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Intellectual Property and Alternatives:

Strategies for Green Innovation

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INTRODUCTION

There is widespread agreement that achieving the very substantial reductions in greenhouse gas (GHG) emissions necessary to stabilize GHG concentrations at 450 to 750 parts per million (ppm) will require innovation and large-scale adoption of GHG-reducing technologies throughout the global energy system.[1] The associated policy debate is therefore not so much over the importance of new technology per se in solving the climate problem, but rather over what the most effective policies and institutions are for achieving the dramatic technological changes and associated emission reductions necessary for stabilization.

Although many policies and institutions relevant to green innovation have been discussed, one area to which relatively little attention has been paid until recently is intellectual property rights (IPRs). The absence of attention may stem from the reality that IPRs are, by design, decentralized, market-driven incentives that presume appropriate market signals on the demand side. In the area of green innovation, by contrast, the primary problem has been the absence of appropriate greenhouse gas (GHG) pricing and hence the absence of an appropriate demand side signal. However, assuming the demand side problem is fixed (through interventions such as carbon taxes or cap and trade systems,)[2] then the issue of how IPRs – and various alternatives to IPRs – can most usefully play a role in fostering the supply of green innovation will necessarily come to the fore.

In this report, we provide an analysis of how IPRs, and alternatives to IPRs, might operate in green innovation. Part I of the paper discusses the economics of green innovation, including the important role that will need to be played by the private sector. Because of the critical role of the private sector, demand side issues will need to be fixed in order for there to be an appropriate level of green innovation. Part II discusses the IPR issues, principally involving patents, that may arise if and when GHG externalities are addressed through the appropriate pricing of greenhouse gases. Because these problems will primarily arise in the future (if at all), we rely heavily in this

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[1] IPCC, *Climate Change 2007: Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A.(eds.)]. IPCC: Geneva, Switzerland, 2007.

[2] For reviews of the policy options to limit greenhouse gas emissions, including the effect of such policies on private sector innovation, see Robert N. Stavins & Joseph Aldy, (Eds.), *Architectures For Agreement: Addressing Global Climate Change In The Post-Kyoto World* , Cambridge: Cambridge University Press, 2007; Richard B. Stewart & Jonathan B. Wiener, *Reconstructing Climate Policy: Beyond Kyoto*, Washington DC: American Enterprise Institute Press, 2003, available at: http://www.aei.org/publications/bookID.211/book_detail.asp .

part on analogies to current technological sectors (and sections thereof) that are currently experiencing difficulties. Part III addresses alternatives to traditional patents and exclusive licenses, including patent pools, liability rules, and prizes.

Currently, more than 95% of global R&D takes place in OECD countries. Thus Parts II and III primarily address IPR difficulties for R&D in these countries. However, if climate change is going to be addressed successfully, clean technology must be adopted globally. Thus, in Part IV, we examine at some length the international context. cuses on intellectual property buyouts, the potential for international R&D treaties, impediments to technology transfer that may be posed by IPRs, and the use of IPRs to stimulate indigenous innovation in developing countries.

I. ECONOMIC BACKGROUND

While the idea of balancing the atmospheric GHG stock by reducing the net GHG flow to zero seems simple enough, the technological reality of what it will take to do this is far from simple. Currently 69 percent of global anthropogenic GHG emissions come from fossil fuels such as oil, coal, and natural gas, which satisfy 81 percent of global energy supply.[3] The remainder of global energy is supplied by renewable energy (13 percent) and nuclear power (6 percent).[4] Stabilizing GHG concentrations will therefore require large-scale and widespread substitution toward energy technologies with low to zero net GHG emissions throughout the global energy system. New technologies may also be needed in other sectors to reduce GHG emissions, such as improved agricultural methods or crop varieties to reduce the conversion of forests (which sequester carbon) to farmland; improved technologies for biofuels that avoid raising corn prices and thereby spurring deforestation; and improved agricultural techniques to produce crops and raise ruminant animals with reduced emissions of methane and nitrous oxide.

To gauge, in economic terms, the magnitude of the innovation challenge presented by climate change, it is helpful to consider possible targets for GHG reduction and the projected costs of achieving these targets.[5] These projected costs, most commonly measured in terms of reduced Gross Domestic Product (GDP), indicate the scale of the benefit that could come from innovations that significantly reduce (or eliminate) the cost disadvantage of climate-friendly technologies relative to the competition. Many proposals, and most analyses, have centered on reduction paths that are consistent with ultimate stabilization targets in the range of 450-550 ppm CO_2. Modeling scenarios of cost-effective global climate mitigation policy suggest that, for targets in this range, the cost of GHG mitigation through 2050 is trillions or tens of trillions of dollars of discounted GDP, or an annualized cost in the tens to hundreds of billions per year. Longer-term total costs through 2100 are approximately double this amount. While these estimates are based on numerous economic and policy assumptions, they give a sense of the magnitude of the payoff from innovations that could significantly lower the cost of achieving various GHG reduction goals.

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[3] IEA, World Energy Outlook 2007, Paris: IEA/OECD, 2007. IEA, CO2 Emissions from Fuel Combustion: Emissions of CO2, CH4, N2O, HFC, PFC, FS6, Vol 2007 release 01. Paris: OECD/IEA, 2007.
[4] IEA, World Energy Outlook 2007.
[5] Richard G. Newell, *A U.S. Innovation Strategy for Climate Change Mitigation*, Washington, DC: Brookings Institution, Forthcoming 2009.

Many studies demonstrate the central role that the availability and cost of advanced energy technologies plays in determining the cost of achieving various GHG reduction goals.[6] Virtually all studies find that a cost-effective technology solution entails a mix of energy efficiency, low-GHG energy supply, as well as emission reductions in non-CO_2 GHGs. Thus, R&D supporting such a transition must also be broad based, covering a wide range of technological opportunities. For example, one study finds that if we were limited to technologies available in 2005, the present value cost of achieving stabilization at 550 ppm CO_2 would be over $20 trillion greater than with expected developments in energy efficiency, hydrogen energy technologies, advanced bioenergy, and wind and solar technologies.[7] While it is not typically made explicit in these models, they presume a significant degree of innovative effort in the form of R&D, learning, and diffusion of new technologies that would have to underpin these assumed technological improvements.

Other studies have found that accelerated technology development offers the potential to dramatically reduce the costs of stabilization, with advanced technology scenarios reducing the cumulative costs of stabilization by 50 percent or more, yielding economic benefits of hundreds of billions to trillions of dollars globally (Figure 1).[8] While one might reasonably argue over detailed modeling assumptions, these and other results demonstrate that technological advances have the potential to significantly decrease the costs of attaining societal goals for climate change mitigation. The challenge is to structure policy to maximize the likelihood that we will harness these technological opportunities as effectively and efficiently as possible.

With respect to technological innovation, both the public and private sector play a critical role. However, in terms of scale, the private sector is currently the major actor. One useful indicator of innovative activity is R&D spending. Industry is by far the largest player in R&D spending, funding over 60 percent and performing almost 70 percent of R&D globally in 2006 (the most recent year for which complete data are available). This industrial R&D is stimulated by market demand for technologically advanced products and processes. Establishing a GHG emission price (through policies such as cap-and-trade and emission taxes) is thus essential from a technology perspective: such pricing creates a demand-driven, profit-based incentive for the private sector to gain from selling low-GHG products that are currently available and, more

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[6] IPCC, *Op. Cit.*
[7] Jae Edmonds et al., *Global Energy Technology Strategy: Addressing Climate Change*, 2007, available at: http://www.pnl.gov/gtsp/docs/infind/cover.pdf

importantly, to invest effort in developing new, lower-cost climate-friendly innovations.

If private-sector profit incentives are not clearly aligned with societal GHG reduction goals then any public R&D spending will likely push against an insurmountable tide. Conveniently, as discussed further in Part IV, the vast majority of innovative effort globally currently takes place in the developed countries that are expected to take the most significant initial steps towards implementing GHG emission pricing.

For GHG emission policy to provide an effective inducement to innovation, however, it is critical that the policy be credible to the private sector over the long-term. Given the sometimes substantial time lags between initial discovery and profitable market penetration, companies must be confident that there will indeed be sufficient demand once their innovations reach the market. Such confidence would be increased by domestic policies and international agreements that put in place GHG emission targets whose stringency is spelled out for many decades in advance, and that provide stable financial incentives across a wide array of technological solutions.

Of course, government funding of relevant basic research does exist and could grow beyond its current levels. Thus the discussion below addresses at some length the special IPR issues raised by publicly funded research.

II. GREEN TECHNOLOGY AND INTELLECTUAL PROPERTY: A SURVEY OF THE CENTRAL QUESTIONS

As discussed in Section I, innovation in the climate mitigation arena faces an environmental externality problem not raised by other types of innovation. The GHG externality must be addressed on the technology demand side, by putting a price on greenhouse gases. But the GHG externality does not represent the only potential barrier to innovation. In this section, we address IPR issues that need to be thought through, particularly as the GHG externality is increasingly addressed.

In recent years, a few analysts have begun to address how IPRs might affect the development of green technologies. Given the early stage of research in certain areas, and in the absence of appropriate GHG pricing in most of the world, this analysis is necessarily quite speculative. Nonetheless, some analysts have suggested reasons why patenting and associated restrictive

[8] Richard G. Newell, *Op. Cit.*

practices might pose impediments to creation and diffusion of climate-friendly technologies. In contrast, others have seen little current evidence of dysfunction and have suggested that strong patent rights may assist in the development and dissemination of environmentally friendly technologies. Unfortunately, given the relatively nascent stage of much of the technology, there is little compelling empirical evidence to support either point of view.

At the moment, green technology looks too heterogeneous to be subject to any across-the-board generalizations. Unlike other heterogeneous technologies, moreover, (e.g., nanotechnology), the U.S. Patent and Trademark Office (PTO) does not recognize green technology as a class. Thus it is not necessarily easy to find reliable quantitative information about patent rights in green technology.

However, there is considerable evidence that the patent system is not functioning effectively[9] in some other areas of technology, particularly information technology and to some extent biotechnology. Controversy over the existing system has spurred concerted efforts to implement patent reform in the United States. It has also blocked attempts to further harmonize substantive patent law norms in a proposed WIPO treaty.[10]

Accordingly, we begin this section by examining the operation of the patent system with respect to other technologies for which we have considerable evidence. Because of the possibility that a significant percentage of green innovation may eventually have a publicly funded component, we pay special attention to the role of IPRs in areas such as biotechnology that rely substantially on public funding of relevant basic research. We then discuss green innovation, both generally and in particular sectors. In each of the major sectors, we suggest scenarios for the future by drawing upon the roles, both positive and negative, that IPR is playing in other, more developed areas of innovation.

a. The Existing Evidence for Other Technologies

1. Innovation Generally

The economic and legal literature on IPRs has long recognized the positive role that such rights (and particularly patents) can play in the innovation

[9] For discussion of this evidence, *see* notes __ and accompanying text.

context. The most obvious positive role involves the incentive effects that should emerge if the innovator can capture a substantial percentage of the very significant positive externalities associated with innovation (as defined to include initial invention, further development, and ultimate commercialization/diffusion). Economists have estimated that social rates of return from innovation can be 30% or more.[11] Although innovators should be able to capture some of this return through mechanisms such as head start advantages and trade secrecy, patents also represent a powerful mechanism.[12]

A related, potentially positive, effect is the role patents can play in creating small-firm-driven "markets for technology." Economic theory suggests that patents should help to ensure that information retains its value even when it is disclosed outside the boundaries of the firm.[13] In other words, patents should allow innovation rents to be appropriated even when a firm is not vertically integrated and thus cannot itself participate in all stages of the R&D process. To the extent that a system of industrial organization that includes small firms and markets is likely to yield more innovation (particularly cumulative innovation) than a system that comprises only large, vertically integrated firms,[14] patents' role in promoting the former type of industrial organization is important.

To some extent, the available empirical evidence backs these propositions on the positive role played by patents. In particular, for small firms, patents do appear to play a positive role in attracting venture capital, particularly in the biotechnology industry. One study reports that 50% of biotechnology firms that received venture capital (VC) backing in the late 1990s held patents;[15] moreover, this 50% is probably an underestimate, because (as discussed

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[10] See, Jerome H. Reichman & Rochelle Cooper Dreyfuss, "Harmonization Without Consensus: Critical Reflections on Drafting a Substantive Patent Law Treaty", *Duke Law Journal*, Vol. 57, No. 85, 2007, pp. 85-130.

[11] See, Charles Jones, "Sources of U.S. Economic Growth in a World of Ideas", *American Economic Review*, Vol. 92, No. 1, 2002, p. 220.

[12] In general, empirical studies have found that social rates of return from private firm research and development are at least twice private rates of return. Charles I. Jones & John C. Williams, "Measuring the Social Return to R&D", *Quarterly Journal of Economics*, Vol. 113, No. 4, 1998, p.1119.

[13] See, Ashish Arora, Andrea Fosfuri and Alfonso Gambardella, "Markets for Technology and their Implications for Corporate Strategy", *Industrial and Corporate Change*, Vol. 10, No. 2, 2001, pp. 419-451.

[14] Joseph A. Schumpeter, *Capitalism, Socialism, and Democracy*, New York: Harper & Brothers, 1942, p.13 (making the theoretical point that entrepreneurial firms may be more likely than large firms with vested interests in existing products to be able to be able to move outside routine tasks into "untried technological possibilities"); see also William J. Baumol, *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*, Princeton: Princeton University Press, 2002; Zoltan Acs and David Audretsch, *Innovation and Small Firms (MIT Press 1990);* David Audretsch*, Innovation and Industry Evolution*, Cambridge, MA: MIT Press, 1995 (presenting empirical data on the extent to which significant innovations in biotechnology and information technology have been driven by small firms).

further below) many biotechnology firms receive exclusive licenses on university-backed research.[16]

For large, publicly traded firms, by contrast, the evidence indicates that in the 1990s, U.S. patents had significant private value (i.e. value for appropriating returns from innovation) primarily in the chemical and pharmaceutical sectors.[17] In the pharmaceutical and medical device sectors, the cost of regulatory approval for end products make patent protection for such products (or marketing exclusivities that resemble patent protection, such as those provided by the Orphan Drug Act) a virtual *sine qua non*.

Patents can also pose obstacles for innovation. Many of these obstacles consist of transaction cost problems that can arise in the licensing necessary for follow-on innovation. For example, as a historical matter, progress in the automobile and aircraft industries was hampered by problems in licensing broad patents on foundational platforms.[18] In other areas, problems associated with broad patents on research platforms were narrowly averted. In the area of computer hardware, the threat of broad patents loomed large until government action forced licensing of the AT&T transistor patent as well as patents obtained by Texas Instruments and Fairchild Instruments on integrated circuits. As for software, it was already a robust industry before software patents became available, at least in any widespread fashion.

A relatively small number of broad patents on foundational research do not represent the only potential difficulty. There is also the possibility that a follow-on inventor will be deterred by the need to clear rights on a "thicket"[19] of overlapping patents[20] that cover either a research platform or individual components of an end product. In this regard, it bears mention that a 2003 IP survey of IP managers found that 23% said that competitor patents played an

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[15] Ronald J. Mann and Thomas W. Sager, "Patents, Venture Capital, and Software Start-Ups", *Research Policy*, Vo. 36, 2007, pp. 193-208.

[16] Additionally, the late 1990s represented a time when venture capital markets were relatively robust.

[17] James Bessen & Michael J. Meurer, *Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators at Risk*, Princeton: Princeton University Press, 2008, especially Chapters 5 and 6 (collecting existing research data based on patent renewal statistics and market value regressions and presenting new data).; see also Wesley Cohen, Richard Nelson, & John Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why Manufacturing Firms Patent (or Not*), NBER Working Paper Series, No. 7752, Feb. 2000 (finding, based on survey conducted in 1990s, that R&D managers in the chemical and pharmaceutical industries ranked the effectiveness of patents higher than managers in other industries). In fact, according to one analysis that relied on renewal data, market value regressions, and event studies in attempting to calculate both the private value of patents and the private costs of patent litigation, the net private incentive provided by the patent system outside the chemical and pharmaceutical industries had, by the late 1990s, turned negative. See Bessen & Meurer, *Op. Cit*.

[18] R.P. Merges & R.R. Nelson, "On the Complex Economics of Patent Scope", *Columbia Law Rev*iew, Vol. 90, No. 4, 1990, p. 839.

[19] Carl Shapiro, "Navigating the Patent Thicket: Cross Licenses, Patent Pools and Standard Setting", in Adam B. Jaffe, Josh Lerner & Scott Stern (eds), *Innovation Policy and the Economy 1*, Cambridge, MA: MIT Press, 2001, pp. 119-150.

important role in decisions to abandon development of otherwise promising technologies.[21] Currently, these problems appear to be most salient in the area of information and communications (ICT) technology.[22] Not only do products in information technology represent combinations of dozens if not hundreds of patented components, but patent claims in this area often do not give clear notice of their boundaries.

Even where patent thickets do not prevent projects from going forward,[23] they create the potential for inefficient holdup. If a follow-on improver has to clear rights on a plethora of patents with vague boundaries, it may either miss certain patents or simply not bother with the rights-clearing exercise. The patent holder can then sue for infringement after the improver has already invested. And to the extent that the patent holder is able credibly to assert the threat of injunctive relief, it may be able to appropriate from the improver far more than the value of their patent.

Holdup problems are particularly salient in the related context of standard-setting, where substantial investments in standards are often made prior to a patent holder's coming forward to assert its claim. Although these types of problems are usually associated with the ICT industries, they can arise in other industries. Indeed, one prominent recent case of alleged patent abuse in a standard setting context directly involved environmental technology. In this 2003 case, the Federal Trade Commission alleged that the Union Oil Company of California ("Unocal") violated Section 5 of the FTC Act in falsely representing to the California Air Resources Board that it did not have relevant patent interests when it participated in a standard setting exercise involving the composition of low-emissions gasoline. In fact, according to the FTC, Unocal had begun the process of obtaining relevant patents. After the standard had been adopted, and other refiners had made investments to comply with the standard, Unocal obtained and disclosed the patents. When other refiners filed suit to have the patents declared invalid and not infringed, Unocal counterclaimed with a charge of infringement. The court found Unocal's patents valid and infringed and ordered the other refiners to pay royalties that could exceed $500 million.

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[20] Patent law explicitly allows for overlapping, or blocking, patents.

[21] Iain Cockburn & Rebecca Henderson, *Survey Results from the 2003 Intellectual Property Owners Association Survey on Strategic Management of Intellectual Property,* Oct. 2003, available at: http://www.ipo.org/AM/Template.cfm?Section=Home&Template=/CM/ContentDisplay.cfm&ContentFileID=55152

[22] As discussed further below, the situation in biotechnology is less clear.

[23] For example, there is some dispute about the extent to which firms in the information technology industries bother to examine the patent landscape. To the extent that they do not do such examination, they may not be deterred by patent thickets.

In certain cases the potential problems caused by patents do not involve transaction cost difficulties associated with licensing foundational research for follow-on work or negotiating patent thickets. Rather, the prospect of patents may lead to "too much" R&D – that is, rent-dissipating races.[24] Moreover, because patent law sometimes allows multiple parties to own overlapping patents over what is essentially the same technology, some races may have multiple victors. In that case, the overlapping patents held by multiple parties may lead to substantial, and expensive, litigation. A case in point is microarray technology. Microrrays are a powerful genomic research platform that involves depositing short DNA sequences on a support medium as a mechanism to test for gene expression. Over the past decade, multiple firms (including Affymetrix, Hyseq, Incyte, and Oxford Gene Technologies) that raced to dominate the platform have tangled in court with respect to patents they hold on this platform.[25] Although many of these suits have resulted in settlements involving cross-licensing, with the result that no firm is currently a monopoly provider, it is unclear whether microarray patents have, on balance, been beneficial.

In the case of microarray technology, the overlapping patents held by multiple firms were arguably the consequence of an inefficient race. In other cases, particularly in the information technology industry, firms may amass patent portfolios that overlap heavily with those of their competitors and are used almost exclusively for defensive purposes. Although this defensive accumulation of patents appears at best inefficient, and at worst can be used to exclude competitors that do not have such patents, eliminating defensive use poses an obvious collective action problem.

Problems with foundational patents, patent thickets, races, and patent portfolios, are exacerbated when patents are of low quality. Low quality can stem from patentability standards that are too lax or from the PTO's failure to mandate compliance with those standards. Low quality patents may cover inventions that are obvious. Alternatively, they may claim too much inventive territory or fail to specify exactly what territory they cover. In recent years, problems with low quality patents have been particularly salient in the ICT industries.

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[24] Edmund Kitch bases his famous argument for granting broad patent rights very early in the R&D process on the idea that later grants would lead to such rent-dissipating races. Edmund Kitch, "The Nature and Function of the Patent System", *Journal of Law & Economics*, Vol. 20, No. 2, 1977, pp. 265-290.

[25] Richard Rouse and Gary Hardiman, "Microarray Technology: An Intellectual Property Retrospective", *Pharmacogenomics* , Vol. 4, No. 5, 2003, pp. 623-632.

At least in the United States, some recent decisions by the Supreme Court may alleviate some of the problems caused by low-quality patents. The Court's 2007 decision in *KSR v. Teleflex*[26] raises the patentability requirement of "nonobviousness" in a manner that calls into question many patents that represent combinations of previously known information. Additionally, the Court's 2006 decision in *eBay v. MercExchange* reverses prior patent law that appeared to mandate injunctive relief once a patent had been proved valid and infringed. Under the Court's new standard, district courts have discretion to award monetary damages rather than injunctions barring use of the patented invention, particularly when the patent in question covers only a small piece of the defendant's product, and the patent holder is not a direct competitor of the infringer.[27]

Interestingly, one of the first Federal Circuit cases to address a district court's handling of damages post-*eBay* arises in the area of green technology. In *Paice v. Toyota*, the patentee, a non-manufacturing entity, had sued Toyota for manufacturing cars that infringed patents covering a drive train for hybrid electric vehicles. The Federal Circuit affirmed the district court's decision to deny permanent injunctive relief and instead order Toyota to pay Paice an "ongoing royalty."[28] The potentially significant effects of these Supreme Court decisions illustrate that assessments regarding whether patents are likely to hinder or promote innovation are subject to ongoing revision.

On the other hand, even with new decisions from the courts, administrative processes are likely, for the foreseeable future, to continue to produce questionable patents. In the United States, the available evidence indicates that the PTO struggles to keep quality at acceptable levels. The PTO has fewer than 6000 examiners for the more than 400,000 patent applications filed each year. So the typical examiner has only a few days to examine an application on which the applicant may have spent many months. The examiner also bears the burden of proving a patent application is invalid. Moreover, under the complex incentive-based compensation regime for patent examiners, accumulating disposal credits (or "counts") may be easier if the examiner grants a patent application rather than denying it.[29] Similarly,

[26] KSR v. Teleflex, 550 U.S. 398 (2007).
[27] eBay Inc. v. MercExchange, LLC, 547 U.S. 388 (2006).
[28] The CAFC did, however, remand for the district court to reevaluate the royalty rate, as the opinion had given no reason for the decision to impose a fee of $25 for every Prius II, Toyota Highlander, Lexus RX400h manufactured during the remaining life of the infringed patent.
[29] The question is not entirely clear because an examiner can also accumulate "counts" if a patent denial results in the applicant coming back with a repeat (or "continuation") application.

the President of the European Patent Office has expressed concern that the patent system is "drifting towards dysfunctionality."[30]

In addition to false positives in the form of improperly granted patents, there is also some possibility of false negatives. There are anecdotal reports that, in the last few years, the U.S. PTO has responded to complaints that it grants "too many" patents by routinely (and arbitrarily) denying patent applications the first time they are filed. Certainly the evidence indicates that the percentage of first applications that are denied has gone up in the last few years.[31]

Finally, in both the U.S. and Europe, there are very serious concerns about increasing time delays in patent examination. In the U.S., total pendency for a first application rose from 25.9 months in 2003 to 31.9 months in 2007. Overall, the U.S. has a backlog of over 750,000 patent applications. The delays caused by this backlog have particularly severe implications for small firms that may use patents to attract venture capital.

2. The Case of Biotechnology

For purposes of thinking about green technology, biotechnology represents a particularly interesting area in which to investigate in some detail the effect of patents. Not only will green technologies such as second and third generation biofuels be based on biotechnology but the green technology sector, like the biotechnology sector, is likely, in the long run, to rely heavily on complex interactions between publicly and privately funded research.

The history of publicly funded research in biotechnology suggests several key lessons. First, where the invention in question is a publicly funded research platform that can be adopted by industry without transfer of tacit knowledge or follow-on investment, the conventional rationale for patenting publicly funded research – that patents provide incentives for such knowledge transfer and investment – does not apply. Many of biotechnology's most useful, widely diffused platform technologies – including monoclonal antibodies and Maxam-Gilbert sequencing – were generated through public funding and were not patented. Second, if the publicly funded platform invention does happen to

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[30] Alison Brimelow, "Closing remarks at the European Patent Forum", *European Patents Forum*, May 2008, available at http://www.epo.org/about-us/events/epf2008/forum/details2/closing.html

[31] Evidence of this percentage is a bit misleading because, under current U.S. rules, there is no such thing as a final denial of a patent application – rather, the applicant can file the same patent application as many times as he wishes. But even taking account these continuation applications, the percentage of applications granted appears to have decreased in recent years. At some point, applicants appear to abandon their quest for a patent. Mark A. Lemley & Bhaven

be patented, nonexclusive licensing should be used to ensure maximum diffusion. For example, although the Cohen-Boyer recombinant DNA technologies were patented, the University of California voluntarily converted its exclusive right into a liability rule—a non-exclusive "take and pay" rule—under a standard form contract.[32] Although such nonexclusive licensing increases costs relative to free technology transfer, modest licensing fees should not impose an undue burden on commercialization.

Unfortunately, at least in the U.S., the available empirical evidence indicates that institutions that make decisions on whether to seek patents on their publicly funded research, and on how to license patents that they have secured, do not always make these decisions in a manner that comports with the public interest in efficient technology transfer.[33] Thus there is reason to consider modifying laws such as Bayh-Dole that govern the patenting of publicly funded research, at least to the extent that they confer unfettered discretion over patenting to institutions that receive public funding.

In the case of research tools and platforms that are privately developed, patents are likely to be necessary. As noted, small firms that develop such platforms appear to need patents to attract venture capital. Thus, for example, patents on polymerase chain reaction (PCR) technology may have been critical to the business model of the small firm, Cetus, that initially developed the technology. But such patents may also pose problems. Given the lack of an exemption for academic research in U.S. patent law,[34] academics who cannot afford to pay commercial licensing fees for a key patent must rely on the hope that the patent holder will refrain from suing academics. Essentially, academics must hope that the patent holders engage in an informal regime of price discrimination. This price discrimination ultimately arose in the case of PCR but only after some uncertainty.[35] More generally, although academics appear routinely to ignore patents with impunity,[36] routine lawbreaking is not necessarily a stable equilibrium.

N. Sampat, "Is the Patent Office a Rubber Stamp?", Stanford Public Law Working Paper No. 999098, 2008, available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=999098

[32] Jerome H. Reichman, "Of Green Tulips and Legal Kudzu: Repackaging Rights in Subpatentable Innovation", *Vanderbilt Law Review*, Vol. 53, No. 6, pp. 1743-1798.

[33] For a review of this evidence, see David Mowery *et al*., *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act*, Chicago: Stanford University Press, 2004.

[34] See Madey v. Duke Univ., 307 F.3d 1351, 1362 (Fed. Cir. 2002).

[35] JH Reichman & J Giordano-Coltart, "A holistic approach to patents affecting frontier science: Lessons from the seminal genomic technology studies", paper presented to the European Patent Forum, 6-7 May 2008; Ljubljana, Slovenia.

[36] John P. Walsh, Charlene Cho and Wesley M. Cohen, "The View from the Bench: Patents, Material Transfers and Biomedical Research." *Science*, Vol. 309., No. 5743, 2005, pp. 2002 – 2003. See also John P. Walsh, Charlene Cho and Wesley M. Cohen, "Where Excludability Matters: Material Versus Intellectual Property in Academic Biomedical Research", *Research Policy*, Vol. 36. No. 8, 2007, pp. 1184-1203.

While biotechnology platforms like PCR and recombinant DNA were covered by a few patents with a single owner, other research platforms may be covered by multiple patents held by dispersed owners, public and private. Such thickets may become particularly salient in interdisciplinary research areas of biotechnology, such as synthetic biology, that draw not only upon the life sciences but also upon computer science and electrical engineering.[37] Although there is evidence that biotechnology and pharmaceutical firms may be able to avoid thickets through infringement that is secret (e.g. infringement of a research tool or process that is discovered only after the statute of limitations for lawsuits has expired) or by "off-shoring" research to countries with fewer patent restrictions,[38] these are not necessarily strategies that should be encouraged. In addition, secret infringement may not always be possible: for example, if (as discussed further below) synthetic biology's goal of producing standardized biological parts is realized, the use of such standards may be apparent. In that case, synthetic biology may be subject to the same possibility of holdup that we see in the information technology industries.[39] Notably, even those analysts who are relatively optimistic about the transaction cost difficulties associated with thickets note that "even if patents do not stop ongoing research, the very prospect of a thicket or restricted access may dissuade researchers from choosing particular projects and limit lines of attack in that way."[40]

As with the legal picture in innovation generally, the legal picture in biotechnological innovation is not stable. The *KSR* decision on nonobviousness may raise the bar for patents in interdisciplinary research: to the extent such research simply combines well known knowledge in different fields, it may no longer be patentable. The *KSR* decision may also lead to case law that makes it more difficult to secure gene patents.

b. Green Technologies

With this overview of how patents work in other, more developed, technological areas, we can now consider how they may work in different sectors of green technology. Some key technological areas[41] in which there exists some nascent evidence regarding the influence of patents include: 1) second and third generation biofuels; 2) thin-film (photovoltaic) solar; 3)

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[37] Reichman & Giordano-Coltart, *Op. Cit*.
[38] Walsh *et al.* 2003.
[39] Arti K. Rai and Sapna Kumar, "Synthetic Biology: The Intellectual Property Puzzle", *Texas Law Review*, Vol. 85, No. 7, 2007, pp. 1745–1768.
[40] Wesley M. Cohen & John P. Walsh, "Real Impediments to Academic Biomedical Research", *Innovation Policy and Economics* , Vol. 8, No. 1, 2008, p. 11.

transportation, specifically hybrid cars and fuel cells; and 4) wind energy. These sectors are at different stages of technological development. For example, while third generation biofuels are still at a relatively early stage of development, wind energy and hybrid cars are already at the commercialization stage. Not surprisingly, the areas in which we see some evidence of IPR-related problems – for example, wind and hybrid cars – are areas that are both further along commercially and where numbers of patents have increased in recent years. (Figure 2) But even in areas where we do not currently see difficulties, it bears emphasis that the situation may change as recent research bears fruit in the form of issued patents and as R&D escalates in response to appropriate GHG pricing.

Second and Third Generation Biofuels

As a purported green technology, the "first generation" biofuel of corn-based ethanol is quite controversial: it necessarily creates a conflict between the use of plants for food and fuel, and it has a carbon emissions profile similar to that of fossil fuels.

In contrast, second and third generation biofuels are more promising. Second generation biofuels include cellulosic ethanol, which is made from non-food crop residues such as corn stover and wheat straw, or from timber and lumber residues. In the area of cellulosic ethanol, a major challenge is the phenomenon of "biomass recalcitrance," a term that refers to the natural resistance of plant cell walls to microbial and enzymatic decomposition.[42]

It thus appears that small firms are finding, and patenting, novel enzymes that catalyze such decomposition. Then, in a pattern reminiscent of the biopharmaceutical industry, they are collaborating with large firms in a manner that develops the technology.[43] To date, patents do not appear to have posed problems in this context – to the contrary, there are multiple joint ventures working on different enzymes, and patents on enzymes appear to have fostered markets for technology driven by small firms. More generally, as Figure 1 shows, the number of patents granted in the biofuels area (as in

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[41] These are areas particularly important for developing countries.

[42] Michael E. Himmel *et al*., "Biomass Recalcitrance: Engineering Plants and Enzymes for Biofuels Production", *Science*, Vol. 315, No. 5813, 2007, pp.804-807.

[43] Steve Suppan*, Patents: Taken for Granted in Plans for a Global Biofuels Market*, IATF Working Paper, 2007; see also John H. Barton, *Intellectual Property and Access to Clean Energy Technologies in Developing Countries: An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies*, ICTSD Programme on Trade and the Environment, 2007, available at: http://www.trade-environment.org/page/ictsd/projects/BARTON_DEC_2007.pdf.

the biopharmaceutical industry) appears to be relatively small.[44] Of course, the situation may change dramatically in the future, as more recent research in this area has not yet resulted in issued patents.

Another source of worry may be patents in the area of third generation biofuels such as those produced by synthetic biology. Unlike traditional recombinant DNA, which simply transfers one or more genes from one organism to another, synthetic biology aims to create standard, modular DNA parts that can be mixed and matched in different ways within a standard "chassis" organism. In the biofuels context, the designer organisms created through mixing and matching would be designed to take cellulosic feedstock and produce fuel. At the moment, synthetic biology is sufficiently removed from commercial application that current patent applications on items like microbial chasses (Craig Venter's firm Synthetic Genomics has applications pending on several such chasses)[45] are not likely to cover the inventions that will ultimately become the standard. But to the extent standardization is achieved in the future, the prospect of patents on synthetic biology standards raises the same concerns as existing patents on various ICT standards.[46] Perhaps most notably, secret infringement, which (as discussed earlier)[47] is currently one prominent strategy for avoiding patent thickets in the context of biotechnology, may be less feasible when relevant platforms are standardized.

Photovoltaic Solar

Photovoltaic technology involves the use of panels to produce electricity when the panel is exposed to sunlight. While the first generation of this technology used crystalline silicon, the improvement process has involved applying thin films of semiconductors to the surface of materials like glass. Another important piece of PV technology involves the inverter used to convert the DC power produced by the panels to AC power. According to John Barton, who recently studied the photovoltaic industry, although industry players in the developed world do patent, the industry is only moderately concentrated, which allows choice among patented products that are substitutes for each other.

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[44] See Todd Miller, James Peterson, and T. Christopher Tsang, "Patent Trends in the Cleantech Industry", *Intellectual Property & Technology Law Journal*, Vol. 20, No. 10, 2008, pp.1-8 (noting that there has been no "noticeable increase" in the number of U.S. patents issuing in the biofuels/synfuels area).
[45] Jocelyn Kaiser, "Attempt to Patent Artificial Organism Draws A Protest", *Science*, Vol. 316, No. 5831, 2007, pp. 1557.
[46] See generally Sapna Kumar and Arti Rai, *Op. Cit.*
[47] *See* text accompanying notes __ *supra*.

In terms of aggregate patent numbers, the trends do not appear particularly dramatic. In the U.S., the number of patents issued annually in the solar area appear to be holding relatively steady (Fig. 2). In the EPO, patent applications in the solar area grew about 11% between 1998 and 2007, lower than the 16% increase for alternative energy technologies generally.

Transportation: Hybrid Cars and Fuel Cells

As shown in Figure 2, many U.S. patents are currently being issued in the area of fuel cells. Similarly, in the EPO, patent applications in the area of fuel cells grew 22% between 1998 and 2007. In both this area and the area of wind energy (discussed next), many patents may represent relatively incremental improvements. Thus, as with the information technology industries, an end product could conceivably be covered by a large number of patents, each of which contributes only a small percentage to the total value of the invention. Indeed, the *Paice v. Toyota* case, discussed above, represented precisely this situation.

Wind

Because certain types of wind technology (e.g. windmills) have been available for decades, patenting in this space can also represent incremental innovation. Additionally, as shown in Figure 2, the number of issued U.S. patents in this area have been increasing in recent years. Similarly, in the EPO, patent applications in the area of wind power increased 31% from 1998 to 2007.

The wind turbine industry is also quite concentrated, with the top 4 firms accounting for almost 75% of the market. In the U.S. market, General Electric is the major player, and it has a reputation for enforcing its patents aggressively. For example, in February 2008 GE asked the U.S. International Trade Commission to bar imports of wind turbines made by Japan's Mitsubishi Heavy Industries Ltd., arguing that Mitsubishi's turbines infringe on its patents.

Proprietary Rights Beyond Patents

There is more at stake here than patents alone. Green technologies, particularly in the area of second and third generation biofuels, are likely to be

heavily dependent on access to microbial materials and associated data that will have to be processed as part of the overall research trajectory.[48] The challenge is to enable scientists to access vast amounts of materials and data for upstream research, without compromising the possibilities of downstream commercial applications that may be patented.

In other words, if all we focus on are potential patent problems, we may miss problems caused by data protection techniques under copyright and *sui generis* laws (especially the EU Database Law, which now applies in some 50 countries) as well as restrictions on access to genetic resources in material transfer agreements. Our solutions would thus be incomplete because they would fail to address the risk that the scientific system, even when rendered compatible with traditional patent law, might be deprived of necessary data (covered perhaps by crown copyrights or crown database rights in the EU) or deprived of access to essential resource inputs, such as microbial strains held by repositories that restrict access to their holdings even for public scientific purposes. Hence efforts to design a worldwide microbial commons could significantly affect the pace and direction of patented technologies, including green technologies.[49]

III. ALTERNATIVES TO TRADITIONAL PATENTING AND LICENSING

We have already alluded to the need for legal change – perhaps most notably changes to administrative processes that currently do a poor job of granting high-quality patents in a timely manner. But even without such legal change, which may be difficult to achieve, much can be done to avert patent difficulties.

a. Technology Pools

A standard mechanism for addressing certain types of patent thickets is technology pools. These pools function particularly well when multiple complementary patents owned by different parties cover a platform technology or standard. Once the patents are pooled, licenses to the pool can then be made available both to contributors of relevant patents and to outsiders. The MPEG-2 pool, which comprises patents essential for compliance with the MPEG-2 digital compression technology standard,

[48] Reichman, Uhlir & Daedeurdere, *Designing the Microbial Commons* , *infra* note 40.
[49] Reichman, Uhlir & Daedeurdere, *infra* note 40.

illustrates well the central features of a pro-competitive pool. Contributing members of the pool agree to license the patent portfolio on a nondiscriminatory basis to all firms that request a portfolio license. Owners of portfolio patents are also free to license their own patents independent of the portfolio. The entity that administers the MPEG-2 pool is know as MPEG LA, and it receives an administrative fee out of royalties collected. The MPEG LA model has been adopted in a large number of similar situations involving patent thickets.

As a conceptual matter, a package of innovations licensed under a non-exclusive license of this kind invites the world to make use of the package at will, while organizing the contributors to the package as de facto partners of all subsequent users, who labor under a contractually specified obligation to pay reasonable royalties for follow on applications. The more successful the package becomes, the more follow-on users it generates, and the greater are the "lottery effect" royalties paid to those who contribute to the package.[50]

In certain contexts, royalty free licensing might be adopted. In February 2008, various firms launched the Eco-Patent Commons, which aims to pool clean technology patents for royalty-free licensing. Thus far, the Commons is limited in scale. It includes 47 patents, 27 owned by IBM and 12 by Xerox. Other contributors include Nokia, Pitney Bowes, and Dupont. Whether firms will have incentives to contribute significant numbers of patents to this type of commons, and whether it will include patents that are ultimately useful for reducing carbon emissions, remains to be seen. In the context of other firm donations of patents to a commons (e.g. IBM's donation of patents relevant to the Linux operating system), the firms in question have had a financial incentive to contribute, as they make products complementary to the platforms covered by the patents in the commons.

b. Prizes

In addition to the traditional approach of using patents/licensing and basic research funding administered via grants, another option is inducement prizes

[50] On the use of these types of non-exclusive licenses, also known as liability rules, see Reichman, *Green Tulips*; Reichman & Lewis, *Stimulating Innovation in Developing Countries*; Reichman & Uhlir (2003); Reichman, *Legal Hybrids.* A concept related to liability rules (in the sense that it creates markets for technology with low transaction costs) is a clean tech patent clearinghouse. One such site, called Lynxstreet, was recently launched. Membership on the site allows companies to list patents, view what others are offering, and also specify their own technology needs. A clearinghouse site might be particularly useful for small inventors. See Geertrui Van Overwalle *Clearing House Models* etc. (2009).

for achieving specific advances in GHG-reducing science and technology. [51] The idea here is to offer financial or other rewards for achieving specific innovation objectives that have been specified in advance.[52] Prize-like approaches have also gained traction within the private sectors. Firms like Innocentive match "seekers" (organizations with challenging problems) with "solvers" (innovators with solutions) by offering them cash awards. Among other things, Innocentive has a philanthropic subprogram devoted to "clean tech and renewable energy" offering prizes supported by a private foundation.

Although inducement prizes are not suited to all research and innovation objectives, they have the potential to play a larger role alongside research contracts and grants. In contrast to these other instruments, prizes target and reward innovation outputs rather than inputs: the prize is paid only if the objective is attained. This can help encourage maximal research effort per dollar of public research funding. Prizes or awards can also help to focus efforts on specific high-priority objectives, without specifying how the goal is to be accomplished. Because prize competitors select themselves based on their own knowledge of their likelihood of success—rather than being selected in advance by a research manager—prizes can also attract a more diverse and potentially effective range of innovators from universities, other research institutions and the private sector.

The detailed process of selecting appropriate prize topics and crafting prize-specific rules (e.g., the type of contest, size of award, criteria for winning, method of choosing winner, whether patents will be sought on the targeted invention)[53] requires extensive consultation with experts and potential participants. Identification of particular technical and scientific challenges in GHG mitigation that could be fruitfully addressed through an inducement prize approach could be identified as part of the above systematic assessment. Then the best institutional arrangements for administering the prize would need to be determined. Consideration would need to be given to the treatment of intellectual property arising from associated innovations (as with any joint R&D project), and to the development of terms for related licensing.

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[51] Richard G. Newell, A U.S. Innovation Strategy for Climate Change Mitigation. Washington, DC: Brookings Institution, December 2009.

[52] Richard G. Newell and N. Wilson, Technology Prizes for Climate Mitigation, RFF Discussion Paper 05-33; National Research Council, Innovation Inducement Prizes at the National Science Foundation. Recently proposed prizes relevant to energy and climate policy include "Prizes for Achievement in Grand Challenges of Science and Technology" authorized in the U.S. Energy Policy Act of 2005, the H-Prize (for hydrogen) and Bright Tomorrow Lighting Prizes authorized in the U.S. Energy Independence and Security Act of 2007, the privately-funded Progressive

IV. INTERNATIONAL CONTEXT

Thus far, we have focused on the intellectual property situation in the OECD context (and particularly the U.S. context). This focus is justifiable to the extent that more than 95% of global R&D currently takes place in OECD countries. However, reduction of GHG emissions will necessarily be a global effort. Thus in this Part we explicitly consider issues of technology transfer to developing countries as well as innovation in developing countries.

a. Prizes and Other Funding in the International Context

Prizes could be particularly useful for advancing innovation specifically relevant to developing country climate mitigation and adaptation technology needs, given the relatively low market-driven inducement for innovation that may be present in those countries.[54] For similar reasons, the use of innovation prizes has been advocated for medical advances particularly relevant to developing countries (e.g., anti-malaria drugs).[55] One advantage of a prize approach relative to research grants in an international context is that it would not require choosing the winner of R&D funding in advance, which can become politically charged when researchers and research institutions reside in particular countries.

An internationally coordinated climate technology prize fund could be established for these purposes. While contributions for such a fund could be sought on an as-needed basis for specific projects, it would probably be advantageous to have larger-scale general funds that could then be prioritized to specific prize topics.

In addition to a prize fund, a fund that provided peer-reviewed research grants could also be established. A portion of this fund could be set aside for scientists and innovators in developing countries and thus provide them with opportunities and outlets for innovative proposals that do not otherwise exist at the present time.[56]

Automotive X-Prize, and the Earth Challenge Prize announced by British financier Richard Branson. Only the last two private prizes have been funded.

[53] National Research Council, Innovation Inducement Prizes at the National Science Foundation.

[54] See Richard Newell, *International Climate Technology Strategies,* Discussion Paper 2008-12, Cambridge, Mass, Harvard Project on International Climate Agreements, Oct. 2008.

[55] James Love and Tim Hubbard, "The Big Idea: Prizes to Stimulate R&D for New Medicines", *Chicago-Kent Law Review,* Vol. 82, No. 3, 2007, 1519-1546.

[56] For analogous proposals in regard to medical research, see Abbott & Reichman , "The Doha Round's Public Health Legacy: Strategies for the Production and Diffusion of Patented Medicines Under the Amended TRIPS Provisions", *Journal of International Economic Law*, VOL. 10, NO. 4, 2007, 983-84.

b. Buying Out and Pooling Intellectual Property

Parties to the United Nations Framework Convention on Climate Change (UN FCCC) and WIPO could also consider establishing a "Global Fund" within the WIPO for the potential purchase of intellectual property.[57] The UN FCCC, adopted at Rio in 1992, already contains provisions for technology transfer and financial assistance for agreed incremental costs to developing countries. Its Kyoto Protocol added further assistance provisions. And the demand-side incentives in a global regime that used a tax or cap and trade system to limit GHG emissions would spur a flow of funds and technology to developing countries in allowance sale transactions. But the parties to the climate change treaties could go further to address IPRs through the collaboration with WIPO that we are now sketching.

Specifically, a Global Fund could "buy out" selected intellectual property rights and then make the innovation available to others, especially developing countries, as if it were in the public domain or at least a semicommons. An earlier proposal to this effect for pharmaceuticals was made by Professor Kevin Outterson, who pointed out that the aggregate value of the rights to poor country markets may be relatively small, in which case significant public health impact could be achieved with such an investment.[58] Because the inventor will normally have recouped R&D expenses and made the bulk of his profits in OECD countries, such a strategy provides him with an extra source of income while relieving him of concerns about the enforcement of IPRs in the countries for which rights have been purchased. However, thought must be given to the possibility of restricting re-exports of the products developed under such arrangements back into OECD countries under various theories of exhaustion, lest they undermine the innovator's returns from investments in his primary markets.

An organization that administered buyouts might also arrange to pool technologies or inputs to essential technologies, with a view to making them available as a package to innovators, especially innovators in developing countries. This strategy looks promising and has already produced positive results in the pharmaceutical sector. For example, public-private partnerships

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[57] See Richard Newell, *International Climate Technology Strategies,* Discussion Paper 2008-12, Cambridge, Mass, Harvard Project on International Climate Agreements, Oct. 2008.

[58] Kevin Outerson, "Patent Buy-Outs for Global Disease Innovations for Low- and Middle-Income Countries", *American Journal of Law and Medicine*, Vol. 32, 2006, 171-73. Somewhat analogous proposals have also been made by James Love, "Proposal for Patent Pool for Essential Medicines (PPEM)", Addis Ababa--3 March 2005, available at http://www.cptech.org/cm/addisababa03032005.html, and Jenny Lanjouw[?]. See also Yochai Benkler, Amy Kapczynski et alia, Addressing Global Health Inequities: An Open Licensing Approach for University Innovations, *Berkeley Technology Law Journal*, Vol. 20, No. 2, 2005, pp. 1031-1114.

have successfully pooled patented technologies under the auspices of DNDi, with a view to introducing two new malaria drugs onto the market.[59]

c. Technology Transfer and International R&D Agreements

At least in the near term, much of the relevant R&D for clean technology will occur in the developed world. Transferring the resulting technological knowledge and equipment to developing countries—and ensuring that technologies develop that are appropriate—will require additional actions at an international level. While technology-transfer strategies must address typical impediments to technology adoption, such as information availability and technological maturity, they also must address financing barriers specific to developing countries. The degree of intellectual property rights protection, rule of law, regulatory transparency, and market openness are also critical conditions and potential impediments bearing on technology transfer.

Activities undertaken under knowledge sharing and coordination agreements can include meeting, planning, exchange of information, the coordination and harmonization of research agendas and measurement standards, and some degree of integrated, cooperative R&D.[60] In addition to increasing international exchange of scientific and technical information, joint R&D can more directly increase cost-effectiveness through cost-sharing and reduced duplication of effort. The largest number of existing international agreements relevant to climate mitigation technology have been developed as so-called Technology Implementing Agreements under the auspices of the IEA.[61] IEA Implementing Agreements use two primary mechanisms: task-sharing and cost-sharing. In task-sharing, a joint program is pursued within participating countries, but each country funds and implements its own contribution to the project. In cost-sharing, participating countries pool funding for a single contractor to perform a research task. There are 41 existing IEA Implementing Agreements, all of which incorporate task-sharing and about half of which have cost-sharing. They cover the fields of renewable energy and hydrogen (10), end-use energy efficiency (13), fossil-fuel technologies (6), nuclear fusion energy (9), and cross-cutting activities (3). Membership in these agreements is not restricted to governments or to IEA or OECD

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[59] DNDi Press Release, June 23, 2008, *DNDi Partners With Pharma, Biotech, Academia, Public Health Institutes & NGOs to Deliver Lifesaving Drugs*, available at http://www.dndi.org/cms/public_html/insidearticleListing.asp?CategoryId=166&SubCategoryId=167&ArticleId=490&TemplateId=1

[60] de Coninck *et al.,* "International Technology-Oriented Agreements To Address Climate Change", *Energy Policy*, Vol. 36, No. 1, 2008, pp. 335-356; IEA, *Energy Technology Perspectives 2008*.

[61] de Coninck *et* al, *Op. Cit*.

countries, and a number of organizations from non-OECD countries have participated. Activities under these agreements are funded and conducted primarily through domestic R&D programs and budgets, and pooled funds often go to the bundling of research results and provision of a platform for information exchange and learning (i.e., desk studies rather than primary research).

In addition, other agreements have also been developed in recent years, including the Carbon Sequestration Leadership Forum, the Asia Pacific Partnership on Clean Development and Climate, and the International Partnership for a Hydrogen Economy. Energy science and technology agreements that feature a higher degree of joint, collaborative R&D are less common, and appear to be most successful in research that is more fundamental and that has not yet accumulated commercial interests. Examples include the ITER fusion reactor and European Organization for Nuclear Research (CERN).

Invigorated and expanded international agreements on climate technology mitigation R&D coordination could be very valuable, particularly as countries increase R&D efforts and seek maximal impact in addressing this global problem.[62] The IEA is the best-positioned international institution to administer any such agreement(s) related to energy technology, although other international institutions may be more appropriate to engage for non-energy technologies. One concern with the existing IEA implementing agreements, however, is that they each have their own secretariats and operate independently. While this approach eases the need for more central administration, it may also suffer from overlap across agreements, and a lack of overall coordination and strategic vision.

G8, other major R&D-performing countries, and likely major developing country technology users, could therefore consider agreeing to an overall framework for knowledge-sharing and coordination of climate mitigation R&D efforts.[63] This framework could include a process whereby parties make regular submissions of a climate technology development plan, including R&D funding levels, current and future program plans, pertinent R&D policies, and other relevant information. In addition to such national submissions, the process could include an evaluation of existing climate technology agreements—with an eye toward identifying best practices and expanding, integrating, or suspending particular agreements—and draw from other

[62] See Richard Newell, *International Climate Technology Strategies,* Discussion Paper 2008-12, Cambridge, Mass, Harvard Project on International Climate Agreements, Oct. 2008.
[63] *Ibid.*

related national level and international efforts by the European Union[64], Japan,[65] the United States,[66] and IEA work in support of G8 and other processes.[67]

At a minimum, the process would monitor progress, share information on individual national efforts in an integrated manner, and identify where overlaps and gaps exist across countries.[68] One mechanism under this framework could also include the development of roadmaps to assess the current development status of particular technologies, systems, and relevant areas of underlying science, including the identification of appropriate milestones and necessary R&D funding levels. The framework would also provide a more systematic means for improving the cost-effectiveness of R&D by identifying particular areas where it makes sense for individual countries to focus on sub-parts of an integrated overall package and areas where joint funding is sensible. An agreement could also set out general guidelines for expectations for the magnitude of task-sharing and cost-sharing across countries for collaborative R&D projects. This framework could also highlight the importance of human talent to both knowledge development and transfer, by helping to identify high-priority areas for scholarly exchange—including from developing to developed countries.

An international agreement could also be fashioned to increase domestic funding of climate technology R&D, analogous to internationally agreed emission targets for each country.[69] International agreement over the necessary level and reasonable burden-sharing of R&D effort across parties could be valuable. Such an agreement could, for example, target a level of climate technology R&D as a percentage of GDP, or as a percentage increase from recent levels, with those levels set with the intention of significantly expanding R&D. The general idea is not without precedent: in 2002 the European Union set the goal of increasing its relatively low level of overall R&D intensity—currently 1.8 percent of GDP—to 3 percent of GDP by 2010.[70] The goal is EU-wide rather than country-specific and applies jointly to both public and private R&D funding. However, there is little evidence of measurable progress toward the goal thus far, although ongoing discussions

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[64]European Commission, European Strategic Energy Technology Plan (2007).
[65] METI (Ministry of Economy, Trade, and Industry) Cool Earth: Innovative Energy Technology Program (2008).
[66] USDOE (U.S. Department of Energy), U.S. Climate Change Technology Program Strategic Plan (2006)
[67] IEA. Towards a Sustainable Energy Future (2008).
[68] See Richard Newell, Oct. 2008, *Op. Cit.*
[69] *Ibid.*
[70] (OECD 2007a)

among government representatives and major R&D-performing companies have illuminated many of the key impediments.

A more detailed example—albeit in the medical rather than climate arena—is the 2005 proposal to the World Health Organization for a Treaty on Medical Research and Development.[71] The core country obligations in the proposal are for minimum levels of support for qualified medical R&D (both general and "priority" areas), measured as a share of GDP, according to a schedule varying by national income. Among other things, the proposal also identifies methods of qualified R&D financing (e.g., direct public support, tax expenditures, philanthropic expenditures, and certain business R&D).

Specifically with regard to energy, the IEA already collects annual data on public energy R&D spending by IEA countries, a process that could be adjusted if necessary to serve a more formal purpose.[72] Such an agreement could incorporate a "pledge and review" structure, and the necessary reporting on funding levels integrated with the regular climate technology development plan submissions described above. Targets could be structured as a share of GDP, as a percentage increase from recent levels, or some other metric. The IEA could serve as the review body—either directly or as an assistant to a UNFCCC Expert Group on Technology Development. The process could also include a broader energy innovation policy review element: the IEA already conducts regular reviews of the energy policies, include energy technology policies, of IEA member countries and other major energy consumers and producers[73]

d. Impediments to Technology Transfer, with Particular Regard to Intellectual Property Rights

As we have discussed, IPRs provide incentives to invest in R&D and operate as modalities for recouping those investments and turning a profit, despite the intangible and essentially non-rivalrous character of intellectual creations in the raw state of affairs. To this end, the TRIPS Agreement of 1994, by harmonizing international minimum standards of intellectual property protection within the confines of the Agreement Establishing the World Trade Organization, aimed to improve the baseline conditions for the transfer of knowledge and technology in a global marketplace.[74] The "incipient

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[71] A copy of the proposal can be found at www.cptech.org/workingdrafts/rdndtreaty.html. See Love and Hubbard (2007) for a related background discussion.
[72] See Richard Newell, Oct. 2008, *Op. Cit.*
[73] (see, for example, IEA 2006)
[74] F. M. Abbott, "Protecting First World Assets in the Third World: International Property Negotiations in the GATT Multilateral Framework", *Vanderbilt Journal of Transnational Law*,

transnational system of innovation"[75] emerging from this Agreement has created incentives and opportunities for entrepreneurs in developing countries once they become capable of producing and exporting knowledge goods to an increasingly competitive global market.

In principle, this worldwide intellectual property system should encourage the transfer of climate-change technology to and from developing countries. Even if returns generated by IP protection in these countries are relatively small, the availability of such protection should stimulate some transfer as well as foreign direct investment (FDI). Thus developing country governments should give careful thought to mechanisms for addressing the fears of foreign innovators regarding lax protection of their IPRs. Besides implementing their enforcement obligations under TRIPS,[76] governments should consider devising ways and means outside of their intellectual property and administrative laws to reassure companies that are willing to cooperate in transfers of essential technologies. While states may not discriminate against other states with regard to such laws, a long GATT tradition does allow governments to make better deals with cooperative companies than with others who may drag their heels.

On the negative side, however, there is evidence that the TRIPS Agreement has produced an adverse impact on access to essential public goods, especially in areas like public health and agriculture. And when thinking about potential problems in advance of their becoming acute in the environmental sector, it is well to remember that although the TRIPS agreement sets up a baseline of protection, it also has a variety of provisions that give developing countries some flexibility in addressing access issues. Thus it is worth emphasizing that governments in developing countries can under TRIPS maintain relatively stiff standards of patentability. Of course, stiff standards of eligibility must apply without discrimination to both national and foreign innovators. But these same standards might widen the space in which local companies could reverse engineer foreign innovations that fail to qualify and still obtain, say, utility model rights or "compensatory liability" rights in incremental innovations of their own. These same regimes might also serve to protect small-scale innovations held by foreigners, without

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Vol. 22, No. 4, 1989, pp. 689–745; Reichman, "Free Riders to Fair Followers: Global Competition Under the TRIPS Agreement", *New York University Journal of International Law and Politics*, Vol. 29, 1996, pp. 11-93.

[75] Keith E. Maskus & Jerome H. Reichman, "The Globalization of Private Knowledge Goods and the Privatization of Global Public Goods", in K.E. Maskus & J.H. Reichman (eds.), *International Public Goods and Transfer of Technology under a Globalized Intellectual Property Regime*, Cambridge University Press, 2005, pp. 3-45.

[76] TRIPS Agreement, arts 41-49. See Reichman, "Enforcing the Enforcement Provisions of the TRIPS Agreement", *Virginia Journal of International Law*, Vol. 37, 1997, pp. 335-339.

generating the thickets of rights and other barriers to entry that too many patents can produce.

Even when foreign companies qualify for patent protection under suitably exigent domestic patent laws, the existence of second-tier regimes provides incentives to local firms to adapt such inventions to local circumstances and to improve upon them. Moreover, the Japanese experience demonstrates that local firms that obtain second-tier rights of this kind in improvements then possess tradable rights that can become bargaining chips when dealing with large transnational corporations. By the same token, the fact that a local company can obtain, say, only a utility model right or a liability regime at home, in no way affects the patentability of its innovation in other countries, especially OECD countries. This is an important advantage of the "independence of patents" doctrine, incorporated into TRIPS,[77] which developing countries could leverage in the environmental sector so as to generate more significant profits in countries with larger markets.

Should tensions surrounding access in the environmental sector mount as they have in the pharmaceutical sector, the primary defensive options for developing countries would reside in article 31 of the TRIPS Agreement, which allows compulsory licenses to be issued on patented inventions for almost any reason, subject to the payment of compensation and certain other technical prerequisites.[78] Here developing countries have a wide array of defensive options that must be carefully evaluated and duly supported by legislative and administrative provisions.

For example, one of the most relevant and least studied of these options is the right to enact compulsory licenses for so-called dependent patents.[79] These licenses kick in when second comers develop patented improvements on existing dominant inventions, and they permit the improver to exercise his patent, despite its infringing posture, in exchange for a cross-license to and from the holder of a dominant patent. In effect, this compulsory license avoids blocking effects by manufacturing a liability rule solution for improvers.

Compulsory licenses for anticompetitive practices and behavior afford developing countries another set of options, especially when foreign firms refuse to deal with local firms or refuse to make technologies available at prices that local firms can afford.

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[77] Paris Convention, art. 4bis, TRIPS art 2.1.
[78] TRIPS, art. 31; Reichman with Hasenzahl (2003)
[79] TRIPS Agreement, art. 31(l).

While U.S. competition law would not necessarily support compulsory licenses on such grounds, they are fully established in international patent law and are increasingly invoked under the European Commission's own competition law and policy, which closely regulates potential "abuses of a dominant position" by holders of IPRs. Compulsory licenses issued for anticompetitive behavior under article 8, 31(k) and 40 of the TRIPS Agreement are subject to minimum restrictions and prerequisites, other than some administrative or judicial procedures, and even the right to compensation may be virtually nullified by such behavior.

Another compulsory license that might be relevant to the environmental sector is the government use license. Under a government use license, a private contractor may be made an agent of the government for purposes of manufacturing the patented product and making it available to the public at large. Such activity is immunized against an infringement action in the courts. Instead, the patentee must seek adequate compensation from the government itself, which can be measured in terms of local conditions. Government use licenses are also subject to very few prerequisites, they can be rapidly issued for virtually any reason, and the relevant transaction costs are low.

Still another form of compulsory license widely used in the EU and elsewhere is the so-called "public interest" compulsory license. On this approach, the government may enable third-party private contractors to produce the patented goods without license from the patentee, if the public interest requires the goods in question to be made available in greater quantities or at lower prices than the patentee is willing to accept. Such licenses do require notice and prior negotiations with right holders, and prior negotiations themselves usually suffice to break the bottleneck in question without actual need to issue the license in the end. Recently, in the context of public health needs, both France and Belgium have enacted laws allowing the issuance of expedited public interest compulsory licenses for public health purposes, although no such licenses have yet been issued.[80]

It needs to be stressed, moreover, that the existence of these defensive measures gives rise to certain offensive possibilities if planning and coordination problems are otherwise properly managed. Here we refer to interest in pooled procurement strategies that can enable poor countries to boost their bargaining power with respect to foreign suppliers of needed

[80] *See* Part 2, Section 2 of Geertrui van Overwalle (Ed.), *Gene Patents and Public Health*, Brussels, Bruylant, 2007.

technologies.[81] From this perspective, there are gains of trade to be made when small countries coordinate their procurement strategies, especially when the objective is to stimulate foreign producers to lower the price of technologies or even to establish local production facilities in a given region. By pooling their purchasing requirements, countries may achieve economies of scale and scope that will entice foreign suppliers to deal on more favorable terms. Moreover, coordinated procurement strategies toughen the threat of compulsory licenses—if all the participating governments are willing to issue them—while sweetening the carrots of cooperative behavior by offering originators (or willing producers of substitutes) a larger market in which to establish their trademarks, sell their products, or even establish local production. Pooled procurement strategies with or without compulsory licenses look ever more promising in the pharmaceutical sector[82] (where, however, special enabling legislation already exists),[83] and they should be carefully evaluated for application in the environmental sector as well.

However, most of these defensive measures are subject to certain technical, legal, and political constraints. For example, a threat to issue a compulsory license may be meaningless if the country possesses no capacity to reverse-engineer the product or process in question, unless it can obtain similar products from other countries where they are off patent or available under the doctrine of exhaustion. Similarly, most compulsory licenses under article 31(f) of the TRIPS Agreement must be made "predominantly for the supply of the local market," which means no more than 49.9% of the production can be exported to another country (unless such exports can conceivably be justified as an "exception" within article 30).[84] These restrictions can also hinder implementation of pooled procurement strategies, at least to the extent that they depend on compulsory licensing.

Of course, climate mitigation technology is quite different from the pharmaceutical sector, in which many of these defensive measures have been used. Because pharmaceutical products are generally quite inexpensive at marginal cost, developing countries have eagerly embraced such products (and have resisted attempts to raise cost through patent restrictions). In contrast, absent GHG pricing, certain green technology can be more expensive than conventional technology even when sold at marginal cost. Nonetheless these measures demonstrate that there are means for the

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[81] *See* Abbott & Reichman *Op. Cit*, (with regard to pooled procurement strategies in the pharmaceutical sector) at 973-77.
[82] See *ibid.*
[83] See *ibid.*
[84] For the unsettled state of this thesis, see *Ibid.*

international community to address threats to the public good if and when IPRs become an impediment.

e. Indigenous Innovation in Developing Countries

Much of the international climate negotiations, as well as the academic literature, have operated on the assumption that green climate-friendly technologies will primarily or exclusively be developed in wealthy countries, and will then need to be transferred to poor countries through private or public mechanisms. This model of innovation in wealthy countries and diffusion to poor countries has characterized other fields of technology, such as pharmaceuticals (discussed above). And it is underscored by the reality that 95% of global R&D spending currently takes place in wealthy countries.

But the future may hold significant potential for indigenous innovation of green climate-friendly technology within at least some developing countries. If so, the global pattern of climate R&D will look different from that of prior technologies, and the need for technology transfer from OECD countries to others may be somewhat reduced. At the same time, the promise of indigenous innovation in developing countries will require attention to the incentive systems operating within those developing countries. The same choices and debates about the design and limits on IPRs and alternative incentive instruments, discussed above in the context of wealthy countries, will then arise anew in developing countries.

There are several reasons to expect greater supply of indigenous technological innovation in developing countries regarding green energy or climate change, as contrasted to other fields of R&D. First, the impetus for climate-friendly innovation will be greatest in the wealthiest of developing countries, not the poorest. Unlike in the case of essential medicines, where the countries most in need are also the poorest with the least capacity to innovate, in the case of energy and climate technology the major developing countries most in need – that is, the largest emitting countries who will be most called on to reduce their emissions – are the wealthiest with the greatest capacity to innovate. Growing greenhouse gas emissions usually (though not inevitably) correlates with rising energy use, electrification, vehicle ownership and distance traveled, and wealth.

Notably, China, India, and Brazil are three of the largest greenhouse gas emitters in the world (China having surpassed the USA in 2007 to become the

world's largest CO2 emitter).[85] They are also three of the wealthiest developing countries. Indeed they are emerging great powers. They still have significantly lower per capita income than OECD countries, but their aggregate GDP is rising to the point that it equals or surpasses many OECD countries. While GDP in Europe and the USA has been growing at about 2 or 3 percent per year over the past decade, China's GDP has been growing at over 10 percent per year over that period. (On present forecasts, China may be the world's largest economy with a decade or two, although the 2008 economic crisis may reduce growth rates in both China and OECD countries.)

Other major emitters among developing countries, such as Indonesia and South Africa, are less wealthy and are growing more slowly economically, but are still among the better-off among developing countries and thus capable of supporting indigenous innovation. The only large GHG emitters among the very poor developing countries are those experiencing rapid deforestation, such as in central Africa. Technical innovation in agriculture and cooking may be important to slow deforestation and thus reduce GHG emissions in those very poor countries (in order to reduce demand for converting forests to farmland, and for clearing forests for fuelwood, respectively). Some of this innovation may come from elsewhere and be transferred to these countries, but even here there are prospects for indigenous innovation in farming and cooking methods.

Second, the wealthier developing countries already have large communities of well-educated professionals working in R&D. China and India are already home to a large percentage of the world's scientists and engineers. Brazil is already a world leader in liquid fuel technologies. This human capital advantage in high GHG-emitting developing countries is the opposite of the human capital deficit in poor countries seeking pharmaceuticals for destitute poplations.

Third, credit is available to finance indigenous R&D. At least some of these emerging powers, most obviously China, have large pools of available credit. China created a new sovereign investment fund in 2007 endowed with approximately $400 billion, and in early November 2008 announced a new domestic infrastructure investment initiative of $586 billion over the next two

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[85] See International Energy Agency, 2007 *Op. Cit,*; "China to Top USA in Greenhouse Emissions", USA TODAY.com, Apr. 24, 2007, available at: http://www.usatoday.com/weather/climate/globalwarming/2007-04-24-china-emissions_N.htm; "A Large Black Cloud: Rapid Growth Is Exacting a Heavy Environmental Price", *in* THE ECONOMIST*, Special Report: China's Quest for Resources*, Mar. 15, 2008, at 17, 17, 21, available at: http://www.economist.com/specialreports/displaystory.cfm?story_id=10795813.

years.[86] Foreign investors will add to these financial markets. This trend may be reinforced if the current credit market problems in the US and Europe continue and come to make investment opportunities in China, India and Brazil seem relatively more attractive.

Fourth, there is a nascent community of venture capital firms already at work in China and other major developing countries. This source of financing and entrepreneurial insight can be critical to small start-up firms.

Fifth, there is at least domestic demand for innovation to reduce emissions. As China adds a new coal-fired electric power plant each week (and India adds one about every other week), its coal combustion yields not only CO2 but also SO2, NOx, fine particulates, and black carbon.[87] The public health damage from these co-pollutants is serious (in China, up to 750,000 deaths per year).[88] Moreover, this public health burden is increasingly recognized by those countries' leaders as both a drag on economic growth[89] and a source of political unrest.[90] Thus political leaders in these countries have incentives to promote domestic public R&D spending to reduce these emissions; and domestic pollution control policies in these countries may spur private investment in such domestic innovation.

Sixth, if the demand-side market failure of climate change is corrected with a price on carbon (via carbon taxes or a cap and trade regime), and if that policy applies to the major developing countries, then there will be incentives for innovation within those countries to reduce GHG emissions. For example, there would be incentives to reduce CO2 emissions from coal combustion (via, e.g. carbon capture and storage), and CH4 emissions from natural gas pipelines, ruminant animals and rice cultivation. If indigenous innovation can reduce these emissions at lower cost than through imported external innovation, the country would benefit from lower abatement costs (and from

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[86] See David Barboza, "China Unveils Sweeping Plan for Economy", *NY Times*, Nov. 9, 2008, at http://www.nytimes.com/2008/11/10/world/asia/10china.html .

[87] See David G. Streets, *Black Smoke in China and Its Climate Effects*, Asian Economic Papers, 2005, vol. 4, issue 2, pages 1-23; Fei Teng & Alun Gu, *Climate Change: National and Local Policy Opportunities in China* (Fondazione Eni Enrico Mattei, Working Paper No. 74.2007, 2007).

[88] *See A Large Black Cloud*, *supra* note __; Elizabeth C. Economy, "The Great Leap Backward?", *Foreign Affairs*., Vol. 86, No. 5, Sept./Oct., 2007, pp. 38 & 47 (citing 400,000 to 750,000 deaths per year); V. Ramanathan & G. Carmichael, "Global and Regional Climate Changes due to Black Carbon", *Nature Geoscience*, Vol. 1, No. 4, 2008, pp.221 & 226 (finding that black carbon makes a significantly greater contribution to global warming than earlier estimates, and observing that reductions in black carbon could yield major public health benefits, especially in China, India and other developing countries). Note that black carbon is not yet included in the Kyoto Protocol, Annex A, list of regulated GHGs, but could be added in a future international accord. See Annex A to the Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 22 (entered into force Feb. 16, 2005).

[89] The World Bank & State Environmental Protection Administration, People's Republic Of China, Costs Of Pollution In China, at xvii (2007) (citing a cost of 5.78 percent of GDP).

[90] See Jonathan B. Wiener, "Climate Change Policy and Policy Change in China", *UCLA Law Review*, Vol. 55, No. 6, 2008, 1818-21.

the opportunity to sell emissions allowances on the world market, if a cap and trade regime is adopted).

Seventh, several countries may serve as role models. These countries have recently succeeded in stimulating indigenous technological innovation as part of their vault from poor to wealthy, including admission to OECD membership. For example, in the last three decade in South Korea and on Taiwan have demonstrated that indigenous innovation in manufacturing, electronics, biomedicine, and related industries can be part of rapid economic growth in Asia.

These factors are already spurring increased innovation in the energy sector in major developing countries. In China, innovation has accelerated in recent years.[91] This trend is publicly associated with President Hu Jintao's commitment to "harmonious society" and the "scientific concept of development."

To be sure, future progress in green or climate-friendly indigenous innovation in developing countries will depend on several factors. One is the effective demand for new methods of reducing GHG emissions as a result of policies to raise the price of emissions. A second is the reach of this demand across diverse sectors in which several GHGs are emitted, including electricity generation, vehicles, buildings, agriculture, and forests. A third is the role of IPRs or alternatives within these countries in stimulating the supply of new technologies, as discussed in prior sections of this paper.[92] A fourth is the general ease of doing business within these economies.[93]

Thus, it will be important to study the design of IPRs or alternatives to encourage green climate-friendly technological R&D in major developing

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[91] See Shulin Gu & Bengt Åke-Lundvall, "China's Innovation System and the Move Toward Harmonious Growth and Endogenous Innovation", *Innovation: Management, Policy and Practice*, Vol. 8, 1-2, 2006, *available at* http://www.innovation-enterprise.com/8.1/8.1.1.html .

[92] Of course, the US and China have had disputes over IPRs in China. See David R. Weisman, "US Toughens Its Position on China Trade", *NY Times*, April 10, 2007, at http://www.nytimes.com/2007/04/10/business/worldbusiness/10trade.html . Chinese leaders say they seek a stronger system of IPRs. See Xinhua News Service, www.chinaview.cn , "Official: China Needs to Perfect its Intellectual Property System", Oct. 29, 2008 ("Zhang Qin, deputy director of State Intellectual Property Office [said] the country's intellectual property system still lagged behind developed countries and needs improvement. The country also encourage the enterprise to upgrade their innovation level."), at http://news.xinhuanet.com/english/2008-10/29/content_10276636.htm . Meanwhile, in a sign of further movement toward a full market economy, China has been authorizing property rights in land. See Edward Wong, "China May Let Peasants Sell Rights to Farmland", *NY Times*, October 11, 2008, p.A1, at http://www.nytimes.com/2008/10/11/world/asia/11china.html .

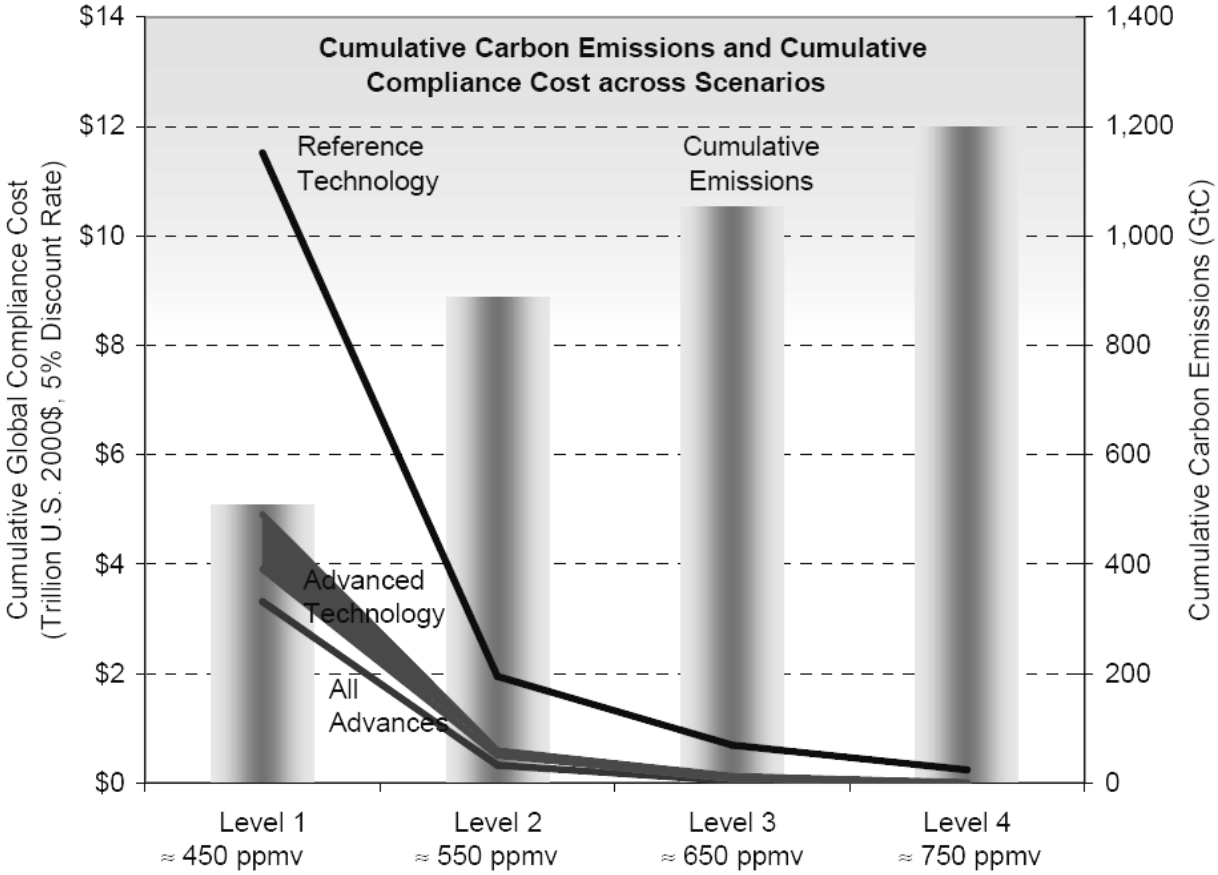
[93] In the most recent Doing Business rankings posted by the World Bank, China, India and Brazil ranked 83rd, 122nd and 125th (out of 181 countries) in overall ease of doing business. See http://www.doingbusiness.org/economyrankings (visited Nov. 9, 2008).

countries, as well as in wealthy countries.[94] Lessons from the performance of IPRs in energy and agricultural sectors in wealthy countries may be useful in this effort, provided that the different economic and social context of each developing country is understood.

[94] For surveys of IPRs in China, see William P. Alford, *To Steal A Book Is An Elegant Offense: Intellectual Property Law In Chinese Civilization*, Stanford, CA: Stanford University Press, 1995; Peter Feng, *Intellectual Property in China*, 2nd ed., Hong Kong, Sweet & Maxwell Asia, 2003.

V. CONCLUSION

In this report, we provide an analysis of how IPRs, and alternatives to IPRs, might operate in green innovation. Because IPR challenges are likely to arise (if at all) only after sufficient levels of innovation have been generated by a combination of appropriate GHG pricing and public funding, we rely heavily on analogies to existing technological sectors that are currently experiencing difficulties. In addition, because over 95% of global R&D is currently generated in OECD countries, we focus on these countries in our discussion of IPR challenges. However, if climate change is going to be addressed successfully, clean technology must be adopted globally. Thus, our paper concludes by examining at some length the international context.



Source: Clarke et al. (2006, p. 6.5).

Figure 1. Cumulative global mitigation costs under alternative technology scenarios

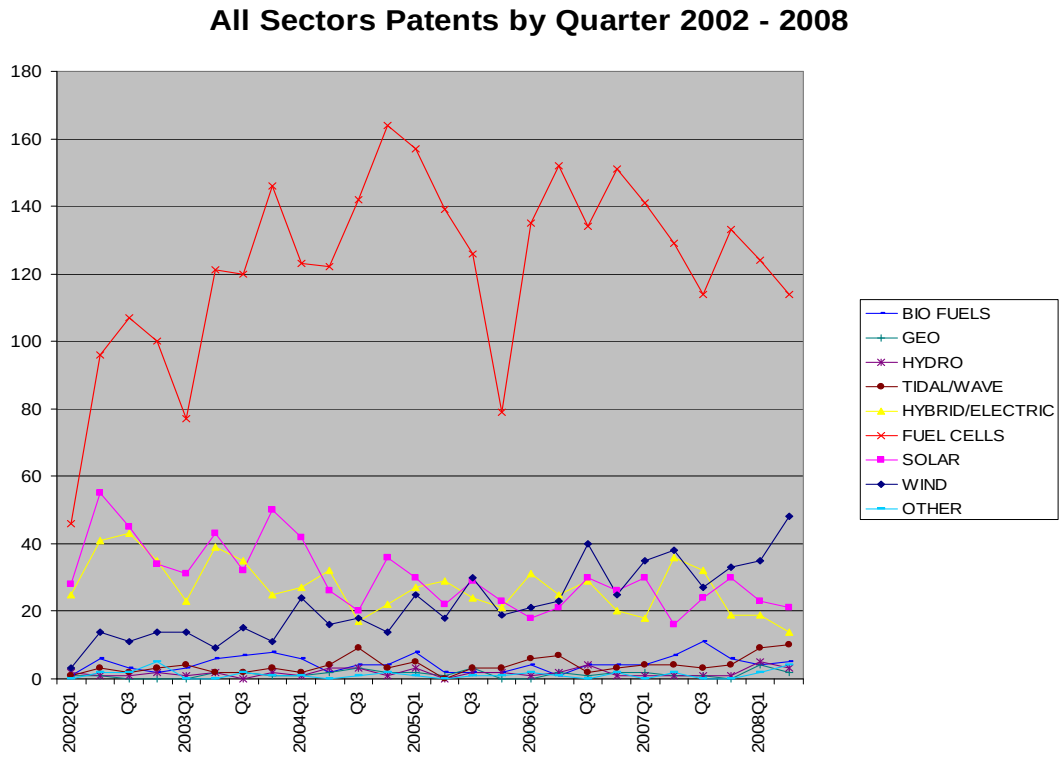


Figure 2: From Clean Energy Patent Growth Index (U.S.)