noting that the "patent landscape" is an "imperfect measure" of innovation); DECHEZLEPRÊTRE ET AL., *supra* note 45, at 3 (noting that the fact that "patents are not the only tool available to inventors to protect their inventions" is a drawback of patent data as a measure of the output of innovation).

74 Such other types of innovation may include, for instance, basic scientific research (see *infra* Part III.B) and non-technological innovative solutions (see *infra* Part III.H). *See* Arnold Plant, *The Economic Theory Concerning Patents for Inventions*, 1 ECONOMICA 30, 37, 41 (1934) (highlighting the potential that the patent system would divert resources from various inventive activities that are not covered by the patent system into attempts to make patentable inventions); Katherine J. Strandburg, *Curiosity-Driven Research and University Technology Transfer*, 16 ADVANCES STUDY ENTREPRENEURSHIP INNOVATION & ECON. GROWTH 93, 94, 108 (2005) (discussing the possibility that university patenting "might skew the choices of research topics toward more applied projects, threatening the socially beneficial production of the curiosity-driven research demand function"); Dirk Czarnitzki et al., *Heterogeneity of Patenting Activity and Its Implications for Scientific Research* 22 (Ctr. for European Econ. Research, Discussion Paper No. 07-028, 2007), https://perma.cc/YQ8W-BY3D (reviewing empirical data and

does not mean that patent incentives induced the relevant R&D projects, *ex ante*.[75] Thus, one cannot conclude—based upon data regarding the rise of patenting activity—that the patent system has been successful in fostering more innovation in the field. Most importantly, even if there is a rise in innovative activity—whether induced by patents or not—this certainly does not mean that the current level of innovation in the field is at the socially desirable level. Surely, there is no way of measuring the gap between the current level of innovation and a hypothetical "optimal" level that could potentially be reached if incentives were structured differently. Nevertheless, it is important, amidst positive evidence of the type described above, to retain a certain degree of skepticism and acknowledge that there is, most likely, such a gap.[76] As Part III of this Article shows, there are, in fact, strong reasons to suspect that the patent system cannot be relied upon to provide adequate incentives to develop climate change technologies.

III. PATENT INCENTIVES FOR CLIMATE CHANGE TECHNOLOGIES

A. General

Patents are generally justified in utilitarian terms.[77] Under the incentive-to-invent theory, the patent system's major role is to supply economic incentive to engage in R&D.[78] Few inventors would be willing to engage in R&D absent the opportunity to recoup their costs and make a reasonable

concluding that the effort to generate patents distracts scientists from their other more fundamentally orientated research tasks).

75 *See generally* Stuart J.H. Graham et al., *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255 (2009) (surveying different motives for patenting).

76 For scholars acknowledging the low level of environmental innovation, see, e.g., Derzko, *supra* note 65, at 12 (discussing the low level of environmental patenting in the United States); Mandel, *supra* note 13, at 56 ("[T]here is considerable consensus that not enough environmental innovation takes place."); Xiang, *supra* note 5, at 206 ("Clean technologies have developed significantly in the past decades. . . . However, even with these achievements, there remains a considerable gap between current efforts to develop clean technologies and the level of investment required.").

77 *See, e.g.*, Burk & Lemley, *supra* note 64, at 1597 (discussing the prevalence of the utilitarian justification for patents); Robert P. Merges, Commentary, *Rent Control in the Patent District: Observations on the Grady-Alexander Thesis*, 78 VA. L. REV. 359, 359 (1992); Lisa Larrimore Ouellette, *Do Patents Disclose Useful Information?*, 25 HARV. J.L. & TECH. 545, 554 (2012). The utilitarian concept of patent law is embedded in the United States Constitution, which empowers Congress "[t]o promote the Progress of Science and useful Arts." U.S. CONST. art. I, § 8, cl. 8.

78 For background on the incentive-to-invent theory, see, e.g., Kenneth W. Dam, *The Economic Underpinnings of Patent Law*, 23 J. LEGAL STUD. 247, 247 (1994). *See also* Wendy J. Gordon, *Intellectual Property*, *in* THE OXFORD HANDBOOK OF LEGAL STUDIES 617, 632 (Peter Cane & Mark Tushnet eds., 2003); Yusing Ko, Note, *An Economic Analysis of Biotechnology Patent Protection*, 102 YALE L.J. 777, 791–93 (1992); Ofer Tur-Sinai, *Cumulative Innovation in Patent Law: Making Sense of Incentives*, 50 IDEA 723, 735–36 (2010).

profit.[79] Yet, in a world without patents, competition by free riders may make it impossible.[80] Thus, despite the potentially high social value of an invention, an inventor may lack an adequate incentive to develop it. The patent system purports to overcome this market failure by granting exclusive rights, which enable the inventor to suppress competition and appropriate a larger share of his or her invention's market value.

In essence, patents do not *create* incentives to invent but rather *enable* market incentives to operate.[81] By design, then, the patent system assigns market demand a major role in directing innovation.[82] Under the patent regime, the current tastes and preferences of current market players comprise the signal guiding prospective innovators as to the directions of R&D worth pursuing.[83] "Roughly speaking, the higher the market demand is likely to be for a future innovation, the stronger the incentive the patent system provides to develop it."[84]

The reliance on the market in driving innovation is commonly conceived as a virtue of the patent system. In fact, in the economic and legal literature comparing patents with alternative mechanisms for incentivizing innovation, the main alleged benefit of patents is their ability to utilize private information about the costs and benefits of R&D investments in order to signal "the desired directions of investment and . . . the quantities of resources that should be committed to invention."[85] Government actors, on the other hand, generally lack such private information that generates

79 Clearly, "[n]ot all inventors are driven by economic motives." Ofer Tur-Sinai, *Beyond Incentives: Expanding the Theoretical Framework for Patent Law Analysis*, 45 AKRON L. REV. 243, 248 (2012). "Alternative motives to invent could be the prospect of gaining professional reputation and fame amongst colleagues or sheer intellectual curiosity." *Id.* at 248 n.22.

80 *See, e.g.*, Tur-Sinai, *supra* note 79, at 244, 248–49, 265–66. Indeed, in certain cases, the existence of high production and imitation costs may be sufficient to deter free riders. *Id.* at 249. In other cases, lead time advantage may enable the inventor to make a sufficient profit. Yet, in many cases this would not be true, and hence the need to supplement market incentives.

81 *See* Peter Lee, *Social Innovation*, 92 WASH. U. L. REV. 1, 45 (2014) ("Although patents *enable* market incentives to motivate inventors to invent, they do not *create* market incentives; it is ultimately market demand that drives the generation of patented technologies.").

82 *See* Tur-Sinai, *supra* note 7, at 155.

83 *Cf.* John T. Gourville, *Eager Sellers and Stony Buyers: Understanding the Psychology of New-Product Adoption*, HARV. BUS. REV., June 2006, at 99, 100 (discussing the need for businesses to predict the "buying behavior of consumers" when making decisions to invest in new products).

84 Tur-Sinai, *supra* note 7, at 155. Needless to say, demand for future goods cannot be accurately estimated based on the market value of existing goods. In addition, patents cannot guarantee their owners full appropriability due to their limited scope and duration, and the existence of transaction costs. *Id.* at 155 n.39, 158. Moreover, "patents might suboptimally track market value due to the fact that some information goods are simply more difficult to exclude than others." *Id.* at 158 (referencing Amy Kapczynski & Talha Syed, *The Continuum of Excludability and the Limits of Patents*, 122 YALE L.J. 1900 (2013)); *see also infra* Part III.G.

85 Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1, 12 (1969); *see* Kapczynski & Syed, *supra* note 84, at 1911–12 (noting the "posited relationship between rights to exclude and the use of private information about the value of inventions"); *see also* Hemel & Ouellette, *supra* note 64, at 327 ("Patents' ability to take advantage of private information is well recognized in the innovation-policy literature.").

market prices,[86] which is the reason government-led strategies are often considered less efficient than the patent system in allocating innovation resources.[87]

Nonetheless, the link between market demand and the direction of innovation has also been proven problematic from various perspectives, and it is widely understood today that a market-based platform cannot always be trusted to direct innovation in a socially optimal manner.[88] Rather than presenting the shortcomings of a market-based platform for incentivizing innovation in general terms, this Part now turns to explore various specific limitations of the patent system as an incentive mechanism that appear to be particularly pertinent in regard to climate change technologies.

B. Nonmarket Goods: Basic Research

To begin, a market-based platform cannot be expected to provide adequate incentives for the production of nonmarket goods.[89] When a research project is not directed towards an invention that could be commercialized, the exclusive rights conferred by patent law are essentially irrelevant.

One important context where this inherent limitation of the patent system is evident is basic research—research carried out for the advancement of scientific knowledge without a specific practical application in view.[90] Thus, those who pursue basic research generally do not do so in order to gain market profits.[91] In fact, the results of basic research are often

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86 *See, e.g.*, Daniel F. Spulber, *Public Prizes Versus Market Prices: Should Contests Replace Patents?*, 97 J. PAT. & TRADEMARK OFF. SOC'Y 690, 732 (2015) (noting that "[c]entral planners necessarily lack the detailed private information of inventors, innovators, producers, and consumers that generate prices in the market for inventions.").

87 *See, e.g.*, Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, 2 INNOVATION POL'Y & ECON. 51, 54–55 (2002) (arguing that one of the patent system's "obvious virtues" is that it enables firms to rely on "their superior knowledge" regarding the costs and benefits of R&D investments in order "to screen investments").

88 For a general review of the relevant literature, see Tur-Sinai, *supra* note 7, at 156–59.

89 *See, e.g.*, BRETT M. FRISCHMANN, INFRASTRUCTURE: THE SOCIAL VALUE OF SHARED RESOURCES 109 (2012) (discussing "the predictable bias" of IP systems for "intellectual goods that generate the most appropriable value in consumer markets," and noting that "[a]s a result, various socially desirable intellectual goods . . . remain underproduced"); Kapczynski & Syed, *supra* note 84, at 1905 (summarizing the argument that patent systems fail to create goods whose value is difficult to appropriate in consumer markets); *see also* Carol M. Rose, *Scientific Innovation and Environmental Protection: Some Ethical Considerations*, 32 ENVTL. L. 755, 764 (2002) (noting, in the environmental context, the lack of incentive to engage in the production of knowledge where there is no "end-product [that] can be turned into property").

90 For the definition of "basic research," see, e.g., 20 U.S.C. § 9501(3)(A)(2012) (defining "basic research" as research "to gain fundamental knowledge or understanding of phenomena and observable facts, without specific application toward processes or products"); 26 U.S.C. § 41(e)(7)(A)(2012) (defining "basic research" as "any original investigation for the advancement of scientific knowledge not having a specific commercial objective").

91 *See, e.g.*, Emily Michiko Morris, *Intuitive Patenting*, 66 S.C. L. REV. 61, 102–03 (2014) (positing that "[t]hose who pursue basic research are sometimes thought to do so purely for the sake of knowledge, not market based gain. To the extent scientists exact returns from their

too abstract in order to have an appropriable market value.[92] Thus, as stated by Richard Nelson: "It seems clear that, were the field of basic research left exclusively to private firms operating independently of each other and selling in competitive markets, profit incentives would not draw so large a quantity of resources to basic research as is socially desirable."[93] It is therefore easy to understand why basic scientific research is commonly funded directly by governments outside the patent system.[94]

This is highly relevant in regard to environmental innovation, which relies, to a great extent, on basic scientific research in the relevant scientific disciplines.[95] In the context of climate change, in particular, there is a need for an ongoing inquiry with respect to the magnitude, rate, and mechanisms of climate change; the impact of climate change on various ecological systems; and other fundamental questions.[96] Absent solid understanding of these issues, one cannot expect R&D to be applied towards the right directions and result in the successful development of technological solutions that significantly impact the state of the environment or the ability of humankind to adapt to climate change.[97] As basic scientific research

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basic research, they are thought to do so in the noncommercial form of publication, promotion, and respect" (footnote omitted)).

92 Notably, this is not always the case. *See id.* at 103 (positing that "[m]any discoveries about nature can be commercially exploited almost immediately").

93 Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 67 J. POL. ECON. 297, 304 (1959); *see also* Strandburg, *supra* note 74, at 94 (stating that "the purpose of basic scientific research is to provide inputs for technological progress in the very long term, in which the potential value of any particular scientific inquiry is largely unpredictable," and hence, "[i]t is . . . widely agreed that the commercial market will fail to invest adequately in such research"); Kapczynski & Syed, *supra* note 84, at 1951 ("[B]asic research is too 'upstream' to be funded by the private sector, meaning that its practical dividends are too uncertain and far off in time to be adequately supported by market incentives.").

94 There are other factors that play a role in undercutting the ability of patents to secure incentives to engage in basic research. Basic research produces significant spillovers, and its main value lies in facilitating various downstream uses. *See* FRISCHMANN, *supra* note 89, at 253; *see also infra* notes 106–114 and accompanying text (discussing spillovers in connection with upstream innovation). In addition, the output of basic research may be highly nonexcludable. *See* Kapczynski & Syed, *supra* note 84, at 1951; *see also infra* Part III.G.

95 *See* Richard M. Jones, *Briefing Stresses the Importance of Basic Research in Meeting Future Energy Needs*, AM. INST. PHYSICS (Sept. 26, 2008), https://perma.cc/9VP8-HHQN (noting the need to invest in basic energy research); *see also* OFFICE OF SCI. WORKSHOP ON ENVTL. MGMT., BASIC RESEARCH NEEDS FOR ENVIRONMENTAL MANAGEMENT, at xi (2015), https://perma.cc/A48M-T8MT (positing that the United States Department of Energy's efforts to clean up waste would be expedited by more investment in basic research); *infra* note 97 and accompanying text.

96 Notably, basic knowledge from various scientific disciplines may need to be combined to form the requisite foundation for climate change innovation. *See* Michal Shur-Ofry, *Connect the Dots: Patents and Interdisciplinarity*, 51 MICH. J.L. REFORM 55, 64–65 (2017).

97 *See, e.g.*, OFFICE OF SCI. WORKSHOP ON ENVTL. MGMT., *supra* note 95, at xi (noting that the United States Department of Energy's progress towards remediation of certain waste problems "has been stymied in part by a lack of investment in basic science" for environmental cleanup).

cannot be incentivized by the patent system, it must be adequately funded in other ways.[98]

C. Upstream Innovation

Even outside the realm of pure basic research, the more upstream a research project is, the less likely it is that the patent system would provide adequate incentives to pursue it.[99] While the results of upstream research endeavors might be the subject of market transactions, the potential consumers of such results are not "end users" (businesses or individuals), but rather "research users" who may engage in follow-on R&D that could ultimately lead to the development of commercial applications.[100] The more removed an R&D project is from commercial applications in terms of time, concept, number of development stages, and amount of follow-on R&D needed to produce such applications, the higher the uncertainty regarding the market value of such project is likely to be. The market value of an upstream R&D project is dependent upon future demand for its results by potential downstream inventors—which is based, in turn, on the likely expectations of such inventors for profits in the markets for commercial applications. At the early point in time when a decision whether to invest in an upstream project must be taken, there are simply too many unknown parameters. Such parameters include, inter alia, the volume and type of follow-on research projects that may evolve; the likelihood that such follow-on projects would lead to the development of commercial applications; the time it may take until such applications are developed, produced, and commercialized;[101] the level of financial gains that such applications may

98 *Cf.* Sarnoff, *supra* note 4, at 336 ("Private investments are unlikely to be sufficient to fund the development of new approaches to climate change technologies that rely on discoveries of basic science.").

99 For most purposes, the literature does not distinguish between basic scientific research and other upstream research endeavors. *But see* FRISCHMANN, *supra* note 89, at 275–76 (listing as types of intellectual infrastructure both "basic research" and "general-purpose technologies," which is a classic example for upstream innovation). Nevertheless, this distinction serves to illuminate two different limitations of a market-based platform for incentivizing innovation. Basic research is an example for a context where market incentives are mostly irrelevant, since the scientific investigation, to start with, is not carried out with a view towards commercial applications, and the results are often too abstract to be commercialized. Tur-Sinai, *supra* note 7, at 159. In contrast, outside the realm of pure basic research, the investigation may be carried out with an expectation that it would ultimately serve as the basis for downstream development of commercial applications, and the results may indeed be sufficiently concrete to be the subject of market transactions designed to facilitate such follow-on R&D; yet, the upstream nature of such innovation may nevertheless cause the incentives provided by a market-based platform to be sub-optimal, for the reasons explored in the text.

100 *See* Jay P. Kesan, *Transferring Innovation*, 77 FORDHAM L. REV. 2169, 2196 (2009) ("Research results that are further away from ultimate commercial usage are commonly referred to as upstream innovations.").

101 *See* Emily Michiko Morris, *The Many Faces of Bayh–Dole*, 54 DUQ. L. REV. 81, 126 (2016) ("Given the long development cycles common in science-based technologies, potential investors may often be nervous about when development will be complete and when they can begin to see returns on their investments.").

ultimately yield; and the division of profits between the parties. Facing such high levels of uncertainty, an upstream researcher is not likely to be able to form any solid expectations regarding the profitability of his or her project. In such circumstances, when market signals are far from clear, the incentives provided by a market-based platform may not be adequate.[102]

One other factor that contributes to the uncertainty in these situations is transaction costs. In order to receive a share of the profits resulting from downstream applications, an upstream researcher must enter licensing deals with follow-on researchers. Unfortunately, the ability to enter such transactions is far from guaranteed. In fact, licensing deals between cumulative inventors often entail high transaction costs.[103] As a result, it is quite possible that certain potential downstream uses may never take place.[104] This makes it even more difficult for upstream researchers to rely on the ability to generate profits from follow-on R&D projects in deciding whether to pursue an upstream research endeavor. For this reason, as well, while a prospect of profits may exist in regard to an upstream research project, it is often too uncertain and remote to adequately incentivize investment in such an endeavor.[105]

In addition, the market value of an upstream innovation may underrepresent its social value due to the existence of substantial spillovers—"uncompensated benefits that one person's activity provides to another."[106] As a general matter, in cumulative innovation settings, "the most important social benefit of an innovation may be the boost given to later innovators, and this may make the benefits harder to appropriate."[107] Upstream innovation may lead over time to a wide range of downstream uses, some of which in remote technological fields and industries.[108] To the

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102 For a discussion on the connection between the ability to foresee profits and the incentive to invent provided by the patent system, see Tur-Sinai, *supra* note 78, at 745. *Cf.* Shyamkrishna Balganesh, *Foreseeability and Copyright Incentives*, 122 HARV. L. REV. 1569, 1574 (2009).

103 Tur-Sinai, *supra* note 78, at 750–51; *see also* Kapczynski, *supra* note 64, at 988 ("[T]ransactions over information . . . are likely to be particularly costly."); Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347, 363 (2000) ("IP may provide sufficient exclusion of competitors but not lead to appropriation because licensing transaction costs are too high . . . .").

104 *See also* Tur-Sinai, *supra* note 7, at 158 (noting that transaction costs could hinder potential licensing deals).

105 *Cf.* Morris, *supra* note 101, at 88 ("Basic research, particularly in complex and unpredictable fields such as biotechnology and nanotechnology, is often too uncertain and distant in value to be attractive investments for private firms, even when protected by patents.").

106 Brett M. Frischmann & Mark A. Lemley, *Spillovers*, 107 COLUM. L. REV. 257, 258 (2007); *see also* Tur-Sinai, *supra* note 7, at 157 (noting that when an innovation has significant positive externalities, market demand will not capture its entire social value).

107 Peter S. Menell & Suzanne Scotchmer, *Intellectual Property Law*, *in* 2 HANDBOOK OF LAW AND ECONOMICS 1473, 1499 (A. Mitchell Polinsky & Steven Shavell eds., 2007); *see also* SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 127 (2004); Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29, 31 (1991).

108 *Cf.* FRISCHMANN, *supra* note 89, at 253 (noting that general-purpose technologies and other types of infrastructural intellectual goods benefit society "primarily by facilitating a wide

extent the social value of such downstream endeavors is internalized by upstream innovators, the concern regarding spillovers is reduced.[109] Yet, even when the results of an upstream R&D project are patented[110]—full appropriability is not guaranteed.[111] Patents have limited scope and duration, and some downstream uses may fall outside the patent's scope or be performed long after it expires.[112] Even with respect to uses that are clearly infringing under current patent law, the ability to enforce upstream patents may be rather limited. For instance, in some cases, an upstream innovation may serve merely as a "research tool" in the development process of second-generation products without being embedded in the final version of such products.[113] At other times, the use of an upstream innovation may simply

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range of downstream productive activities"); *see also supra* 94 and accompanying text (making a similar observation in regard to basic research).

109 *See* Frischmann & Lemley, *supra* note 106, at 261 ("[N]ot all of the difference between producer and social surplus in a transaction should be characterized as a spillover. To the extent that the parties transact and recognize the sharing of a surplus between them, then the benefits are not really external to the transaction.").

110 The question of whether the results of upstream innovation should be eligible for patent protection is highly debated in patent literature and is outside the scope of this Article. One of the main concerns expressed in this regard is that patents on upstream research could unduly inhibit downstream innovation. For relevant discussion, see, e.g., Arti K. Rai, *Fostering Cumulative Innovation in the Biopharmaceutical Industry: The Role of Patents and Antitrust*, 16 BERKELEY TECH. L.J. 813, 838 (2001); Joshua D. Sarnoff & Christopher M. Holman, *Recent Developments Affecting the Enforcement, Procurement, and Licensing of Research Tool Patents*, 23 BERKELEY TECH. L.J. 1299, 1322–23, 1361 (2008). For prominent support of upstream patents, see Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 266 (1977) (positing that such patents increase efficiency in allocation of resources for downstream development).

111 Sure enough, allowing an inventor to internalize the entire social value of her invention would not necessarily be efficient. *See* Gordon, *supra* note 78, at 622 ("[N]o one would suggest that IP should internalize *all* the benefits that flow from an intangible."); Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1032 (2005) (maintaining that there is no need to permit inventors to capture the full social value of their invention); *see also* FRISCHMANN, *supra* note 89, at 39. However, the patent system should at least guarantee an award high enough to cover R&D costs—including a premium for the inherent risk associated with R&D and a reasonable return on fixed-cost investment—whenever the social value of the invention exceeds its costs, and in the presence of substantial spillovers, it is doubtful whether the patent system can guarantee such result.

112 *See, e.g.*, Kapczynski & Syed, *supra* note 84, at 1905, 1914; *see also* Morris, *supra* note 101, at 125–26 (noting, with respect to science-based technologies, that "[p]atent terms last for twenty years, but a development cycle may take so long that patents on upstream research inputs may expire in the meantime. Foundational inventions in particular may be used through several development cycles, such that their patents expire long before their utility does." (footnote omitted)). While, in theory, any limitations of patent incentives that result from the design of the legal regime can be addressed by amending the law—the likelihood that an amendment designed to broaden patent scope or lengthen patent term will take place in the near future is very low. It is also far from clear that such an amendment is warranted, considering the various considerations at stake. Among other things, broadening the scope of upstream patents may unduly inhibit downstream innovation. *See supra* note 110 and accompanying text.

113 Research tools are "products or processes used in research to investigate subjects other than the tools themselves." Henrik Holzapfel & Joshua D. Sarnoff, *A Cross-Atlantic Dialog on Experimental Use and Research Tools*, 48 IDEA 123, 124–25 (2008). Most often, research tools

fail to yield any follow-on products or processes. In these cases, unless the use is very conspicuous, it "may never come to the attention of the patent holder."[114] As a general matter, the broad array of potential downstream uses for an upstream innovation may lead to significant hurdles in detecting and proving infringement and increase enforcement costs. Thus, substantial spillovers may indeed be present in these settings. This may further dilute the *ex ante* incentive provided to an upstream researcher by a market-based platform.

All of this is highly relevant in the environmental context, where the need for upstream innovation as a basis for applied R&D is apparent. Consider, for instance, the important domain of alternative energy sources noted above.[115] While some of the important questions that need to be addressed in this context are more of a basic science nature—e.g., the potential mitigating effect of switching to alternative sources, their disadvantages and the risks associated with their use—there are also multiple questions with a more practical orientation that must be investigated in order to advance the field. For instance, there is a need for R&D targeted at improving efficiency of these energy sources and exploring methods to employ them in a manner that would maximize their energy yield in various settings.[116] R&D projects focusing on these matters are classic examples for upstream innovation—while the results of such projects cannot be marketed to end users, they may serve as the foundation for a wide array of downstream innovative efforts that may ultimately lead to the development of green production methods and consumer end-products. Yet, for all the reasons explored above, market incentives are not likely to adequately incentivize this type of upstream innovation. In fact, in this particular context, the uncertainty faced by an upstream researcher regarding the prospect of profits may be particularly high. An investigation of the questions described above may sometimes lead to "negative"

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are not embedded in the final version of the ensuing second-generation products. *See, e.g.*, HAROLD EINHORN & ERIC E. BENSEN, PATENT LICENSING TRANSACTIONS § 6A.06[1] (Matthew Bender ed., 2017) (noting that research tools by definition form no part of the resulting product); Tur-Sinai, *supra* note 78, at 732 (describing this feature as the defining characteristic of the research tools scenario, as distinguished from other cumulative innovation settings).

114 Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1071–72 (1989); *see* EINHORN & BENSEN, *supra* note 113, § 6A.06 (noting that the owners of research tool patents may find it hard to meet their burden of proving infringement, as they typically have no ability to ascertain whether certain research activities resulting in commercial products involved use of their patents); John P. Walsh et al., *Effects of Research Tool Patents and Licensing on Biomedical Innovation*, *in* PATENTS IN THE KNOWLEDGE-BASED ECONOMY 285, 324 (Wesley M. Cohen & Stephen A. Merrill eds., 2003) (noting "infringement of research tool patents is often hard to detect"); Ofer Tur-Sinai, *The Trans-Pacific Partnership: Experimental Use of Patents on the International Agenda*, 16 N.C. J.L. & TECH. 63, 97–98 (2014) (discussing the difficulty of detecting and proving infringement in cases of research uses).

115 *See supra* notes 52–53 and accompanying text.

116 *See, e.g.*, Samuel C.E. Jupe et al., *Increasing the Energy Yield of Generation from New and Renewable Energy Sources*, *in* RENEWABLE ENERGY 37, 59–60 (T.J. Hammons ed., 2009); *see also supra* note 53 and accompanying text.

answers—for example, it may lead to the conclusion that a certain alternative energy source cannot be used effectively in a specific context.[117] Even when the research culminates in "positive" findings, in order for the use of an alternative energy source to become prevalent, there is often a need for investment by the government in infrastructure. For example, electric vehicles depend heavily on an effective charging infrastructure.[118] In addition, the switch to a new energy source may have health and safety ramifications that need to be addressed prior to implementation.[119] Most importantly, for various reasons discussed below, one cannot anticipate in advance future demand by businesses and individual consumers for products and processes that may use the relevant alternative energy resources.[120] Under these circumstances, market incentives—even if bolstered by patent protection—may fall short in incentivizing this type of research, and thus, should be supplemented in other ways.

D. Technological Solutions Designed for Businesses

Moving down the R&D chain to concrete technological solutions that are designed for direct implementation by businesses—for example, a cleaner production method—one might think that a market-based platform could actually serve as a good incentive mechanism. After all, such technological solutions may be readily and easily commercialized. Yet, even in this context, it appears that patent incentives cannot adequately promote the development of climate change technologies, as market demand tends to significantly underrepresent the social value of green products and processes.

The reason why a systematic gap between market demand and social value exists in this context has to do with the fact that a cleaner environment constitutes a public good, from which we all benefit, whether we contributed to it or not.[121] Thus, just like pollution is a classic example of a negative externality,[122] acting in an environmentally responsible manner often has positive externalities.[123]

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117 Notably, while such a finding may not personally benefit the researcher, it could have a high social value. *See generally* Michal Shur-Ofry, *Access-to-Error*, 34 CARDOZO ARTS & ENT. L.J. 357 (2016) (explaining the importance of negative information as a driver of innovation).

118 *See generally* Andreas Schroeder & Thure Traber, *The Economics of Fast Charging Infrastructure for Electric Vehicles*, 43 ENERGY POL'Y 136 (2012).

119 *See* Morris, *supra* note 101, at 126 ("Because science-based technologies often present a leap from known technologies, development in these fields may face further uncertainty about not only market appeal but also other issues, such as health and safety ramifications.").

120 *See infra* Parts III.D–.E.

121 *See, e.g.*, Felix Mormann, *Requirements for a Renewable Revolution*, 38 ECOLOGY L.Q. 903, 921 (2011) (noting that "a cleaner environment is a public good"); Tran, *supra* note 45, at 133 ("Like national security, a sustainable environment lacks a fixed monetary value, but is a valuable public good.").

122 *See, e.g.*, Hall & Helmers, *supra* note 13, at 488.

123 *See, e.g.*, Tran, *supra* note 45, at 133 ("From an economic perspective, global climate change is a negative externality with global causes and consequences. Conversely, technological solutions that limit the harmful effects of climate change create positive social

Consider, for example, a manufacturing firm that debates whether to implement a new technology designed to reduce the amount of greenhouse gas emitted during production. Beyond any direct benefits that the firm might reap as a result of implementing such a technology,[124] by positively impacting the state of the environment, this step could also have substantial beneficial effects on numerous third parties.[125] Yet, in making its decision whether to purchase and implement such a technology or not, a profit-maximizing firm is likely to focus predominantly on its direct costs and benefits, while failing to account for such indirect benefits to others.

The costs involved in implementing a climate change technology may include purchasing or licensing fees, significant switching costs, and ongoing increased costs of operation.[126] Despite these costs, a firm could still find it beneficial to green its operations. First, it may choose to do so to comply with regulation or reduce its environmental costs and liabilities.[127] In addition, in certain instances, a firm may decide to switch to a greener technology in order to satisfy the preferences of its consumers.[128] Such a decision may also be based more generally on considerations of public

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benefits realized not only by the inventors, but also by the entire country and even the whole world." (footnote omitted)). For the definition of positive externalities, see FRISCHMANN, *supra* note 89, at 37–38 (defining "positive externalities" as "benefits . . . realized by one person as a result of another person's activity without payment" and noting that "[t]oo few . . . resources may be allocated to activities that generate positive . . . externalities because those persons deciding whether and how to allocate resources fail to account for the full range of benefits").

124 *See supra* notes 127–131 and accompanying text.

125 *See, e.g.*, Mandel, *supra* note 13, at 57 ("Implementation of environmental innovation that reduces pollution, improves remediation, enhances conservation, or otherwise provides environmental benefit has substantial salutary effects for many members of society, far beyond the firm that implements the innovation. Framed another way, environmental invention has significant benefits beyond those received by the consumer of the invention.").

126 For the sunk switching costs that often accompany the replacement of existing technologies with green ones, see, e.g., Hall & Helmers, *supra* note 13, at 489–90. As to the increased costs of operation that often accompany the switch to greener methods of production, see, e.g., Mandel, *supra* note 13, at 53–54. *See also* Tran, *supra* note 45, at 133 (noting that "renewable forms of energy still cost more than traditional fossil fuels"). Of course, this would not always be the case, and in some instances, the switch to a more environmentally friendly technology may actually result in energy costs savings or otherwise reduce operation costs, to the benefit of the implementing firm. *Cf.* Hall & Helmers, *supra* note 13, at 511 (positing that regulation is particularly important in the case of "technologies that only achieve improved carbon efficiency without increasing energy efficiency, in which case social benefits exceed private benefits by far").

127 *See, e.g.*, Marchant, *supra* note 45, at 833 (discussing the possibility that a firm may pursue greener technologies in order to reduce environmental liabilities); *see also* Gollin, *supra* note 57, at 195–96 (discussing the incentivizing effect of laws that are intended to "eliminate harmful technologies" or that "encourage or require the use of beneficial technology"); Mandel, *supra* note 13, at 53 (noting regulation as one of the reasons that may cause businesses to implement green technologies).

128 Notably, consumers that are committed to environmental values may care not only about the usage phase, but also about the way products are being manufactured or transported. Nevertheless, as clarified below, environmental considerations generally do not play a central role in decisions regarding consumption. *See infra* Part III.E.

relations,[129] or on the firm's attempt to comply with its own corporate social responsibility (CSR) policy.[130] Finally, some corporate executives may act, at times, out of genuine concern for the environment, even when it does not seem to align with the short-term goals of the firm.[131] Nevertheless, in most cases, a profit-maximizing firm is not likely to assign a significant weight to the indirect benefits that others may derive from the positive impact of its actions on the state of the environment.[132]

Hence, as a general matter, businesses would not be willing to invest in green technologies equal to an amount reflecting the social value of such technologies. Notably, this would impact both the level of demand by industrial firms for environmental innovative solutions developed by others and the incentive of such firms to engage in user innovation designed to "green" their own operations.[133] Overall, the aggregate signal produced by the patent system, in its reliance on market demand, is not likely to incentivize the development of climate change technologies designed to be implemented by businesses at a socially optimal level.[134]

The challenge we face here is, in essence, a "double market failure."[135] One market failure has to do with the public good characteristics of

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129 *See, e.g.*, Mandel, *supra* note 13, at 53 ("Even though such advances increase operation costs, firms may still implement them—for instance, for regulatory, public relations, or Good Samaritan purposes."); Marchant, *supra* note 45, at 833 (mentioning "self-promotion" among the reasons that push corporations to pursue sustainable technologies); Issachar Rosen-Zvi, *You Are Too Soft!: What Can Corporate Social Responsibility Do for Climate Change?*, 12 MINN. J.L. SCI. & TECH. 527, 556 (2011) (giving an example of a corporation acting out of concern for negative publicity in the media or nongovernmental organization campaigns regarding the impact of their practices on climate change).

130 *See generally* Rosen-Zvi, *supra* note 129 (evaluating the effectiveness of corporate codes of conduct and CSR reports in the realm of climate change).

131 *See* Mandel, *supra* note 13, at 53 (noting "Good Samaritan" purposes among the notions that may cause a firm to act an environmentally responsible manner).

132 *See id.* at 58 (noting that, in general, "a firm considering whether to implement additional environmental innovation will not take into account the benefit society reaps from the innovation in the form of improved environmental conditions, but only accounts for the benefit that the firm itself receives"); *see also* Marchant, *supra* note 45, at 833 (observing that "even if we grant that . . . many corporations are sincerely pursuing more sustainable technologies, few believe that corporate efforts alone are sufficient to generate the massive technology changes, fast enough, needed to meet the challenge of sustainability").

133 *See* Mandel, *supra* note 13, at 58 (noting that "environmental innovators, whether in industry or the environmental innovation business, do not receive the socially optimal level of incentive to produce environmental innovation"). With respect to user innovation, see generally ERIC VON HIPPEL, DEMOCRATIZING INNOVATION (2005); William W. Fisher III, *The Implications for Law of User Innovation*, 94 MINN. L. REV. 1417 (2010); Katherine J. Strandburg, *Users as Innovators: Implications for Patent Doctrine*, 79 U. COLO. L. REV. 467 (2008).

134 *See* Jaffe et al., *supra* note 13, at 168–69 ("Given that the development of environmentally beneficial technology is subject to two interacting market failures, in cases where environmental externalities have not been fully internalized it is likely that the rate of investment in such technology is below the socially optimal level.").

135 For a use of this term in this context, see *id.* at 173. *See also* Hall & Helmers, *supra* note 13, at 488–89 (discussing the presence of a "double externality" in this context, and noting, further, that "both externalities act on a global scale, which poses a particularly difficult problem in their mitigation"); Mandel, *supra* note 13, at 57–58 (noting that "[e]nvironmental innovation . . . suffers [from] two public good problems").

knowledge, as a result of which an inventor may not be able to appropriate a large enough share of his or her invention's market value.[136] The patent system is designed to resolve this market failure by granting inventors exclusivity over their inventions.[137] Yet, another market failure, which plays a role in this particular context, has to do with the public good characteristics of the state of the environment. As a result of this market failure, the invention may fail to have a significant market value, to start with, and this is something that market exclusivity cannot help resolving. In other words: "Pollution creates a negative externality, and so the invisible hand allows too much of it. Technology creates positive externalities, and so the invisible hand produces too little of it."[138] Innovative technologies for pollution reduction are thus "doubly underprovided by markets."[139]

E. Consumer End-Products

While the concern that businesses' demand for green technologies underrepresents social value has been noted in innovation literature, it is important to acknowledge that a similar effect characterizes individual consumers as well. For a variety of reasons, it appears that consumers cannot be trusted to sufficiently account for the environment while making market choices. This may have an enormous impact on the ability of the patent system to incentivize green innovation, both at the level of consumer end-goods and at more upstream levels.[140]

The link between consumption patterns and the ability of the patent system to incentivize green innovation has not been sufficiently explored. This dearth of discussion is unsurprising, considering that the prevalent approach to innovation law perceives the state's role in setting the direction of innovation as rather limited, whereas the market's invisible hand is generally trusted to direct R&D resources in an efficient manner.[141] Such perception relies, to a large extent, on a general tendency to attribute much weight to consumer preferences, without questioning their merit.[142] On top of this, up until recently—in proposing and implementing various measures designed to mitigate the environmental impacts of industrialized society, environmental scholars and policy makers have focused almost entirely on industrial targets.[143] Environmental policy has generally accepted consumer

136 *See, e.g.*, Burk & Lemley, *supra* note 64, at 1580; Tur-Sinai, *supra* note 78, at 736 n.48.

137 *See supra* notes 78–79 and accompanying text.

138 Jaffe et al., *supra* note 13, at 166–67.

139 *Id.* at 168.

140 *See infra* note 185 and accompanying text.

141 *See supra* notes 85–87 and accompanying text.

142 *See, e.g.*, James Boyle, *Enclosing the Genome?: What the Squabbles over Genetic Patents Could Teach Us*, *in* PERSPECTIVES ON PROPERTIES OF THE HUMAN GENOME PROJECT 97, 114 (F. Scott Kieff & John M. Olin eds., 2003) ("For those who practice the economics of the Chicago school, current revealed consumer preferences . . . have an almost totemic power.").

143 *See, e.g.*, Bradely A. Harsch, *Consumerism and Environmental Policy: Moving Past Consumer Culture*, 26 ECOLOGY L.Q. 543, 551–54 (1999) (surveying legislation and proposed approaches that reflect this tendency).

attitudes as a given,[144] and very little attention has been paid to the possibility of addressing environmental harms through a consumption-oriented approach.[145] This is starting to change in recent years,[146] but the link between consumption patterns and incentives to develop green technologies has yet to be explored.

Before delving into the attributes of consumer preferences, it is important to stress out consumption's vast impact on the state of the environment in general, and on climate change in particular. Greenhouse gases are released into the atmosphere at every stage of a product's life cycle, "from drilling for oil to running factories to shipping our Stuff all over the planet."[147] Therefore, many agree today that reducing consumption of material goods is a key factor in the struggle to halt the environmental crisis.[148] At the very least, consumption should be channeled towards

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144 *See, e.g.*, *id.* at 545 (pointing out that "environmental policy has accepted consumers' desires as being immutable even though the destructive consequences of fulfilling them have become undeniable"); Katrina Fischer Kuh, *Capturing Individual Harms*, 35 HARV. ENVTL. L. REV. 155, 156 (2011) ("In stark contrast to the social opprobrium and legal strictures directed at corporate polluters stands the legal and social sanction of common individual behaviors—everything from solo commuting to discarding household waste—that harm the environment.").

145 *See, e.g.*, Neil Gormley, *Greening the Law of Advertising: Prospects and Problems*, 42 TEX. ENVTL. L.J. 27, 28 (2011) ("Existing regulatory regimes focus overwhelmingly on the supply side of economic transactions; few efforts—eco-labeling and smart electricity metering stand out as exceptions—have been made to intervene on the demand side in pursuit of sustainability.").

146 *See, e.g.*, Kuh, *supra* note 144, at 155 ("A growing literature recognizes the environmental significance of individual behaviors, critiques the failure of environmental law and policy to capture harms traceable to individual behaviors, and suggests and evaluates strategies for capturing individual harms going forward."). For concrete proposals by legal scholars for steps that may encourage a more environmentally responsible lifestyle, see, e.g., Katya Assaf, *Buying Goods and Doing Good: Trademarks and Social Competition*, 67 ALA. L. REV. 979, 1009–16 (2016) (recommending the use of ethical consumption signs); Gormley, *supra* note 145, at 39–41 (proposing regulation of advertising in service of the environment); Harsch, *supra* note 143, at 603–10 (suggesting various measures).

147 ANNIE LEONARD, THE STORY OF STUFF: HOW OUR OBSESSION WITH STUFF IS TRASHING THE PLANET, OUR COMMUNITIES, AND OUR HEALTH—AND A VISION FOR CHANGE 180 (2010); *see also* Abbott & Booton, *supra* note 38, at 219 ("From the extraction of raw materials, through manufacture, distribution, use, and final disposal, production and consumption have significant environmental effects at all stages in the 'life-cycle' of consumer goods and services."); Harsch, *supra* note 143, at 572 (positing that "the demand for goods and services is the root cause of environmental impacts resulting from the industrial sector"); Kuh, *supra* note 144, at 157–58 ("Since '[p]roducts have environmental impacts throughout their lifecycle, from extraction, transport, and production, to distribution, use, and disposal,' the environmental impact of typical individual acts of consumption, such as the purchase of a pair of jeans or a pair of leather boots, can be significant." (alteration in original) (footnote omitted) (quoting James Salzman, *Sustainable Consumption and the Law*, 27 ENVTL. L. 1243, 1255–56 (1997))).

148 *See, e.g.*, Paul R. Ehrlich & Anne H. Ehrlich, *Too Many People, Too Much Consumption*, YALE ENV'T 360 (Aug. 4, 2008), https://perma.cc/49YS-S5AD (arguing that the environmental crisis is driven in large part by a combination of economic growth and increasing per capita consumption); *see also* NAOMI KLEIN, THIS CHANGES EVERYTHING: CAPITALISM VS. THE CLIMATE 85 (2014) ("Encouraging the frenetic and indiscriminate consumption of essentially disposable products can no longer be the system's goal."); Kenneth Arrow et al., *Are We Consuming Too Much?*, 18 J. ECON. PERSP. 147, 167 (2004) (finding support for the view that current consumption levels are unsustainable); Mona L. Hymel, *Consumerism, Advertising, and the*

products that use less energy and other consumables during their lifecycle, are made to last longer or serve multiple uses, or—for other reasons—have a lower environmental footprint.[149] Unfortunately, consumers cannot be expected to fully internalize and implement these notions, and hence, in this context as well, there is a significant gap between market value and social value.

To start with, public awareness of environmental issues may be growing in recent decades but is still insufficient. While "the great majority of climate scientists have concluded that global warming is happening, mostly human caused and, if left unchecked, will have serious consequences for human societies and the natural world"—surveys show that many Americans think climate change is still a topic of significant scientific disagreement.[150] This may be attributed, in part, to the public's limited ability to comprehend scientific evidence,[151] but may also be the result of other factors, including the unconscious tendency of people to fit evidence of risk to positions that predominate in groups to which they belong.[152] People's opinions on climate change are also undoubtedly affected by politicians, fossil fuel companies, and other organizations who actively promote climate

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Role of Tax Policy, 20 VA. TAX REV. 347, 349 (2000) ("As our consumption levels reach unprecedented highs, the scientific consensus grows that such high levels of consumption significantly contribute to the Earth's environmental decline."); Daniel M. Warner, *Uses of Subjective Well-Being in Local Economic and Land Use Policy*, 23 J. LAND USE & ENVTL. L. 263, 264 (2008) (maintaining that "[w]e cannot 'save the earth' . . . until we confront the argument that 'growth is good'").

149 *See, e.g.*, *supra* note 51 and accompanying text (discussing light bulbs). Other parameters that may affect a product's environmental footprint include, inter alia, the materials from which the product is made, the amount of energy used in its production process, and the impact of any required transportation of materials or distribution of the product itself. *See* LEONARD, *supra* note 147, at 263–68; Abbot & Booton, *supra* note 38, at 221–22, 239 (noting that the parameters determining environmental impact include "[t]he raw materials used in a product, the natural resources consumed during its manufacture, the waste by-products emanating from the manufacturing process, and the options for disposal and recycling or reuse at the end of a product's life").

150 ANTHONY LEISEROWITZ ET AL., YALE PROJECT ON CLIMATE CHANGE COMMC'N ET AL., CLIMATE CHANGE IN THE AMERICAN MIND: AMERICANS' GLOBAL WARMING BELIEFS AND ATTITUDES IN APRIL 2013, at 7 (2013), https://perma.cc/X8KZ-7SR9 (noting that 33% of Americans believe that "there is a lot of disagreement among scientists" about the existence of global warming). According to the study, only 63% of Americans believe global warming is happening, and only 49% believe global warming, if happening, is caused mostly by human activities rather than by natural changes in the environment. *Id.* at 4, 6; *see also* Matthew E. Kahn & Daxuan Zhao, *The Impact of Climate Change Skepticism on Adaptation in a Market Economy* 2 (Nat'l Bureau for Econ. Research, Working Paper No. 23155, 2017) (noting that "a large segment of U.S. voters, members of Congress and the new Trump Administration view climate change as a low policy priority").

151 *See, e.g.*, Dan M. Kahan et al., *The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks*, 2 NATURE CLIMATE CHANGE 732, 732 (2012) ("Seeming public apathy over climate change is often attributed to a deficit in comprehension. The public knows too little science, it is claimed, to understand the evidence or avoid being misled.").

152 *Id.* (positing that "individuals, as a result of a complex of psychological mechanisms, tend to form perceptions of societal risks that cohere with values characteristic of groups with which they identify").

change denial.[153] Notably, even people that have a great deal of information regarding climate change may underestimate the severity of the problem due to cognitive biases and the human tendency to rely on heuristics to assess risk.[154] For instance, people often display unrealistic optimism—thus, even if they know the facts, they may still fail to be alarmed by the current ecological situation.[155] Similarly, people's tendency to weigh immediate outcomes more heavily than distant ones may cause them to underestimate the probability and severity of the ecological threat, which is relatively remote and abstract compared to a host of other risks.[156]

Even people who are generally mindful of, and alarmed by, climate change may fail to make the connection between their own actions and the environment.[157] The harm that an individual may inflict on the environment through consumption is indirect, distant in time and space from such individual's acts, and only occurring "after aggregation with the contributions of many others."[158] In these circumstances, people may find it difficult to appreciate the potential impact of their choices on the environment. In addition, as explained above, environmental policy has focused for many years primarily on industrial targets, conveying a message that "industrial polluters are the source of environmental problems, and individual citizens are enforcers allied with the government to stop them."[159] This may further hinder individuals' ability to acknowledge the link between their personal behavior and climate change.

Even when fully aware of the link between consumption and climate change, an individual consumer may fail to make choices that sufficiently account for environmental concerns. This is mainly the result of the human propensity for self-interest, as narrow self-interests often prevail against the

153 *See* HAYDN WASHINGTON & JOHN COOK, CLIMATE CHANGE DENIAL: HEADS IN THE SAND 89, 93, 96 (2011).

154 *See, e.g.*, Cass R. Sunstein & Lucia A. Reisch, *Automatically Green: Behavioral Economics and Environmental Protection*, 38 HARV. ENVTL. L. REV. 127, 147 (2014) ("For reasons that behavioral economists have emphasized, people may err even if they have a great deal of information." (footnote omitted)).

155 *See id.*; *cf.* Ian Ayres & Amy Kapczynski, *Innovation Sticks: The Limited Case for Penalizing Failures to Innovate*, 82 U. CHI. L. REV. 1781, 1794 (2015) (noting "optimism bias" among the reasons that can "discourage consumers from investing adequately in innovations that reduce the likelihood or cost of accidents").

156 *See, e.g.*, Vladas Griskevicius et al., *The Evolutionary Bases for Sustainable Behavior: Implications for Marketing, Policy, and Social Entrepreneurship*, 31 J. PUB. POL'Y & MARKETING 115, 115–16, 123 (2012) (noting the "predisposition to be shortsighted" as one of the factors that account for human disregard for the environment); Sunstein & Reisch, *supra* note 154, at 147 (noting that people may "neglect the long-term").

157 *See, e.g.*, Kuh, *supra* note 144, at 158–59 ("The connection between individual actions and environmental harms can be difficult for individuals to appreciate.").

158 *Id.* at 159; *see also* Griskevicius et al., *supra* note 156, at 124 (noting that "people rarely see, feel, touch, hear, or smell how their behaviors affect the environment").

159 Kuh, *supra* note 144, at 159 (noting, in addition, "the desire to avoid the cognitive dissonance created by condemning pollution but recognizing one's own behaviors as polluting, hamper individuals' ability to recognize their own environmental significance and culpability"); *see supra* notes 143–145 and accompanying text (describing the traditional focus of environmental policy on industrial targets).

interest of others and the common good.[160] For anyone whose preferences are designed primarily to promote what they believe would advance their own well-being, the private costs associated with reducing consumption or channeling to greener products may simply exceed the personal benefits that they may derive from such a choice.

On the costs side, reducing overall consumption may certainly be perceived as a sacrifice by many individuals. This is especially true considering the prevailing ideology in Western society that still views material advancement, to a large extent, as the key to a good and happy life.[161] This worldview is bolstered by advertising, a significant contributor to high consumption levels in the United States and elsewhere.[162] Regarding a switch to greener products—notably, such products are often more expensive than their non-green equivalents.[163] Replacing an existing product with a greener substitute may also involve significant switching costs.[164] In addition, the shift to eco-friendly products frequently involves changing habits, which may have a deterring effect on potential consumers.[165] This may be exacerbated in light of people's tendency to "irrationally overvalue benefits they currently possess relative to those they don't."[166] This tendency is a manifestation of loss aversion, an element of Kahneman and Tversky's Prospect Theory,[167] according to which "losses are weighted substantially

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160 *See, e.g.*, Griskevicius et al., *supra* note 156, at 118 ("Many environmental problems result from this inherent conflict between personal and collective interests, in which narrow self-interests often prevail against the common good of the group.").

161 *See, e.g.*, Margaret Chon, *Postmodern "Progress": Reconsidering the Copyright and Patent Power*, 43 DEPAUL L. REV. 97, 118, 124 (1993); Estelle Derclaye, *Eudemonic Intellectual Property: Patents and Related Rights as Engines of Happiness, Peace, and Sustainability*, 14 VAND. J. ENT. & TECH. L. 495, 510–11 (2012).

162 Hymel, *supra* note 148, at 352; *see also* Robert P. Merges, *Commercial Success and Patent Standards: Economic Perspectives on Innovation*, 76 CALIF. L. REV. 803, 823–24 (1988) (discussing the impact of marketing efforts on the economic success of commercialized technologies).

163 *See, e.g.*, Damian Carrington, *Electric Cars 'Will Be Cheaper than Conventional Vehicles by 2022,'* GUARDIAN (Feb. 25, 2016), https://perma.cc/manage/create; *Green Goods Cost Nearly 50% More*, TELEGRAPH (May 30, 2010), https://perma.cc/7KR7-PTXZ.

164 *See, e.g.*, Gourville, *supra* note 83, at 100 (discussing the economic costs that are often entailed by the switch to a new product, including learning costs and obsolescence costs); Hall & Helmers, *supra* note 13, at 489–90 (discussing the "sunk switching costs" that often accompany the replacement of existing technologies with green ones).

165 *See, e.g.*, Griskevicius et al., *supra* note 156, at 115 (noting that "changing old habits can be a formidable challenge, especially when those habits have been adaptive for many millennia").

166 Gourville, *supra* note 83, at 100.

167 *See generally* Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263 (1979). Prospect Theory states, in general, that value is a reference-dependent function that decelerates in the domain of losses more quickly than it accelerates in the domain of gains. *See* Christine Jolls & Cass R. Sunstein, *Debiasing Through Law*, 35 J. LEGAL STUD. 199, 205 (2006) (stating that Prospect Theory "posits that people weigh losses more heavily than gains, thus showing loss aversion"); Carey K. Morewedge et al., *Bad Riddance or Good Rubbish? Ownership and Not Loss Aversion Causes the Endowment Effect*, 45 J. EXPERIMENTAL SOC. PSYCHOL. 947, 947 (2009); Eric van Dijk & Daan

more than objectively commensurate gains in the evaluation of prospects and trades."[168] Hence, for example, for a person who has driven a gasoline-powered car for many years, the losses associated with switching to an electric car (e.g., in terms of refueling time) may have a far greater impact than any associated gains.[169]

As to the gains side, the personal benefits associated with reducing consumption or channeling to eco-products (e.g., generating a savings in energy costs associated with the use of energy-efficient products) are often not significant. Moreover, different products compete along various dimensions, of which energy efficiency (or similar benefits associated with eco-friendly products) is only one, and it may certainly be the case that other parameters weigh more in a consumer's decision-making process.[170] In addition, individual preferences are not formed in a vacuum, and consumers are known to exert much influence on each other.[171] Thus, to be convinced that the switch to a new technological product is indeed beneficial, a potential user would often wait to see that others have adopted it and become convinced in its superiority.[172] Consequently, as long as the use of a green technology is not widespread, some consumers would not even give it a serious consideration. Therefore, even if shifting to a green technology carries significant potential benefits for consumers, demand may be lacking when the relevant technology is still in early stages of diffusion.

In regard to the positive impact on the state of the environment entailed by "green" consumerism—unfortunately, the environmental impact of one consumer's behavior is typically negligible,[173] may take a while to materialize,[174] and cannot be experienced by such individual on a personal level—and therefore, is not likely to be treated as a personal gain by him or her. While an environmentally responsible behavior may ultimately benefit

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van Knippenberg, *Buying and Selling Exchange Goods: Loss Aversion and the Endowment Effect*, 17 J. ECON. PSYCHOL. 517, 518 (1996).

168 Daniel Kahneman et al., *Experimental Tests of the Endowment Effect and the Coase Theorem*, 98 J. POL. ECON. 1325, 1326, 1328 (1990); *see also* Sunstein & Reisch, *supra* note 154, at 143 ("People dislike losses far more than they like corresponding gains . . . .").

169 *See* Gourville, *supra* note 83, at 102.

170 *See, e.g.*, Sunstein & Reisch, *supra* note 154, at 150 (noting that "there is active competition in the markets for motor vehicles and appliances, and energy efficiency is only one dimension along which producers compete").

171 *See* Michal Shur-Ofry, *IP and the Lens of Complexity*, 54 IDEA 55, 64 (2013) (discussing the impact of network dynamics on success); *see also* Griskevicius et al., *supra* note 156, at 117 (discussing "proclivity to unconsciously copy others" as a factor that contributes to non-environmental behavior).

172 *See, e.g.*, Jaffe et al., *supra* note 13, at 167 (discussing the importance of "learning-by-using" in the diffusion process of a new technology).

173 *See, e.g.*, Kahan et al., *supra* note 151, at 734 (noting that the actions that an ordinary person takes as a consumer will not "by itself aggravate or mitigate the dangers of climate change: On his own, he is just not consequential enough to matter").

174 Individuals may often set aside long-term benefits that may flow from a certain behavior in the face of short-term gains associated with a different behavior. *See, e.g.*, Liselot Hudders & Mario Pandelaere, *The Silver Lining of Materialism: The Impact of Luxury Consumption on Subjective Well-Being*, 13 J. HAPPINESS STUD. 411, 428 (2012) (noting that individuals prefer smaller short-term gratifications, even when it goes at the expense of achieving long-run goals).

the common good, such benefit constitutes a positive externality and is not likely to be accorded much weight by an individual whose preferences are mostly self-interested.[175] Sure enough, if one could trust other individual consumers to make similar environmentally responsible choices, than the prospect of achieving a significant improvement in the state of the environment might be sufficient to motivate him or her. Yet, absent such assurance, many individuals would refrain from acting for the common good. In the face of this collective action problem,[176] it is easy to understand why even an individual with a strong commitment to environmental values, when acting as a *consumer*, might find himself or herself making non-environmental choices, while setting aside his or her environmental "citizen" preferences in favor of other more self-regarding preferences.

Thus, this is a context where the often-observed discrepancy between consumer preferences and citizen preferences comes into play. People are said to hold and express different preferences in their "consumer" role and in their "citizen" role. When acting as consumers, people generally behave in a manner that reflect their more egocentric interests, while their choices in political settings often reflect a greater regard for the good of society as a whole.[177] One prevalent explanation for the differences between consumer and citizen behavior is the prisoner's dilemma or tragedy of the commons explanation.[178] An alternative theory maintains that "[t]he differences in observed choices occur because hopelessness causes lower-ranking preferences to be adopted in market settings."[179] Regardless of the explanation, the ultimate result is that in a market setting, many people would fail to make choices that align with society's best interests.

To be sure, many people do consider the environment in making consumer choices.[180] Some people's preferences are more altruistic and less self-interested than others' and may be motivated by a genuine concern for the environment. Consumption of eco-friendly products may also, at times, result from a desire to feel good about oneself or be conceived as environmentally friendly by others.[181] In other cases, a consumer choice

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175 *See supra* note 160 and accompanying text (explaining the propensity for self-interest); *see also supra* notes 121–132 and accompanying text (discussing positive externalities in connection with businesses' demand for green innovation).

176 *See* Sunstein & Reisch, *supra* note 154, at 148 ("Choosers may also face a collective action problem. Asked individually, they might rationally select gray energy, but they might prefer green energy if everyone else was doing so as well.").

177 *See* Daphna Lewinsohn-Zamir, *Consumer Preferences, Citizen Preferences, and the Provision of Public Goods*, 108 YALE L.J. 377, 379–84 (1998) (discussing alternative explanations for this discrepancy).

178 *Id.* at 386–88 (explaining how the prisoner's dilemma or tragedy of the commons approach accounts for differences between consumer and citizen behavior).

179 *Id.* at 396.

180 *See, e.g.*, KLEIN, *supra* note 148, at 90 (acknowledging that "[p]lenty of people are attempting to change their daily lives in ways that do reduce their consumption"); Rosen-Zvi, *supra* note 129, at 536 (noting that there is market demand for "green electricity").

181 *See, e.g.*, Sunstein & Reisch, *supra* note 154, at 129 ("Some consumers select green energy not because of a careful calculation that the environmental benefits justify the private costs, but because of a desire to express certain values or to act in accordance with their

motivated by other reasons, such as health benefits, may incidentally benefit the environment as well.[182] Yet, all in all, such individual lifestyle choices are not likely to amount to a major shift in consumption patterns in the level that is required to combat climate change.[183]

The implications for this Article's analysis are clear. Ultimately, if individual consumers cannot be trusted to make choices that align with environmental concerns, then the patent system, being predicated on market demand, certainly cannot be trusted to produce signals which are sensitive enough to environmental outcomes. For lack of sufficient demand, the system is likely to under-incentivize investment in R&D projects that may lead to the development of climate change technologies or other green products. At the same time, by reflecting consumer preferences that do not fully account for environmental considerations, the patent system may also provide an inflated incentive to develop consumer goods with a relatively high environmental footprint.[184] This may be unfortunate both in itself and in terms of opportunity costs: R&D is resource-intensive, and as resources are scarce—allocation matters. Inasmuch as the patent system incentivizes development of new carbon-emitting products, it may further divert resources away from other more socially valuable activities, including the development of greener products.

As briefly noted above, this may ultimately have an impact not only on downstream development of green consumer products, but also on incentives to engage in R&D of more upstream technologies, the demand for which derives, at least to some extent, from the demand for end-products. After all, absent significant demand for electric cars, why would companies invest significant resources in R&D that aims to improve performance of rechargeable batteries or other components embedded in such cars?[185]

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idealized self-conceptions."). *See generally* Steven E. Sexton & Alison L. Sexton, *Conspicuous Conservation: The Prius Halo and Willingness to Pay for Environmental Bona Fides*, 67 J. ENVTL. ECON. & MGMT. 303 (2014) (finding that, depending on their location, consumers are willing to pay higher prices to signal their environmental bona fides through their car choices).

182 This may be the case, for example, with respect to organic food consumption. *See* Tamar Haspel, *Is Organic Agriculture Really Better for the Environment?*, WASH. POST (May 14, 2016), https://perma.cc/S8VQ-S72K.

183 *See, e.g.*, Kuh, *supra* note 144, at 181–82 ("Although some evidence suggests that a norm of environmental protection is common, evidence also indicates that it may be weak (or 'shallow') and frequently subverted to other prevailing norms. . . . That many individuals support protection of the environment generally and are willing to spend more for a hip pair of organic Levis may suggest little about their willingness to reduce their overall consumption or take other, less hip or convenient, actions to reduce environmental harms."); *see also* Griskevicius et al., *supra* note 156, at 115 (discussing a recent survey finding that "only 9% [of respondents] use any environmentally friendly products, only 7% turn off unneeded lights or appliances, and just 6% curb water consumption").

184 The use of the term "inflated incentive" in this context is meant to reflect the fact that the level of demand for such products may exceed their net social value, as it does not take into account environmental externalities.

185 *See supra* note 140 and accompanying text.

F. Technological Solutions Addressing the Needs of Poor Populations

One other parameter that may dilute the signal of social value produced by a market-based platform for incentivizing innovation is the inability of consumers to pay for various innovative products and services. This is often pointed out in discussions regarding distributive implications of the patent system, as its reliance on the market may result in undersupplying production for the poor, particularly when the rich and the poor have different needs.[186] This problem is evident, for example, in the global health field, where due to the poor's limited ability to pay, very few medicines are developed for diseases that affect them but have little or no impact upon the rich.[187]

Inability to pay may surely dilute the signal of social value produced by the patent system in the context of green innovation as well. Some low-income consumers may not have the means to pay for eco-friendly products, even if they would otherwise have wanted to.[188] The same goes with respect to developing countries, in their capacity as consumers of innovative goods. This may be highly problematic in regard to solutions that are particularly required to address the needs of poor populations.[189] Indeed, in light of "extremely heterogeneous local conditions," different countries may have different needs for technological solutions that would enable them to participate in the global effort to mitigate climate change and adapt to its consequences.[190] For instance, countries may differ from each other in terms of the availability of certain alternative energy resources.[191] As another example, a country with a greater reliance on the agricultural sector may be in dire need of various solutions that enable adaptation to increasing temperatures, which are less of a concern for other, more industrial

186 *See, e.g.*, Kapczynski, *supra* note 64, at 996–99 (highlighting the concern that using IP to generate innovation will undersupply production for the poor); Lee, *supra* note 81, at 69 (maintaining that the patent system fails to generate social innovations that address the "substantive needs of underprivileged populations").

187 William W. Fisher & Talha Syed, *Global Justice in Healthcare: Developing Drugs for the Developing World*, 40 U.C. DAVIS L. REV. 581, 613 (2007); Hemel & Ouellette, *supra* note 64, at 328; Kapczynski, *supra* note 64, at 999 n.109; Maxwell R. Morgan, *Medicines for the Developing World: Promoting Access and Innovation in the Post-*TRIPS *Environment*, 64 U. TORONTO FAC. L. REV. 45, 51 (2006); Arti K. Rai, *The Ends of Intellectual Property: Health as a Case Study*, 70 L. & CONTEMP. PROBS. 125, 130 (2007).

188 *See supra* note 163 and accompanying text (discussing the costs of eco-friendly products).

189 *See* Adler, *supra* note 2, at 17 (noting that private markets may not incentivize "technological innovations that would be of primary benefit to low-income consumers and people in developing nations").

190 Hall & Helmers, *supra* note 13, at 492, 510 (noting that "required technologies may not be the same in developed and developing countries").

191 *See, e.g.*, Mark Z. Jacobson & Mark A. Delucchi, *Providing All Global Energy with Wind, Water, and Solar Power, Part I: Technologies, Energy Resources, Quantities and Areas of Infrastructure, and Materials*, 39 ENERGY POL'Y 1154, 1162–1163 tbls.5 & 6 (2011) (comparing the availability of certain raw materials required for the operation of various alternative energy systems among different countries).

countries.[192] To the extent that a developing country, in a need for such an innovative solution, does not have the means to pay for it, then, if we rely on private markets—such a solution may never be developed.[193] Sure enough, due to the global nature of climate change, this may ultimately have a detrimental impact on the entire planet.[194]

G. Highly Nonexcludable Innovation

So far, the analysis has focused on various parameters that could result in a gap between market value and social value in different contexts. Yet, even if market demand accurately reflected social value, some types of innovations are more difficult to exclude than others. As a result, expected private returns to inventors under the patent system may not correlate with market value. This point has been recently made by Amy Kapczynski and Talha Syed, who demonstrated, through detailed examples in the context of public health, that the ability to exclude others, upon which the patent system relies in providing incentives to invent, operates in asymmetrical ways for different kinds of information goods.[195] Hence, "patent rights have the potential to predictably and systematically distort private investment decisions over innovations by overstating the value of highly excludable information goods and understating the value of highly nonexcludable ones."[196] Ultimately, valuable innovations that happen to be closer to the nonexcludable end of the continuum may be undersupplied by the patent system.

In the environmental context, this may be relevant, for instance, with respect to industrial methods that are designed to "green" certain aspects of the production process of manufactured goods.[197] To the extent that the use

192 *See, e.g.*, Hall & Helmers, *supra* note 13, at 488, 508–09 (discussing developing countries' greater reliance on the agricultural sector).

193 *See, e.g.*, Adler, *supra* note 2, at 17 (noting that "not many firms see massive profit opportunities in developing low-carbon energy options for developing nations"). The concern for insufficient incentive in these circumstances is likely to be particularly acute with respect to adaptation measures, due to the global nature of mitigation efforts.

194 *See* FREDERICK M. ABBOTT, INT'L CTR. FOR TRADE & SUSTAINABLE DEV., INNOVATION AND TECHNOLOGY TRANSFER TO ADDRESS CLIMATE CHANGE: LESSONS FROM THE GLOBAL DEBATE ON INTELLECTUAL PROPERTY AND PUBLIC HEALTH 1 (2009), https://perma.cc/7SPV-TBHV ("Innovation must take into account different geographic, wealth and environmental conditions because technologies suitable for implementation only in wealthy developed countries may result in a shift of greenhouse gas output to less wealthy regions."). However, climate change may ultimately have a disproportionate negative effect on developing countries, among other things, due to their greater reliance on agriculture. *See, e.g.*, Hall & Helmers, *supra* note 13, at 508–09 (discussing the "enormous inequality in the consequences of climate change between developed and developing countries").

195 *See generally* Kapczynski & Syed, *supra* note 84.

196 *Id.* at 1907.

197 Another context, discussed above, where the difficulty of enforcing exclusive rights is among the factors that weaken the effectiveness of patent incentives, is upstream innovation. *See supra* notes 113–114 and accompanying text. With respect to basic research, see *supra* note 94 and accompanying text.

of such a "green" production method by competitors of the patent owner can be kept in secrecy and is not embedded in the final product, it might not be possible for the owner of a patent on such a method to detect and prove infringement.[198] In light of the difficulty to enforce exclusive rights in such inventions, patents may fail to serve as an effective incentive mechanism in this context.

To be sure, some firms—ones that emit greenhouse gas in the course of their industrial activity—may still be motivated in certain cases to attempt developing such methods for their own use. They may do so, for example, in order to abide by regulatory standards or for public relations purposes.[199] In some instances, "greening" operations may even reduce operation costs or result in another concrete benefit to the implementing firm.[200] Yet, such motivations would not play any role with respect to firms whose primary business is the development of innovative products or processes for use by others. The latter type of firms can only profit from green innovation by commercializing the ensuing products or processes—yet, when the ability to enforce exclusive rights is limited, they may not have an incentive to engage in such endeavors.[201]

As to industrial firms that may develop such methods for their own use—considering the relative ineffectiveness of patents in this domain—they might rationally prefer to keep any innovative methods they develop in secrecy, whenever this is possible, in order to gain a competitive advantage over their competitors.[202] Thus, unfortunately, such results are not likely to be widely disseminated.

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198 *See* Alan Wright, *The North American Free Trade Agreement (NAFTA) and Process Patent Protection*, 43 AM. U. L. REV. 603, 607–08 (1994) (describing the inherent difficulty of proving infringement of a process patent).

199 For a discussion of the reasons why businesses may choose to "green" their operations, see *supra* notes 127–131 and accompanying text. Yet, as explained above, generally speaking, profit-maximizing firms cannot be expected to accord much weight to environmental considerations. *See supra* Part III.D.

200 *See supra* note 126 and accompanying text.

201 *Cf.* Mandel, *supra* note 13, at 53 (distinguishing between "firms that cause environmental degradation . . . and firms whose primary business is developing products or processes to reduce environmental degradation," and pointing out that the latter type of firms can only profit by disclosing and selling their inventions). With respect to the distinction between these two types of firms, see *supra* note 133 and accompanying text.

202 *Cf.* Derzko, *supra* note 65, at 57 (noting, as part of the discussion of state-issued permits, that "[a] polluting firm may have a tendency to not disseminate its new innovations because it will gain a direct competitive advantage over its competitor who, in the absence of the new technology, will be forced to purchase expensive new permits. This counter-diffusion incentive may hurt the public because some new technologies will not be widely adopted across industry."). *But see* Mandel, *supra* note 13, at 53–54 (arguing that when the greener method increases operation costs, "the implementing firm would prefer that competing firms implement the environmental innovation as well, in order to level the operations-cost playing field," and hence, it will not seek to keep its innovation secret).

H. Low-Tech Solutions

The final point in this critical analysis of the way patent incentives function in promoting green innovation has to do with the design of the patent system itself. While seemingly extending its protection uniformly to "anything under the sun that is made by man,"[203] patent protection only applies to certain types of innovation—technological inventions that meet the statutory patentability criteria. The IP Clause of the U.S. Constitution empowers Congress "[t]o promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."[204] While the term "Science" is generally understood as referring to knowledge, the term "useful Arts" used by the Framers is commonly equated with the modern-day term "technology."[205] Hence, even though the U.S. Patent Act[206] does not impose an explicit requirement that the invention must be in a technological field, the technological character of an invention does constitute a central element in patent-eligibility determinations.[207] The requirements of novelty and non-obviousness further reinforce this focus. Hence, non-technological innovations are essentially outside the scope of patent protection.[208]

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203 Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980).

204 U.S. CONST. art. I, § 8, cl. 8.

205 *See, e.g.*, Alan L. Durham, "*Useful Arts*" *in the Information Age*, 1999 BYU L. REV. 1419, 1425, 1437 (noting that "courts and scholars have suggested 'technological arts' as the modern-day equivalent of the term 'useful arts'"); Karl B. Lutz, *Patents and Science: A Clarification of the Patent Clause of the U.S. Constitution*, 18 GEO. WASH. L. REV. 50, 54 (1949) ("The term 'useful arts,' as used in the Constitution and in the titles of the patent statutes is best represented in modern language by the word 'technology.'"); Richard H. Stern, *Scope-of-Protection Problems with Patents and Copyrights on Methods of Doing Business*, 10 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 105, 128 (1999) ("Some case law has attempted to resolve the definitional problem by defining the useful arts as those that involve application or utilization of technology, and thus equating the useful arts to the 'technological arts.'"). For interpretation of the term "useful arts," see Sean M. O'Connor, *The Overlooked French Influence on the Intellectual Property Clause*, 82 U. CHI. L. REV. 733, 739–41 (2015); Sean M. O'Connor, *The Lost "Art" of the Patent System*, 2015 U. ILL. L. REV. 1397, 1415–19.

206 Act of July 19, 1952, ch. 950, 66 Stat. 792 (codified as amended in scattered sections of 35 U.S.C.).

207 *See, e.g.*, Morris, *supra* note 91, at 62 ("[A]lthough the Federal Circuit has rejected technological arts as a linguistically bright-line test, the court implicitly recognize that, given the Constitution's mandate, all patentable subject matter must be technological by some measure." (footnote omitted)); *see also* Amy L. Landers, *Patentable Subject Matter as a Policy Driver*, 53 HOUS. L. REV. 505, 530 (2015) ("The patentable subject matter requirement has been described as a technological arts test.").

208 *See* Clark D. Asay, *Intellectual Property Law Hybridization*, 87 U. COLO. L. REV. 65, 70 (2016) (noting that "technological innovation . . . is generally viewed as the domain of patent law"). For a discussion regarding specific types of innovations that are not typically covered by patents, see, e.g., Lee, *supra* note 81, at 17–21, 43–47 (explaining why "social innovation," which includes innovations in fields like cognitive behavioral therapy, microfinance, and strategies to reduce hospital-based infections, is not likely to be patentable); Shlomit Yanisky-Ravid, *Eligible Patent Matter—Gender Analysis of Patent Law: International and Comparative Perspectives*, 19 AM. U. J. GENDER SOC. POL'Y & L. 851, 876 (2011) (proposing, in the context of a feminist analysis of patent law, that the patent system will accommodate "patent applications in new categories, such as social, educational, psychological, and familial inventions").

Furthermore, within the realm of the technological arts, patent law—with its rather rigid requirements for protection—is often said to be biased towards high-tech inventions over low-tech inventions.[209]

Notably, green technologies range from high-tech inventions, such as genetically modified seeds for drought resistance, to low-tech inventions, such as mechanical farming techniques.[210] The more low-tech an invention is, the higher the chances are that it would not meet the requisite patentability requirements. To illustrate, an attempt to patent a method to improve efficiency of water use by proper irrigation scheduling, or methods of using natural alternatives in lieu of various industrial products, may fail on patent-eligibility, novelty, or non-obviousness grounds.

Furthermore, while this Article focuses on technological innovation, it is important to note, in brevity, that there are many types of non-technological innovations that may be highly valuable as well in the attempt to mitigate and adapt to climate change. Consider, for instance, creative methods to educate consumers regarding the environmental impact of their market choices or to enable them to reduce consumption.[211] These types of "no-tech" innovations are clearly outside the scope of patent protection. Thus, in this context as well, society cannot rely on patents to provide effective incentives to innovate.

In theory, as this limitation of patents has to do with the particulars of the legal regime, one could consider addressing it by amending the law. The proposal could be to make patentability requirements more lenient in various manners so that patent protection would be available to certain low-tech (and even no-tech) inventions of the sorts described above. Yet, amending patent law in such a manner may not be feasible. Among other things, patent law applies in a uniform manner to various technological fields,[212] and it may not be possible to make such changes in the particular domain of climate change innovation without simultaneously impacting patentability standards in other industries.[213] Even if this was a feasible step,

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209 *See, e.g.*, Michael Halewood, *Indigenous and Local Knowledge in International Law: A Preface to* Sui Generis *Intellectual Property Protection*, 44 MCGILL L.J. 953, 955 (1999) ("Through the application of relatively rigid criteria for protection, intellectual property law, as it pertains to genetic resources, tends to favour high-tech innovations that require expensive, long-term institutional investment in research and development."); Alejandro Madrazo, *Biocolonialism: TRIPs and the Genetic No Man's Land*, 25 GEO. INT'L ENVTL. L. REV. 487, 489 (2013) ("Intellectual property law regulates technology with deeply entrenched biases that disregard 'low tech' means of innovation and wealth creation . . . while it simultaneously overvalues 'high tech' applications that do not necessarily create wealth or innovate at all."); *see also* Stern, *supra* note 205, at 128 n.100 (noting that "many arts well recognized as useful arts are not technological or are so 'low tech' as not to deserve the designation of technological art").

210 Hall & Helmers, *supra* note 13, at 509–10; Xiang, *supra* note 5, at 222.

211 *See supra* notes 150–159 and accompanying text (regarding the limited awareness of the public that education could potentially alleviate).

212 *See, e.g.*, Burk & Lemley, *supra* note 64, at 1576 (noting that "the patent statute creates a general set of legal rules that is designed to govern a wide variety of technologies").

213 However, one could consider adopting a *sui generis* form of protection for environmental technologies. For a detailed proposal for such a regime, see Derzko, *supra* note

the benefits of patent protection in these contexts are doubtful. Many inventions of the types described above are likely to face low market demand—if they could be commercialized at all—and be highly nonexcludable,[214] and hence, the availability of patent protection would not provide a significant incentive to develop them.[215] At the same time, exclusive rights may not be a prudent incentive mechanism in this context, in light of the need for a wide diffusion of such practices in order to make a significant impact on the state of the environment.

Admittedly, in these contexts, there may be generally a lesser need to invest significant amounts of money in R&D, and hence, there is arguably a lesser need for state intervention in order to secure incentives to develop such solutions.[216] Yet, even to the extent this is true, by emphasizing the need for high-tech solutions and harnessing the patent system to incentivize their development, we may divert intellectual resources away from engaging in the development of such low-tech and no-tech solutions.[217] More generally, the emphasis on techno-fixes to the environmental problem may reinforce the common—though wrong—belief that we can preserve our current lifestyle and continue consuming away without worrying at all about the environmental impact of our behavior.[218]

IV. IMPLICATIONS

Part III highlighted various factors that undercut the ability of the patent system to effectively incentivize climate change innovation. Part IV will explore the potential implications of these findings.

A. Awareness

To begin with, it is important to simply acknowledge the shortcomings of the patent system in the environmental domain. We can rejoice in the great technological advancements of recent years and celebrate the accelerated pace of patent applications in the field, but at the same time, we must be aware of the fact that certain directions of R&D, which could bear a

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65, at 14 ("Congress should consider . . . introducing new legislation that would be specifically formulated for environmental technology.").

214 *See supra* Part III.G.

215 *Cf.* Lee, *supra* note 81, at 45 (concluding, for similar reasons, that patenting social innovations "would be unlikely to generate significant revenues").

216 *See* Xiang, *supra* note 5, at 222 ("Patents rights are likely more relevant to the drought-resistant seeds, which may require more R&D investments than the mechanical farming techniques.").

217 *See* Harsch, *supra* note 143, at 545 (positing that the literature on altering consumption is flawed in over-emphasizing technical solutions while neglecting cultural ones).

218 *See* KLEIN, *supra* note 148, at 89–90 (noting that public relation efforts by advocates of green capitalism portray "a picture of a world that can continue to function pretty much as it does now, but in which power will come from renewable energy and all of our various gadgets and vehicles will become so much more energy-efficient that we can consume away without worrying about the impact").

significant contribution to environmental outcomes, may not be effectively incentivized by the prospect of patent rewards.

In a sense, this Article cautions against "greenwashing" in discussing the role of the patent system in the environmental domain. Greenwashing occurs when "disinformation [is] disseminated by an organization so as to present an environmentally responsible public image."[219] Emphasizing the patent system's positive role in incentivizing certain types of green technologies, without noting its inability to incentivize many others, operates like "greenwashing" in conveying an optimistic message, while masking the fact that patents are, in fact, far from an ideal incentive mechanism in this domain.

In fact, the patent system may actually contribute to the environmental problem by incentivizing economic activities that negatively impact the environment. Such a potential negative impact of the patent system on the environment has not been studied so far. Technological innovation results in the introduction of a wider selection of products and services to the marketplace, and by doing so, it may bring about an increase in the overall level of consumption. Likewise, innovation may accelerate the pace of development of improvements in a manner that leads to quicker obsolescence of existing products. A discussion of the possible manners by which the patent system may negatively impact the environment is outside the scope of this Article's analysis. It is sufficient, for the purposes of the discussion herein, to acknowledge that the effectiveness of patents as an incentive mechanism in the environmental domain is limited.

Notably, as the analysis in Part III demonstrates, the difficulty to rely on patent incentives to promote environmental innovation results primarily from an inherent feature of the patent system: its reliance on market exclusivity as the means to incentivize innovation. Accordingly, adjusting patent doctrine or revising the patenting process in manners that favor climate change technologies is not likely to resolve the fundamental problems discussed in Part III.[220] This, of course, does not mean that patent scholars and policy makers should stop engaging in efforts to fine tune the patent system in order to make it easier to obtain environmental patents and strengthen patent incentives while preserving wide access to patented technologies. Yet, such initiatives clearly cannot suffice. Parts IV.B and IV.C explore other directions that may need to be pursued as well.

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219 Jacob Vos, Note, *Actions Speak Louder Than Words: Greenwashing in Corporate America*, 23 NOTRE DAME J.L. ETHICS & PUB. POL'Y 673, 673–74 (2009) (quoting *Greenwash*, CONCISE OXFORD ENGLISH DICTIONARY (10th ed. 2003)).

220 For a discussion of such initiatives, see *supra* notes 66–70 and accompanying text. *See* Mandel, *supra* note 13, at 62 (noting that the regulations prioritizing environmental patents in the United States "are rarely utilized" and concluding that "streamlining patent prosecution would not significantly increase incentives for environmental innovation"); *see also* Derzko, *supra* note 65, at 12 (pointing out that the failure of such regulations to incentivize environmental patenting may result from the fact that the patent system "is not an effective stimulant for environmental technology innovation").

B. Resort to Alternative Incentive Mechanisms

In light of the patent system's shortcomings in the environmental domain, the analysis conducted in this Article supports increasing the use of other policy instruments for incentivizing innovation alongside the patent system.[221] There is a variety of such alternative incentive mechanisms that may be applicable in different contexts.[222] In the environmental domain, two non-patent incentive schemes that seem to hold a particular promise are prizes (monetary rewards provided to the first person to deliver a specified invention),[223] and direct *ex ante* governmental funding via R&D subsidies and grants, cooperation agreements, or procurement.[224]

Despite the central role of the patent system in discussions of incentives for R&D,[225] there has been a reemerging scholarly interest in the foregoing alternative mechanisms in recent years.[226] Several scholars have also noted the potential beneficial use of such alternative mechanisms in the specific context of environmental innovation.[227] Sure enough, governments

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221 For a discussion of alternative institutional mechanisms for incentivizing innovation, see Tur-Sinai, *supra* note 7, at 189–94. *See also* Gallini & Scotchmer, *supra* note 87, at 53; Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115, 122 (2003) (discussing patent prize systems); Frischmann, *supra* note 103, at 348; Hemel & Ouellette, *supra* note 64, at 307; Joshua D. Sarnoff, *Government Choices in Innovation Funding (With Reference to Climate Change)*, 62 EMORY L.J. 1087, 1116–23 (2013) (describing various policy instruments to incentivize innovation); Steven Shavell & Tanguy van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525, 525 (2001) (comparing patent prizes to the traditional process of awarding patent rights); Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691, 695 (1983).

222 Aside from the funding schemes discussed above, other possible approaches to encourage innovation that have recently gained scholarly attention and that might be relevant in the environmental context are tax incentives (see Shaun P. Mahaffy, Note, *The Case for Tax: A Comparative Approach to Innovation Policy*, 123 YALE L.J. 812, 817 (2013); Hemel & Ouellette, *supra* note 64, at 306) and commons-based schemes (see Shur-Ofry, *supra* note 117, at 391–92). For simplicity reasons, this Article will not discuss these approaches.

223 For sources discussing prizes as an incentive mechanism, see, e.g., Gallini & Scotchmer, *supra* note 87, at 53; Hemel & Ouellette, *supra* note 64, at 311; Kapczynski & Syed, *supra* note 84, at 1904. Similarly to patents, the reward under a prizes scheme is provided *ex post*, upon successful completion of the project. *See* Hemel & Ouellette, *supra* note 64, at 308.

224 Under this category of incentive mechanisms, the literature also typically addresses direct spending on research carried out by government agencies. *See, e.g.*, Frischmann, *supra* note 103, at 387–88; Hemel & Ouellette, *supra* note 64, at 320–21; Kapczynski & Syed, *supra* note 84, at 1904. For a survey of different forms of direct governmental funding of innovation, see Danielle Conway-Jones, *Research and Development Deliverables Under Government Contracts, Grants, Cooperative Agreements and CRADAs: University Roles, Government Responsibilities and Contractor Rights*, 9 COMPUTER L. REV. & TECH. J. 181, 188–201 (2004).

225 *See supra* note 64 and accompanying text.

226 *See* Hemel & Ouellette, *supra* note 64, at 305 (describing this trend). For examples of scholarly work in this domain, see *supra* notes 221–224 and sources cited therein.

227 *See, e.g.*, Adler, *supra* note 2 (advocating the use of prizes in order to encourage development of climate change technologies); Hall & Helmers, *supra* note 13, at 489 (exploring the possibility of using targeted R&D subsidies to foster green innovation); Jaffe et al., *supra* note 13, at 173 (discussing various policy measures that may be used to foster environmental innovation, including, for example, public-private partnerships); Mandel, *supra* note 13, at 64 (advocating a shift to an innovation rewards system—under which the government acquires

already employ these (and other) types of mechanisms to incentivize innovation alongside the patent system.[228]

The critical analysis of the patent system conducted in this Article supports this direction and provides further justifications to look beyond IP while designing innovation policy. Recognizing the substantial limitations of the patent system as an incentive mechanism in the particular domain of climate change technologies reinforces the need to afford a significant role to non-patent incentive schemes in this context and attend to important questions related to the operation of such schemes. This Article's systematic exploration of the patent system's limitations can assist in identifying the categories and types of innovations with respect to which the need to rely on such non-patent mechanisms may be particularly acute.[229] For instance, while the case for direct government funding of basic research is well established, it is much less so with respect to applied research.[230] Yet, once we acknowledge that patents may underperform even in the context of green consumer goods, as this Article's analysis clearly shows,[231] it becomes apparent that governments must find ways to supplement patent incentives in regard to downstream R&D as well.

The main advantage of the aforementioned alternative schemes over the patent system in the context of climate change technologies is that they do not rely on market demand in directing the allocation of resources for R&D. While patents are generally considered superior to other incentive mechanisms because of their ability to use "private information about the value of inventions" to direct innovation,[232] in a context where market demand so clearly fails to reflect societal needs, the use of alternative

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rights to patentable subject matter in exchange for compensation to the inventor and then makes the invention available for use by the general public—in order to increase incentives for environmental innovation); Gregory N. Mandel, *Innovation Rewards: Towards Solving the Twin Market Failures of Public Goods*, 18 VAND. J. ENT. & TECH. L. 303, 313–17 (2016) (elaborating on said proposal); Sarnoff, *supra* note 221, at 1116–56 (providing a taxonomy of government innovation funding choices with reference to climate change).

228 *See* Hemel & Ouellette, *supra* note 64, at 316 (noting that the "federal government currently uses prizes, patents, grants, and tax credits to incentivize the invention and commercialization of new technologies").

229 *See also infra* notes 234–238 and accompanying text.

230 *But see* Adler, *supra* note 2, at 17–18 (noting, while comparing between prizes and grants, that "the use of a prize mechanism is dependent upon the initial identification of a particular problem that needs to be solved or goal to be achieved. As a consequence, prizes may be better suited for applied research than for basic scientific research.").

231 *See supra* Part III.E.

232 Kapczynski & Syed, *supra* note 84, at 1911–12; *see* Howard F. Chang, *Patent Scope, Antitrust Policy, and Cumulative Innovation*, 26 RAND J. ECON. 34, 50 n.31 (1995) (noting that "the regulatory authorities lack information that innovators possess, such as knowledge about the demand for inventions," and therefore, the patent system is superior in ensuring that "the monopoly profit extracted from the market is correlated with the social surplus created by the invention"); Tur-Sinai, *supra* note 7, at 155–56 (summarizing the traditional argument regarding the superiority of patents over nonmarket institutional arrangements); *see also supra* notes 85–87 and accompanying text.

mechanisms may actually be advantageous.[233] Among other things, such nonmarket incentive mechanisms can be used to incentivize basic and upstream research,[234] development of innovative products and processes that are not highly demanded by businesses or individual consumers,[235] and innovative solutions that are required to address the needs of poor populations.[236] In addition, as these alternative incentive schemes do not rely on exclusionary mechanisms in providing incentives to innovate, they can be used to promote development of valuable but highly nonexcludable innovations.[237] Furthermore, such alternative mechanisms may be more compatible with a broader definition of innovation that does not necessarily focus on "techno-fixes" but may encompass other types of innovative solutions as well.[238]

More generally, within such nonmarket institutional arrangements, there is a greater role for the state in setting and implementing innovation policy, and hence, it is easier to account for environmental considerations. Under such schemes, it is the government—rather than the market—that establishes the criteria for receipt of a reward.[239] The government sets the targets within a prizes scheme, defines categories of research within which grants are available, and prioritizes research projects conducted in its own laboratories.[240] In doing so, the government may prioritize the need to develop climate change technologies. The government may also set various criteria and conditions for funding that relate to the environmental impact of the innovation at hand. Such criteria and conditions "could be incorporated, for example, into guidelines for peer review of grant applications [or] in award criteria for procurement auctions."[241]

Under both the prizes and public-funding schemes, the government sets the size of the reward as well. With respect to prizes, though administrators commonly fix the reward in advance, various scholars have advocated for the use of sales data—or other proxies of the invention's actual impact—in setting the reward.[242] Notably, in the specific context of climate change

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233 *See* Mandel, *supra* note 13, at 68 ("[T]here is no reason to expect that the market values inventions more accurately than a rewards system would generally, and in the case (as here) where there are significant externalities that result from the use of an invention, the market is expected to value the invention much less accurately than a patent rewards system."); *see also* Adler, *supra* note 2, at 14 ("Like traditional research and development . . . grants, government supported prizes reward innovations that 'are publicly valued but not privately marketable.'").

234 *See* discussion *supra* Parts III.B–.C.

235 *See* discussion *supra* Parts III.D–.E.

236 *See* discussion *supra* Part III.F; *see also* Adler, *supra* note 2, at 17 ("Prizes can also be particularly important to spur investment in technological innovations that would be of primary benefit to low-income consumers and people in developing nations.").

237 *See* discussion *supra* Part III.G.

238 *See* discussion *supra* Part III.H.

239 *See* Abramowicz, *supra* note 221, at 119, 121; Adler, *supra* note 2, at 4–5, 12.

240 *See* Tur-Sinai, *supra* note 7, at 191–93.

241 *Id.* at 193.

242 *See, e.g.*, Abramowicz, *supra* note 221, at 175–76 (discussing the advantages of basing rewards on sales); Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON. 1137, 1146–47 (1998) (proposing an *ex post* patent buyout mechanism that uses

technologies, due to the significant gap between market demand and social value, sales data cannot serve as a good measure of social value, and other assessments of *ex post* outcomes (e.g., in terms of reduced greenhouse gas emissions) need to be articulated.[243]

One "side benefit" of nonmarket funding mechanisms—which is, in fact, often presented as their main virtue—lies in their potential to foster innovation while avoiding the deadweight loss resulting from noncompetitive pricing of patented inventions.[244] This is, indeed, a major benefit in the particular context discussed in this Article, in light of the significance of ensuring broad access—both by consumers and by follow-on inventors—to climate change technologies.[245]

Surely, these alternative institutions for incentivizing innovation are far from perfect, and there are many challenging aspects associated with their operation that must be attended to. One of the major difficulties relates to the need for the government to allocate funding without access to information regarding the "costs and benefits of R&D investments" reflected in market prices.[246] Yet, as explained above, where market demand systematically fails to reflect social value, the patent system loses its informational advantage, and the government's greater involvement should be viewed as an opportunity rather than a drawback. In fact, administrative agencies that deal with environmental matters may have a significant amount of information at their hands that can be used as a basis for funding decisions in this domain.[247] In addition, decision makers have ample opportunity to retrieve input from researchers and industry players throughout the process. For instance, with respect to grants, researchers are typically invited to submit proposals for R&D projects under broad

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an auction in order to elicit information regarding the value of the invention); Shavell & van Ypersele, *supra* note 221, at 541 (proposing the use of sales data by the government).

243 *See* Mandel, *supra* note 13, at 64 (arguing that "for the purposes of environmental innovation, compensation could be based on the expected environmental benefit provided to society by the invention").

244 *See, e.g.*, Gallini & Scotchmer, *supra* note 87, at 54 ("Monopoly pricing is equivalent to taxing a single market, which is generally thought to impose greater deadweight loss than the broad-based taxation that generates general revenue."); Hemel & Ouellette, *supra* note 64, at 381 ("Prizes and grants also avoid the deadweight losses associated with patent monopolies . . . ."); Mandel, *supra* note 13, at 65 (noting that "rewards systems . . . reduce the deadweight loss created by grants of traditional patent monopoly rights"). Notably, however, under U.S. policy, recipients of prizes or direct public funding are generally permitted to seek patent protection as well. *See, e.g.*, Hemel & Ouellette, *supra* note 64, at 316 (noting that "U.S. policy typically uses patents as a *complement*, so that innovators may be rewarded through patents, and prizes, grants, or tax incentives" (footnotes omitted)). For example, under the Bayh-Dole Act, 35 U.S.C. §§ 200–211 (2012), results of research funded by federal grants may be patented by the grant recipient. Hemel & Ouellette, *supra* note 64, at 380. Clearly, if patent protection is used as a complement, this "side benefit" of the alternative schemes cannot be realized.

245 *See supra* note 5 and accompanying text.

246 Gallini & Scotchmer, *supra* note 87, at 54–55.

247 *See* Mandel, *supra* note 13, at 66 ("[V]aluing environmental benefit is a practice that multiple administrative agencies already engage in, both explicitly and implicitly.").

categories set by the administrator.[248] Similarly, under a prizes scheme, the government generally sets innovation targets, but it does not dictate the specific directions that should be pursued in search of a solution, and it leaves such directions open for exploration by the potential candidates themselves.[249] "Even in setting targets, the government can employ a relatively low degree of specificity and permit creativity on behalf of innovators in choosing projects."[250]

Aside from the challenge associated with the need to allocate funding without relying on the invisible hand of the market, direct government funding of innovation might also involve the risks of politicization, regulatory capture, and mismanagement.[251] A different challenge has to do with the need to raise general revenue in order to fund such schemes.[252] While this Article does not purport to resolve these problems associated with the operation of non-patent incentive mechanisms, it reinforces the need for a continuing inquiry by scholars and policy makers regarding the challenges at hand. Due to the significant shortcomings of a market-based approach in regard to the particular domain of climate change technologies, discussion of innovation policy in this context must devote adequate attention to the ability of employing non-patent mechanisms.[253]

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248 *See, e.g.*, Frischmann, *supra* note 103, at 388 ("Grants are often employed to support or stimulate innovation without a predetermined application or result in mind."); *cf.* Gallini & Scotchmer, *supra* note 87, at 56 (noting that "[f]or medical research, the sponsor may solicit open-ended proposals").

249 *See* Kapczynski & Syed, *supra* note 84, at 1954 (distinguishing between setting innovation targets and finding the most promising lines of attack); *see also* Marchant, *supra* note 45, at 836 (positing that "the government should set the performance goals, but should avoid, as much as possible, picking which specific technologies should be developed to achieve those goals").

250 Tur-Sinai, *supra* note 7, at 191. Admittedly, though, the lower the degree of specificity in setting the prize criteria, the more uncertainty market players have as to their chances to win the prize and, therefore, a lower incentive to assume the risk.

251 *See* Hemel & Ouellette, *supra* note 64, at 327; Joshua D. Sarnoff, *The Likely Mismatch Between Federal Research & Development Funding and Desired Innovation*, 18 VAND. J. ENT. & TECH. L. 363, 366, 380 (2016) (pointing at the likely mismatch between the way funding decisions are actually made and desired innovation policy); *see also* Frischmann, *supra* note 103, at 361 n.45 (discussing the need to "recognize the public choice concerns regarding [regulatory] capture by special interest groups"). Notably, such concerns exist in the "patent district" as well, where the legislature is subject to intense pressure on behalf of interest groups. *See, e.g.*, Christopher M. Holman, *Biotechnology's Prescription for Patent Reform*, 5 J. MARSHALL REV. INTELL. PROP. L. 318, 325 (2006) (noting that the biotechnological industry "is against virtually all of the major proposed reforms [to patent law] that would weaken patents or restrict the rights of patent holders"); Jay P. Kesan & Andres A. Gallo, *The Political Economy of the Patent System*, 87 N.C. L. REV. 1341, 1353, 1359–61 (2009) (discussing the lobbying efforts on behalf of pharmaceutical companies in order to maintain a strong patent system).

252 *See, e.g.*, Hemel & Ouellette, *supra* note 64, at 314 (discussing the deadweight loss of taxation).

253 *See* Tur-Sinai, *supra* note 7, at 193–94 (arguing that this direction must be pursued in light of the failure of a market-based system to direct innovation in a manner that aligns with social value); *see also* Kapczynski, *supra* note 64, at 1026 (encouraging the adoption of "a broader frame of reference" for IP scholars and policy makers).

One final issue that must be attended to in regard to the potential use of nonmarket incentive schemes is the need to ensure that any products and processes induced by such schemes will ultimately be broadly diffused and implemented after they have been developed. This may be challenging in cases where, to start with, businesses or individual consumers are unwilling to pay an adequate amount of money for such technologies. In these cases, where demand is lacking, reverting to nonmarket mechanisms to incentivize development of green technologies could leave us with valuable products at hand, which only few care to use, in which case the potential contribution to the state of the environment may not be realized.[254] Yet, supply-side changes may very well impact demand. Among other things, prices may go down once there are more "green" options in the market,[255] and this may ultimately make the eco-products at hand more attractive to consumers.[256] Nevertheless, in some cases this may not suffice, and therefore, it is advisable that any governmental scheme that seeks to foster development of climate change technologies would consider the need to include certain policy measures directly targeting diffusion as well.[257] Such measures could encompass, for instance, restricting or taxing the sale or use of non-green products,[258] offering consumer subsidies for the purchase of green products,[259] and having the government purchase certain technologies for its own use, which may ultimately have a significant effect on the rate of

254 *See* Marchant, *supra* note 45, at 845 ("If consumers are unwilling to accept or pay for a new technology, that technology is unlikely to prosper. Therefore, policies that attempt to 'push' a technology onto unreceptive or even uninterested consumers are particularly prone to fail.").

255 Inventors may also charge less for their products, to start with, once their R&D costs are covered by the governmental award. In addition, in cases where the ensuing technology is not patented, competition by free riders who may manufacture and sell the same product or close imitations will surely drive down prices.

256 *See supra* note 163 and accompanying text (regarding the costs of eco-friendly products).

257 *See* Marchant, *supra* note 45, at 846 ("Incentives for consumers to purchase and use more sustainable technologies are an essential component of any program that seeks to 'push' new technologies onto the market when consumer demand for such products is latent or underdeveloped."); *see also* Hall & Helmers, *supra* note 13, at 489 (pointing out that the use of R&D subsidies may incentivize development of technologies that will not be adopted at "an optimal scale in the absence of a policy intervention directly targeting diffusion").

258 *See* Jaffe et al., *supra* note 13, at 172 (noting that "command and control regulations can also be used to try to force the diffusion of particular technologies, often by removing less expensive and less environmentally beneficial competing technologies from the market"); *cf.* Gourville, *supra* note 83, at 104–06 (arguing to "eliminate the old," which may assist in dealing with consumer resistance).

259 *See* Hall & Helmers, *supra* note 13, at 489 (discussing the potential use of subsidies to help consumers overcome the large up-front cost investment involved in the replacement of existing technology by a greener one, and thereby promote diffusion). Subsidizing the purchase of green technologies can also be done by offering tax credits. *See, e.g.*, Jaffe et al., *supra* note 13, at 171 ("Technology diffusion, and achievement of any associated benefits of dynamic increasing returns, can also be encouraged with tax credits that reduce the effective purchase price of new equipment that meets specified criteria.").

diffusion in other sectors as well.[260] Part IV.C shall deal in somewhat greater details with policy measures designed to affect demand for climate change technologies.

C. Demand Side Intervention

Whereas this Article recommends increasing the weight assigned to alternative schemes for incentivizing innovation, it does not prescribe avoiding the use of patents altogether in the environmental domain. To start with, in certain cases where public funding or prizes are available, patents could still be used as a complementary mechanism to bolster incentives.[261] In addition, as the use of nonmarket schemes imposes a budgetary cost on the government—to the extent that further increase of general revenue is not feasible—policy makers must rely on private markets. Finally, despite the benefits entailed in using the alternative mechanisms, in certain instances, patents may still be considered more advantageous for a variety of reasons.[262]

However, to the extent that the state wishes to rely on patents to incentivize the development of climate change technologies in an effective manner, it cannot ignore the deficiencies of patent incentives in this particular domain. Hence, the state must operate the patent system in tandem with other policy instruments that impact market demand for climate change technologies. The use of such policy measures is designed to turn patent signals regarding expected private returns from innovation more sensitive to environmental outcomes.[263]

Such measures can include, for instance, command-and-control regulation, which prescribes "what parties can and cannot do."[264] Such

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260 *See* Jaffe et al., *supra* note 13, at 171 ("As the government is a very large landlord, vehicle operator, and user of many other kinds of equipment, its decision to purchase certain technologies for its own use can have significant effects on the rate of diffusion."); *see also* Adler, *supra* note 2, at 44 (noting the possibility that prizes would "include advance market commitments, through which a government commits in advance to purchase a given quantity of an innovation that meets predetermined characteristics," in order to create "additional incentives to translate new inventions into commercially viable products"); *infra* note 273 and accompanying text.

261 For the possibility of using patents as a complement to prizes or public funding, see *supra* note 244 and accompanying text.

262 For instance, in some contexts it might be more sensible to fund an innovation by its direct beneficiaries than by the general public. *See generally* Hemel & Ouellette, *supra* note 64, at 345–52. In addition, as stated above, there are certain drawbacks associated with the use of nonmarket incentive schemes. *See supra* notes 246–252 and accompanying text.

263 For a similar observation, see Hall & Helmers, *supra* note 13, at 510 ("Given the double externality problem, a combination of policy interventions that address both the imperfect appropriability and the environmental externality are needed.").

264 James Salzman, *Teaching Policy Instrument Choice in Environmental Law: The Five P's*, 23 DUKE ENVTL. L. & POL'Y F. 363, 364 (2013); *see also* James W. Coleman, *How Cheap Is Corporate Talk? Comparing Companies' Comments on Regulations with Their Securities Disclosures*, 40 HARV. ENVTL. L. REV. 47, 53 (2016) (explaining that, as part of command-and-control regulation, "the agency directly mandates facilities' emission rates"); Thomas W. Merrill, *Explaining Market Mechanisms*, 2000 U. ILL. L. REV. 275, 275 ("Command-and-control

regulation can take various forms. Among other things, it can set performance standards, prescribing an allowable level of emissions while enabling flexibility in choosing the means to achieve compliance with the standard; or technology standards, requiring firms to implement a certain prescribed technology.[265] As examples for command-and-control regulation, consider a regulation that forces firms to install a pollution-reducing scrubber,[266] or restrictions on the use of incandescent light bulbs by homeowners.[267] While the primary goal of such regulation is to directly reduce environmental harm by the regulated parties, it may also serve as a catalyst for innovation, both by the regulated parties themselves and by innovative firms who can expect an increasing demand for innovative solutions that allow compliance with such regulation.[268]

Another approach entails the use of market mechanisms in order to cause the relevant parties to internalize the costs of environmental harms. Such mechanisms may include cap-and-trade programs, where a limit on emissions is set and tradeable emission rights are sold,[269] or the imposition of pollution (for example, carbon) tax.[270] By increasing the costs of using fossil fuels or engaging in other activities that cause environmental harm, such measures motivate firms to seek alternatives and thereby increase demand for environmentally superior technologies and incentivize

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regulation refers to a system of pollution control based on uniform standards of performance for sources of pollution.").

265 *See, e.g.*, Derzko, *supra* note 65, at 18–19 (describing both approaches); *see also* Jason J. Czarnezki & Katherine Fiedler, *The Neoliberal Turn in Environmental Regulation*, 2016 UTAH L. REV. 1, 4 (explaining that command-and-control regulation "can set effects-based standards or technology-based standards, demanding that harms do not surpass a specific threshold or requiring the use of certain technologies to reduce harm").

266 *See* Jonathan S. Masur & Eric A. Posner, *Toward a Pigouvian State*, 164 U. PA. L. REV. 93, 95 (2015).

267 *See* Hall & Helmers, *supra* note 13, at 511 (providing, as an example for top-down interventions, "restrictions on the use of technologies such as on incandescent light bulbs"); *see also* Bryan H. Druzin, *The Parched Earth of Cooperation: How to Solve the Tragedy of the Commons in International Environmental Governance*, 27 DUKE J. COMP. & INT'L L. 73, 84 (2016); *supra* note 51 and accompanying text (discussing light bulbs).

268 *See, e.g.*, Gollin, *supra* note 57, at 226 ("Technology-forcing environmental statutes and regulations create a market for environmental technology."); *see also* Derzko, *supra* note 65, at 21–22 (discussing the effect of various regulatory approaches on innovation). *See generally* Ayres & Kapczynski, *supra* note 155 (discussing the role that "innovation sticks" can play in innovation policy). As to the distinction between the two types of entities referred to in the text, see *supra* note 133 and accompanying text.

269 *See, e.g.*, Hall & Helmers, *supra* note 13, at 511 (explaining that cap-and-trade schemes involve a limit on total emissions and the sale of tradable emissions rights); Marchant, *supra* note 45, at 834 (naming cap-and-trade schemes among market approaches to promote sustainable energy technologies); *see also* Derzko, *supra* note 65, at 50 (explaining that "[u]nder a marketable permit regime, permits allowing firms to pollute are sold by the government and then traded among firms").

270 *See, e.g.*, Marchant, *supra* note 45, at 834 (listing carbon tax as another market approach to promote sustainable energy technologies); *see also* Harsch, *supra* note 143, at 553–54 (discussing green taxes as an example of a market-based approach for internalizing environmental externalities).

innovation in the field.[271] Another way to "create" market demand is by offering subsidies to consumers or businesses for the purchase or use of environmentally sound technologies.[272] Demand can also be increased by having the government commit to purchasing certain technologies for its own use.[273]

These different types of regulatory measures and market mechanisms constitute basic tools of environmental law and policy. While the potential "side effect" of such policy measures as catalysts of technological innovation is well recognized,[274] the important notion for the purposes of this Article is that such instruments may need to be directly integrated within innovation policy and employed in various contexts as supplementary measures to patent protection. Thus, innovation scholars and policy makers must attend to various questions related to the operation of such instruments and explore the interaction between the incentives they provide and patent incentives.

Finally, it is important to address one other type of "intervention" that could be employed to affect demand. As mentioned above, many people underestimate the potential impact of climate change and fail to make the connection between their own actions and the state of the environment.[275] Thus, the state needs to invest in educating the public and raise its "environmental consciousness." This may influence preferences and increase the weight consumers ascribe to environmental considerations while making market choices.[276] Furthermore, it is important to ensure that individuals who wish to act in a more environmentally responsible manner have adequate information that allows them to do so. Some measures that

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271 *See, e.g.*, Jaffe et al., *supra* note 13, at 165 ("Environmental policy interventions, such as carbon cap and trade systems and carbon taxes, generate incentives that will affect which new technologies will be developed and how rapidly and deeply they will diffuse."); *see also* Derzko, *supra* note 65, at 50 ("Such [market based] systems are believed to provide firms with continuous incentives to adopt environmentally superior technologies because, if sufficiently inexpensive pollution prevention or abatement technologies can be found, it is always in the interest of firms to clean up more pollution. If a firm produces less pollution, that firm will have to purchase fewer pollution permits under a marketable permit regime, or pay less in pollution taxes under a pollution tax regime." (footnote omitted)).

272 *See supra* note 259 and accompanying text.

273 *See, e.g.*, Taylor, *supra* note 45, at 2837 (noting, as an example, California, which "has been particularly creative and persistent in its approaches to creating markets for solar energy technologies," by, among other things, "act[ing] as a customer for these technologies through the state's procurement efforts"); *see also supra* note 260 and accompanying text (discussing the ability of the government to encourage adoption through its own use of certain technologies). *See generally* Denis Borges Barbosa & Charlene de Avila Plaza, *The Role of Government Procurement in Regard to Development, Dissemination and Costs of Climate Change Technologies*, *in* RESEARCH HANDBOOK ON INTELLECTUAL PROPERTY AND CLIMATE CHANGE, *supra* note 45, at 316 (explaining the role of government procurement in promoting technology development and transfer).

274 *See supra* notes 268–271 and accompanying text.

275 *See supra* notes 150–159 and accompanying text.

276 *See, e.g.*, Abbott & Booton, *supra* note 38, at 245 (positing that "by raising 'environmental consciousness,' information can lead to changes in behavior and decision-making" (footnote omitted)).

may be instrumental in this context are labeling and regulation of advertising.[277] Sure enough, education and information dissemination may ultimately result not only in increased demand for green products, in a manner that makes patent incentives to develop such products more effective, but also in reducing consumption altogether for the benefit of the environment.[278]

Part IV explored the possibility of resorting to various non-patent institutions and policy tools in order to substitute or supplement patent incentives. Ultimately, optimal innovation policy is context dependent, and certain combinations of incentive schemes and complementary instruments may be more adequate than others in different settings. Notably, in choosing among the various policy tools that may be employed alongside patent protection in order to bolster market demand, policy makers must take into account not only such tools' impact on incentives to innovate, but also various important considerations that exceed the scope of this Article's analysis.[279] Further research in the directions highlighted above, as well as "field experimentation" with various combinations of policy instruments, may enable more concrete prescriptions regarding optimal innovation policy in particular settings.[280]

V. SUMMARY

Climate change poses a major threat to mankind. This Article examines the role of the patent system in facilitating the development of technologies that may be instrumental in mitigating and adapting to climate change. While the literature attending to the interface between patents and the environment has dealt primarily with potential restrictions on access to patented technologies, this Article focuses on the question whether the patent system can effectively incentivize the development of such technologies from the start.

The analysis reveals that the patent system is far from an optimal incentive mechanism in the environmental domain, and thus, it cannot be trusted to adequately promote the development of climate change technologies. In various contexts—ranging from upstream innovation to

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277 *See, e.g.*, Czarnezki & Fiedler, *supra* note 265, at 1 (noting that such measures could "influence consumer preferences").

278 *Cf.* Harsch, *supra* note 143, at 555–56 ("Even green consumerism fails to address the underlying causes of overall demand, seeking only to create preferences for environmentally friendly goods.").

279 For relevant discussion, see, e.g., Masur & Posner, *supra* note 266, at 95 (analyzing various aspects related to the choice between Pigouvian taxes and command-and-control regulations). Clearly, these measures that are designed to affect demand are not effective when the problem with patent incentives does not have to do with lack of demand, but rather, for example, with low excludability. *See* discussion *supra* Part III.G. In such cases, even if demand exists, patents cannot effectively incentivize innovation; hence, in these instances, it seems that the incentive mechanisms discussed in Part IV.B may be a better choice.

280 *See, e.g.*, Lisa Larrimore Ouellette, *Patent Experimentalism*, 101 VA. L. REV. 65, 118 (2015) (discussing policy experimentation in the context of patent law).

green end-products—it appears that the reliance of patents on the market in rewarding inventors, coupled with other factors, may lead to a systematic failure of the patent system to adequately promote innovation in this field. Notably, the inherent limitations of a market-based platform discussed in this Article cannot be addressed by amending patent doctrine or revising the patenting process.

Thus, this Article concludes that in order to effectively incentivize development and diffusion of climate change technologies, there is a need to combine patents with other policy measures—some of which are designed to directly incentivize innovation (e.g., prizes and grants), while others are intended to impact demand and thereby enhance the effectiveness of patent incentives (e.g., command-and-control regulation, consumer subsidies, and information dissemination). The proposals made in this Article are not mutually exclusive, and this Article's ultimate recommendation is to embrace a flexible approach to innovation policy in the environmental arena that will make use of various combinations of policy measures in different settings and scenarios.