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Background Paper

IP and Climate Technology

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This study was commissioned by Chatham House on behalf of the Interdependencies on Energy and Climate Security for China and Europe project. It is distributed as a background paper for the experts meeting on IPRs and the Innovation and Diffusion of Climate Technologies, to be held on 16th November 2007 at Chatham House, London. 'Leading the Technology Race', a background paper drawn from the Final Report of the project, Changing Climate, will also be disseminated to the participants. This paper will be revised, edited and published following the experts meeting. For further information please contact Bernice Lee at blee@chathamhouse.org.uk.

Professor John Barton is the George E. Osborne Professor of Law (Emeritus) at Stanford Law School. His academic career has examined the intersection of science and the law, with particular focus on international patent law and its relation to trade and innovation. He has chaired or been a member of numerous national and international committees on intellectual property rights, health and agriculture including the US. National Research Council Committee on Intellectual Property Rights. Professor Barton is co-director of the Stanford Program in Law, Science & Technology and has worked with organisations such as the Rockefeller Foundation and the World Bank.

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This paper explores methods for encouraging the diffusion of new environmental technologies to and within China and the European Union (EU), and considers the role of intellectual property (IP) in encouraging and discouraging that diffusion. It is organized according to the various forms of technology encouragement and of standardization. For each of the areas, the paper describes the intended role of the encouragement or standard, the ways that it might encourage innovation and diffusion of technology, the way IP affects that encouragement, and finally way, such as licenses and pools, to deal with any IP problems. The paper uses a series of historical examples as case studies, and attempts to apply the findings to current issues. To the extent possible, the examples are taken from the contemporary climate change/energy context; in some cases earlier examples of other technologies have proven more illuminating. The paper explores diffusion and adoption of new climate change technologies in both the EU and China. Clearly, its findings must be viewed as provisional; the historical examples often raise controversies on their own, and application to future issues is necessarily tentative.

I INCENTIVES/SUBSIDIES BASED ON REGULATION OF INDUSTRY

The development and dissemination of climate-change associated energy technology suffer from two market imperfections, both of which have been a basis for government interventions.[1] First, these technologies require significant research and development. In many cases, the benefits of investment in research and development are not readily appropriable to the firm making the investment. One major government response is the patent system, and more broadly the IP system, in which the protection of trade secrets, also known as confidential information, is especially important. (The other major government response, financial support of research, is considered in Part II of this paper.) The second market imperfection is that the social benefit of reducing greenhouse gas emissions is not yet generally reflected in cost structures, i.e., not yet internalized. Hence, deployment of socially desirable technologies is not necessarily economically profitable. The government response has taken the form of a variety of regulations and subsidies to encourage the relevant technology development

[1] See generally A. Jaffe, R. Newell, & R. Stavins, *Technology Policy for Energy and the Environment*, NBER Innovation Policy and the Economy Meeting, April 15, 2003.

and deployment. There is little solid evidence on when these approaches are successful; some specific programs, e.g. the US. program on photovoltaics, have been said to be much more successful than others, e.g. the US. program on synthetic fuel.[2]

The patent system is designed to deal with the first market imperfection, that of the difficulty of appropriation, by providing exclusive rights for a fixed period of time to the use of particular inventions. The expectation is that the exclusivity will enable the firm holding the patent to charge a price above the marginal cost of production and thus to recoup the investment, and, of course, to have the incentive to make the investment in the first place. The working of the incentive in the energy area is likely generally to be quite different from that in the pharmaceutical area, where there has been much debate over the patent-based model of product development. In that industry, it is sometimes possible for a firm to charge a monopoly price for an individual product. In the energy area, however, it is likely that there will be competition both within the general product area (e.g. wind turbines), and among different methods of producing electricity or fuel. Hence, the role of patents will generally be first to deter the entry of competitors and shape the industry into an oligopoly able to charge prices somewhat above marginal costs and thus to support research[3] and second to provide a basis for developing a differentiated product that has features that help it gain larger market share. Clearly, the costs are that the new innovations are not shared by competitors unless there is a license, and that prices may be somewhat above marginal costs. The likelihood that the patent system will greatly encourage research, the likelihood that there will be licenses to spread the technology, and whether such licenses will encourage innovation and its adoption are all dependent on the competitive conditions of the industry.

In dealing with the second market imperfection, that associated with the failure of prices to internalize environmental costs, nations have adopted many types of approach such as direct regulation, application of a shadow price for emitting greenhouse gases, requirements that a specified portion of environmentally preferable sources be used in the production of electricity or fuel (with the sources sometimes chosen through bidding), and requirements that environmentally preferable sources be used at specified prices in producing

[2] Id.
[3] See, e.g., J. Barton, Antitrust treatment of oligopolies with mutually blocking patent portfolios, *Antitrust Law Journal* 69:851-882 (2001).

electricity or fuel. It is to be emphasized that the mechanisms must be applied effectively in order to obtain private sector investment in alternatives that present higher immediate costs – this is particularly an issue when competition makes it unappealing to a firm to use the technology. There has, for example, been question whether China's laws are yet adequate to encourage such investment, particularly in the face of the divisions of authority within the nation.[4] Nevertheless, China has "aggressive energy efficiency policies" and is also the largest source of Clean Development Mechanism (CDM) credits under the Kyoto Protocol.[5]

Direct regulation has been the long-term typical mode of government action, exemplified by regulations restricting the production of certain pollutants by automobiles or by power plants. Obviously this approach will bring forth investment in the application of the technology to just the extent needed to satisfy the regulation. If the regulation is difficult to satisfy or if new technologies appear likely to allow satisfaction of the regulation more cheaply, there will be investment in new technologies. Such regulation, or at least an analogue to it, has been used in China, which has set targets for energy efficiency, with the target allocated among provinces and industrial sectors.[6]

The creation of an effective shadow price is the approach most likely to be favored by economists, because it leaves as many allocation issues as possible to the market. In the economist's ideal mode the shadow price would be imposed through a carbon tax. Political realism has, instead, led to the design of regulations in such a way as to require reduction but to allow a market in emission rights. This creates a shadow price, as measured by the costs of emission rights defined by the market, and permits trading so as to allow lowest-cost overall emissions reduction. In this case, investment in emissions reduction will depend on the regulatory requirements that force one to enter the emissions market and on whether the investment will be less expensive than the alternatives available through the market. As long as low-cost alternatives are expected to be available within the planning horizon, there will be no incentive to

[4] J. Cherni & J. Kentish, Renewable energy policy and electricity market reforms in China, *Energy Policy* 35 (2007) 3616-3629; S. Ohshita & L. Ortolono, Effects of Economic and Environmental Reform on the Diffusion of Cleaner Coal Technology in China, *Development and Change* 37: 75-98 (2006).
[5] Pew Center on Global Climate Change, *Climate Change Mitigation Measures in the People's Republic of China; International Brief 1*, April 2007.
[6] J. Lewis, China's Climate Change Strategy, *China Brief*, Vol 7, Issue 13, June 27, 2007.

invest in research (and this is the intended result of the concept). Research investment will be made only as investors see an adequate likelihood that the long term cost of carbon credits will be so high that the research and following investment are likely to pay off in comparison with purchasing credits.

Requirements that specified quantities of products based on emissions reducing technologies be purchased have been used in both the electricity and the fuel markets, as in requirements that specified portions of a grid's electricity supply derive from renewable sources or that specified percentages of a motor fuel be made from ethanol. This is the approach of the UK "renewables option,' which requires that a specific share of electricity be based on renewable sources,[7] and the EU requirements that a particular proportion of fuels derive from renewable sources.[8] (The EU's requirement that each nation adopt a target for use of renewable sources for electricity consumption[9] can certainly be implemented in this way, but could also be implemented by other forms of measure.) It is alternatively possible to require a grid (or perhaps a fuel blender) to pay a specified minimum price, i.e. a feed-in tariff, for a renewably-derived component. The price is, of course, set high enough to encourage investment in the renewable process, and is therefore likely to be higher than the price of the other available resources. This requirement can be essentially uncapped, so that all the supplies derived from such a source if available; or it can be capped in the sense that only a specified share need be purchased at the price. China has versions of both of these mechanisms in its requirement that grids use a particular portion of renewably-sourced energy, and in its provision of tax incentives to the wind energy sector (which amounts to a method of reducing the price of that source of energy in comparison with other sources).[10]

For purposes of this paper, it is significant that different mechanisms are likely to differ in the incentives they create for technology development and diffusion. In general, the market share approach will lead to satisfaction of the renewable source requirement through use of the cheapest available technology – if there is an incentive for technology development, it is for least cost technology, and the market is likely to be relatively competitive, and therefore provide little margin to

[7] UK DTI, *Meeting the Energy Challenge; A White Paper on Energy* (May 2007).
[8] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport.
[9] Communication from the Commission to the Council and the European Parliament, *Renewable Energy Road Map; Renewable energies in the 21st century: building a more sustainable future* COM(2006) 648 final (10.1.2007).
[10] J. Lewis, supra.

support research. (Indeed, one of the current UK policy concerns is that the renewables obligation has encouraged only some renewable technologies.[11]) In contrast, the fixed purchase price or feed-in tariff approach will allow suppliers of technology to gain not just market share but extra profit, and therefore capability to invest in research, should they produce a lower cost product. Thus, the fixed purchase price tends to favor cost reduction, while the feed-in tariff provides greater ability to carry out research (but also represents a more explicit and therefore politically contentious subsidy).[12] The effect of a tax break depends on whether the market-determined price leaves the benefit of the tax break with the firms or with the customers.

A Regulations designed to encourage the industry being regulated to develop and install new technology

The regulatory systems will work differently depending on whether they are designed to encourage research and technology application within the industry being regulated or to encourage the creation of a separate industry that is expected to advance the technology. This is obviously not a hard-and-fast line – there are likely to be subcontractors and engineering firms in all cases. And new industries may emerge during the evolution of a technological change. But there is often a clear difference between those situations in which the regulated industry is to change and modify its own processes and those in which it is to buy products from a separate industry which is the one expected to develop new technologies.

There are several historical examples of regulation designed to encourage change within the regulated industry, and they illuminate some of the IP issues involved, particularly the relative wisdom of encouraging firms to compete in developing the new technologies or of encouraging them to cooperate and share technology. One is the US. auto industry's response to the first generation of emissions controls; the other is the US. Electric Power Research Institute (EPRI).

At the time of the early move toward reducing auto emission, the US, auto industry was a concentrated oliogopoly in which the firms competed through

[11] UK DTI, *White Paper*, supra.
[12] P. Menanteau, D. Finon, & M. Lamy, Prices versus quantities: choosing policies for promoting the development of renewable energy, *Energy Policy* 31: 799-812 (2003).

product differentiation oriented toward consumer appeal. As the scientific understanding of automobile-derived pollution evolved, the industry responded in 1955 by signing an agreement to exchange information on emissions control devices. Under the agreement, each of the firms promised to share information it held on pollution control technology and to permit other parties to the agreement to use each party's technology without any need to pay a royalty.[13] Critics of the industry alleged that this cross-license was a way to bottle up the technology,[14] and the technology did not move quickly, with the only real outcome being a device to reduce crankcase emissions, a technology that had long been available.[15] In 1969 the Antitrust Department filed an antitrust suit, alleging that the parties to the agreement had conspired to eliminate competition in the research of emissions control equipment and in the purchase of patents from others developing such technology. Indeed, according to a Department of Justice memo, the industry thought it crucial that no one "should expect to take advantage competitively by being the first, or claiming to be the first to offer" pollution controls.[16] The suit was settled by a 1969 consent decree ordering withdrawal from the agreement, prohibiting the parties from making any such agreement for a period in the future, and directing that they make available to others any technology developed under the earlier agreement. The parties were also prohibited from exchanging confidential information on research in the area, except for basic research.[17]

Pressure for research then came from regulation such as the Clean Air Act,[18] in which a key issue was to balance the severity of the regulation with the availability of the technology to live up to the regulation. This created a new environment of quite sharp confrontation between the regulatory agency and the industry, but also led to catalytic conversion technology, and ultimately to today's use of on-board diagnostics.[19] Also in this new environment, certain of the provisions of the antitrust consent decree came up for renewal, a renewal sought by the government and opposed by the industry. The issue was resolved before

[13] B. Goldstein & H. Howard, Antitrust Law and the Control of Auto Pollution: Rethinking the Alliance Between Competition and Technological Progress, *Environmental Law* 10: 517-558 (1980).
[14] S. Taylor, The Great Smog Conspiracy 25 Years Later: Is History Repeating? *Paradigm Magazine* (undated).
[15] Goldstein & Howard, supra.
[16] J. Brock, Antitrust policy and the oligopoly problem, *Antitrust Bulletin* 51: 227-280 (Summer 2006).
[17] Goldstein & Howard, supra.
[18] C. Schroeder, *Symposium: Regulating Automobile Pollution: An Environmental Success Story for Democracy*, *Saint Louis University Public Law Review,* 20: 21-46 (2001).
[19] D. Gerard & L. Lave, Implementing technology-forcing policies: The 1970 Clean Air Act Amendments and the introduction of advanced automotive emissions controls in the United States, *Technological Forecasting & Social Change* 72: 761-778 (2005); J. Mondt, *Cleaner Cars; The History and Technology of Emission Control Since the 1960s* (Society of Automotive Engineers, 2000).

federal courts in California, where the real question was choosing between the cooperative research pattern envisioned by the 1955 agreement and the competitive research pattern envisioned by the 1969 decree. Ultimately, moved by concerns about the risk and cost of technology development in the area, and by the possibility of a cooperative agreement among industry, government, and academia, the courts chose the cooperative pattern, and effectively permitted the consent decree to expire.[20]

It is, of course, frequently unclear whether cooperative research or competition is the right answer. The benefit of the cross-license is that the costs and risks of developing technology can be shared and that the technology developed by any one firm can be used by all; the cost is that each firm's incentive to develop new technology is diluted, because there is no competitive advantage derived from a particular firm's technological; advance. This defines the basic balance that must be made by a regulator in evaluating the economic wisdom of a cross-license. Clearly, the balance is affected by the strength of the emissions control regulations themselves, for these regulations may provide an incentive for research. It is also affected by the principles of patent enforcement, which are, at least in the United States, moving in the direction of weaker remedies.[21] The effectiveness of the regulatory process in forcing technological advance depends also on the regulator's ability to evaluate the industry's technological progress – experience in the auto case suggests the need for the regulator to be able to learn about each firm's progress individually, rather than to be informed through a joint submission agreed upon by the members of the industry.[22]

The other example is the US. Electric Power Research Institute (EPRI), organized in 1972, as the US. electric utilities realized that they would benefit from cooperative research in a number of areas including the goals of efficiency and emissions reduction. The Institute is supported by an assessment on each of its members, and the membership is now global.[23] It finances specific studies of specific technologies; it has also recently prepared an analysis to define the

[20] Goldstein & Howard, supra; *United States v. Motor Vehicle Manufacturers Association*, 643 F.2d 644 (9th Cir. 1981).
[21] This is exemplified by the 2006 decision, *Paice LLC v. Toyota MotorCorp.* 2006 US. Dist. LEXIS 61600 (ED Texas 2006). Note that, although the remedy – a reasonable royalty rather than an injunction – may be effectively a compulsory license, it was granted primarily because the patent holder was an outsider to the industry and would have, at most, obtained a royalty in nay event. This was an application of the recent US Supreme Court decision, *eBay Inc. v. MercExchange, L.L.C.*, 126 S.Ct. 1837 (2006), which changed the general principles for injunctive relief. The patents involved described particular methods of hybrid vehicle technology.
[22] Goldstein & Howard, supra.
[23] Electric Power Research Institute, 2006 Annual Report.

technology portfolio needed to reduce CO_2 emissions in the United States.[24] When it contracts for research, EPRI, at least traditionally, applied two IP restrictions. One was that "EPRI funds must not be used to create or strengthen a monopoly resulting from ownership of proprietary rights obtained with EPRI support," and the other was that "EPRI will negotiate the disposition of proprietary rights on the bases of the contribution of its funding."[25] Currently, EPRI generally takes rights in research it supports and grants only non-exclusive licenses. Nevertheless, exclusive licenses are used when significant further private investment is needed to commercialize a product; moreover a contractor who has already invested heavily in a technology may retain some exclusive rights in the results of research on specific applications or aspects of the technology. Those technological results, including patents, reports, software, and data, that can be directly applied by the member utilities are made available to the members under an internal-use license. And some are made public. The key benefit that the institution brought to the field was to create a research management team far beyond what any single utility could support. The underlying institutional pattern was very different from that of the auto industry; for EPRI, there were local utilities, not directly competing with each other, setting up a jointly-managed institution that would support research and provide it to all its members.

There are at least two industries in Europe and China in which this general regulatory and industrial structure pattern is applicable. One is environmental improvement of the cement production industry. In cement production, calcium carbonate, $CaCO_3$ is heated to break it into calcium oxide, CaO, the intended product, and carbon dioxide, CO_2, which is, of course, a greenhouse gas. There are two levels of technology improvement available.[26] One is to use energy more efficiently, including both the energy for heating the $CaCO_3$ and the energy for all the auxiliary operations of preparing the raw materials and grinding and the like. This is a matter of investment, and, to some extent of research, on various ways to redesign the details of the process and to recover waste heat and the like. The second level is much more difficult and involves an effort to recover the CO_2 that derives from the $CaCO_3$, as well as that which derives from the combustion used to heat the $CaCO_3$, and then to sequester that $CO_{2,}$, (a technology to be discussed in Part III). This has not yet been done (as of 2001).

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[24] EPRI Energy Technology Assessment Center, *The Power to ReduceCO_2 Emissions; The Full Portfolio* (Discussion Paper; August 2007).
[25] C. Starr, The Electric Power Research Institute, *Science* 219: 1190-1194 (1983).
[26] E. Worrell et al, Carbon Dioxide Emissions from the Global Cement Industry, *Annu. Rev. Energy Environ* 2001, 26: 303-329.

The other industry taking this pattern is steel. Here, there is a first phase emphasizing energy efficiency.[27] In general the mechanisms of this phase are those of avoiding allowing the iron or steel material to cool if it is to be heated for a subsequent operation and those of recycling waste heat as effectively as possible. The second phase, involves fundamental changes in the overall process to reduce CO_2 emissions deriving from such key sources as the combustion of carbon in the blast furnace or the oxidation of carbon in the process of purifying iron to produce steel. Thinking here is at a very early point. Thus, ULCOS ("Ultra Low CO_2 Steelmaking"), a consortium headed by ArcelorMittal has recently been formed to explore various concepts -- the group is still some years away from choosing a lead technological approach.[28] And – and the same is likely to be true for cement – the key economic barriers are the capital cost of constructing all the systems necessary for energy management. There is, however, a major contrast between cement and steel – because of the cost of transportation and the relative value and weight of the products, the competition in cement is comparatively local and that is steel is comparatively global. Moreover, steel firms are on the whole larger.

The historical examples suggest several principles to be taken into account in thinking out the encouragement of technology development and spread in the cement and steel and similar industries – and many of these principles will apply in any context where technology is to be encouraged in an industry that is imperfectly competitive. First, there is the obvious question whether the structure and regulation of the industry creates an adequate incentive to conduct research. There will be essentially no privately-sponsored technological progress unless the members of the industry find it economically desirable to support research and have the resources to do so. Although competitive considerations will sometimes encourage research (as they may be doing in the case of hydrogen-powered vehicles),[29] it is often necessary that the regulatory restrictions be seriously binding.

[27] J. de Beer, E. Worrell, & K. Blok, Future technologies for energy-efficient iron and steel making, *Annu. Rev. Energy Environ.* 23: 123-205 (1998).
[28] European Consortium to Start Work on Steel Production Processes with Reduced CO2 Emissions, Azoma.com, Feb 15, 2005.
[29] B. Solomon & A. Banerjee, A global survey of hydrogen energy research, development and policy, *Energy Policy* 34: 781-792 (2006).

Second, there must be an actor or actors with the size and financial ability to conduct research. This was not the case of the individual utility, but may have been the case of the automobile firm. Because of the relative sizes of firms, there are likely to be fewer such entities in cement (especially in China0,[30] than in steel. Where there is no such entity, then collaboration, perhaps of the EPRI type, is essential. But note that, although size of firm may be essential to support substantial investment in research and development, there is very mixed evidence as to whether larger firms are then faster or slower to adopt new technologies than are smaller firms.[31]

Third, if several entities are able to support research, should they be allowed to cooperate or required to compete? What kind of industry cross-licensing system should be encouraged or accepted? This is a question of the extent to which a variety of technologies are available (if there is only a single plausible technology, cooperation must be permitted) and of the ability of the regulators to obtain reliable information from the industry to set intelligent standards if the industry cooperates in providing the information. Probably most of all, it is a question of the extent to which the firms have the incentive to compete in satisfying the regulatory goals (as the auto makers may with respect to fuel efficiency but not with respect to emissions control). Note, for example, that the semiconductor industry sees very rapid progress even though firms effectively cross-license one another, either by actual license or by failing to sue (because of fear of countersuit) – and the reason is almost certainly that the customers demand and reward rapid technological progress.[32]

Based on these points, although more detailed analysis is certainly needed, the cement industry would probably benefit from a cross-license and EPRI-style arrangement. On the other hand in the international steel industry, firms themselves are probably the ones to do the research. But there is so much competition that – once serious emissions restraints are imposed – the steel firms may be less willing than the cement firms to license new technologies to one another. If there are a number of technological responses available, this may be

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[30] J. Nordqvist & L. Nilsson, Prospects for Industrial Technology Transfer in Chinese Cement Industry, Lund Institute of Technology (2001); China Govt steps up efforts to restructure cement industry, CementChina.net, April 26, 2006.

[31] Compare N. Rose & P. Jaskow, The diffusion of new technologies; evidence from the electric utility industry, *RAND Journal of Economics,* 21: 354-373 (Autumn 1990) (larger firms adopted first); with S. Oster, The diffusion of innovation among steel firms: the basic oxygen furnace, *The Bell Journal of Economics* 13: 45-56 (Spring 1982) (larger firms slower to adopt).

[32] See J. Barton, Antitrust Treatment, supra.

acceptable. It not, it may be wise to attempt to impose some form of compulsory cross-license. This, however, clearly raises difficult political issues, and may be a problem under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Moreover, as will be seen in consideration of more recent industry cooperative agreements in automobiles and semiconductors discussed below, it is extremely difficult to make firms cooperate in areas that affect core technologies, i.e., a compulsory cross license may not lead to significant cooperative research.

B Regulations designed to strengthen a separate industry

Sometimes, the intent of the regulation is to create or strengthen an industry that will supply the industry being regulated. The clear examples here are photovoltaic and wind energy, as encouraged by regulations on electrical grids. In these cases, there are two technology diffusion questions. First, how broadly will the ability and incentive to use the renewable technologies spread? This depends on the regulatory structure and the expense of the technologies, which may be affected by the royalties that are typically implicit in the price. Second, how broadly will technological advances within the subsidiary industry develop and spread to new firms or new nations within that industry? This is a much more difficult question that depends on both the industry structure and on the regulatory structure.

Several points can be made, based on the experience of the photovoltaic and wind sectors. First, these industries will certainly be generally reasonably competitive – in contrast, say, to the production of electricity where the industry of each region is in only weak competition with that of other regions.

Second, as a result of the competition, firms are unlikely to be interested in cross-licensing, at least not with respect to core technologies. This is exemplified by the fact of substantial litigation over wind technologies, particularly within the United States.[33] In the wind turbine industry, the carbon reduction benefit is precisely what the industry is selling. This is in contrast to the auto industry, where emissions control is a feature that constitutes only a minor part of the product (perhaps an automobile viewed as a psychological experience?) that is being

[33] See J. Barton, *Patenting and Access to Clean Energy Technologies in Developing Countries: An Analysis of Solar Photovoltaic, Biofuel, and Wind Technologies* ICTSD, forthcoming.

marketed to the consumer. And to the extent that there is substantial research investment, the wind power industry is likely to become an oligopoly, where a number of different designs compete with one another. The products will differ, as exemplified by vertical shaft and horizontal shaft turbines, and competition, depending on market conditions, will perhaps drive toward a number of different proprietary technological solutions, each of which may end up especially appropriate for a different market niche.

Third, the royalty amounts (which may be implicit in the prices of products) will depend on the structure of competition. In the wind turbine sector, royalties have not been that big, perhaps on the order of 1 %, although there is an additional implicit royalty in any price mark-up that is available due to market concentration.[34] The supplier firms that support development of the technology have an incentive to market their products to the regulated industry. The larger the number of firms and the more competing technologies, the more they will have the incentive to lower prices and therefore share the benefit of the technology with the regulated purchaser, and therefore the consumer. This, of course, depends also on the character of structure of the regulation. The rents in a market based on feed-in price requirements will remain with the industry, while those in a market based on a requirement to purchase a particular quantity of renewable energy will be shared with the regulated purchaser as prices are competed down.

Finally, although the royalties are probably the most important IP issue for European or Chinese utilities' ability to apply the technologies, there is also the question of the spread of the ability to make PV cells or wind turbines. Here, the spread depends on the extent to which new, often Chinese, firms can imitate existing technologies or develop their own technologies and on the willingness of the globally leading firms to license their technology to such firms. The Chinese pattern has frequently been one of gaining understanding and know-how through a joint venture or licensed manufacturing and then building toward independent design and manufacture capability.[35] The willingness of foreign firms to supply technology is then likely to depend on the firms' confidence that they can supply core technologies without losing control over them – an issue dependent in part

[34] Ibid.
[35] J. Barton, *New Trends in Technology Transfer*, ICTSD Issues Paper No. 18 (Feb. 2007).

on the strength of China's IP system.[36] In general, core technology is perhaps most likely to be transferred from one nation to another as part of a deliberate globalization of the production process (as to reduce production costs), or through integration of Chinese and developed-world firms. Both the PV and the wind turbine sectors show examples of developing-nation firms buying developed-nation firms as a mechanism of gaining technology.[37] Obviously, local production can be encouraged by local content requirements, but such arrangements may be economically sub optimal, in contrast to globalization driven by production efficiencies and the balances between economies of scale and transportation costs. Local content requirements may also violate international trade agreements.

C Regulations designed to stimulate disruptive investment and entry

Sometimes, innovation disrupts existing markets. Such options should be encouraged, but it is obviously hard to predict or plan for them. Three points can be suggested. First, such innovations are unlikely to evolve from planned subsidy or regulatory programs save as these programs allow substantial freedom. This is an area where the carbon tax is a clearly superior incentive! Second, it is probable that IP incentives will be helpful in these sectors, for the disruptor is likely to be motivated by the possibility of substantial profits. Third, the key disruptive innovations are likely to come from firms and researchers other than the current leaders in the field.[38]

II SUBSIDIES TO TECHNOLOGY

Another governmental approach is directly to subsidize research in a particular technology. (Where this is done through tax credits that allow firms to design their own research programs, it increases the general incentives to invest in research.) Typically, of course, the project may contribute to the public interest in developing

[36] J. Watson, Rising Sun; Technology Transfer in China, *Harvard International Review* 26: 46-49 (Winter 2005).
[37] J. Barton, *Patenting*, supra.
[38] See D. Sperling, Public-private technology R&D partnerships: lessons from US partnership for a new generation of vehicles, *Transport Policy* 8:247-256 (2001), and A. Pilkington, The Fit and Misfit of Technological Capability: Responses to Vehicle Emissions Regulation in the US, *Technology Analysis & Strategic Management* 10: 211-224 (1998).

new technology, to the commercial goals of the nation (or regional entity) by assisting its firms in comparison with those of other nations, and to the security goals of the nation (or regional entity) by, at least in the energy area, reducing dependence on imports. The firms receiving the subsidy are likely to participate in designing the research program, but the government usually defines a group of overarching goals. They may be anywhere along a continuum from basic research to prototypes. At the basic research end of the continuum, universities or government laboratories are likely to conduct the research; at the prototype end, industry is more likely to conduct the research. Clearly, the IP and diffusion issues will vary depending on the state of the technology.

It is hard to obtain solid data on the successes and failures of these programs, let alone on the details of the IP arrangements. As one analysis states, "[e]valuating technology programs is technically very difficult," and "[p]oliticians who favor allocating technology funds on the basis of constituencies may object to comprehensive evaluations, which have the potential to highlight funds allocated for reasons other than economic efficiency." The same analysis goes on to discuss the IP issue:

> [H]ow do we balance a firm's need for secrecy involving its research with society's desire to disseminate widely the results of publicly funded research and to evaluate the programs? Firms will not participate in these programs if results are immediately made available. On the other hand, making publicly funded research results available to only a few firms – which may profit enormously from them – puts the government in an awkward position.[39]

It should be emphasized that the IP issues are only a portion of the barriers to commercialization. As in other areas, firms will not invest in technologies unless they find it economically positive – making it so may require regulation or subsidy. But there are also frequently barriers based on the lack of linkage between the technical community and the business community. A National Academy panel, reviewing a program by the US. Department of Energy to develop energy-saving technologies for industry, emphasized this point and called for regular interactions with all stakeholders, making presentations at relevant technical meetings, expanding networks beyond the technical community, including "rudimentary"

[39] J. Stiglitz & S. Wallsten, Public-Private Technology Partnerships; Promises and Pitfalls, *American Behavioral Scientist* 43: 52-73 (1999).

business plans for later-stage research and development, ensuring debugging of the technologies, and recognizing that technology development is only one stage in the technology commercialization process.[40] And the 2003 UK Lambert Report emphasized the importance of human to human technology transfer and the risks of spin-offs that lack adequate funding.[41]

A Basic research and subsidies to researchers or firms in an established industry

There are several models of government support of research. At one time, governments provided grants, especially to academia, with an expectation that the results would be published and be placed in the public domain for the benefit of all. That pattern has changed, based on a belief – that has proven partially justified – that technology would be more effectively commercialized if the grant recipients were entitled to patent the technologies and then authorized to license out the patents to industry. This alternative pattern was adopted for US. academic grantees in 1980 under the Bayh-Dole Act and for US. government laboratories under the Stevenson-Wydler Technology Innovation Act. Under a variety of other statutes, the same pattern it applies effectively to grants and contracts with industry as well. This is a pattern which is being followed broadly throughout the world.[42]

In general, under Bayh-Dole, and the emerging global norm, the grantee has the ability to obtain IP protection. Although it will typically be a grantee scientist or engineer who is the actual inventor, the grantee institution will gain control over the invention, either through law or through an agreement that the employee will sign as part of gaining employment. The grantee institution maintains an office of technology licensing, which seeks to license and commercialize the invention. The most important decision for that office – other than the choice of licensee and payment level demanded – is whether to make the license exclusive or non-exclusive. At least in the United States, the government normally retains a right to use the technology for its own purposes, as well as a "march-in right" to use the

[40] National Research Council Committee on Industrial Technology Assessments, *Industrial Technology Assessments: An Evaluation of the Research Program of the Office of Industrial Technologies* (1999).
[41] HM Treasury, *Lambert Review of Business-University Collaboration* (Dec. 2003).
[42] See, e.g. J. Sathaye & E. Holt, *Overview of IPR Practice for Publicly-funded Technologies,* Berkeley National Laboratory, 31 October 2005.

patented technology for the public good if the university is not doing so.[43] So far, however, it has not chosen to exercise this right – and the political barriers to doing so make it problematic whether it will ever do so.[44]

The real measure of success of this structure has to be not how many patents are obtained or how large the university royalties are, but whether the process contributes to bringing new products into the commercial world – something on which very little is known.[45] In some areas, particularly some aspects of biotechnology, the exclusive license has provided the basis for a company to invest in the clinical trials necessary to bring a pharmaceutical to market. In other areas of biotechnology, however, universities have obtained very broad patents, which might provide the basis for many industries. If these are licensed exclusively rather than non-exclusively, they may slow research in other institutions, rather than contribute to the development of the technology. In general, therefore, a non-exclusive license should be chosen, unless it appears likely that significant private-sector investment will be needed to move the concept from the university to commercial reality. In that case the exclusive license (or at least one exclusive to the relevant market) is essential. The success of the licensing programs depends highly on the skill of the technology transfer office in identifying licensees able to use the technology well and in negotiating contracts that maintain the licensees' incentives to develop and market the technology.

Although the Bayh-Dole model has been widely copied throughout the world, and has held great academic attention, it is not the only model used by the US or other governments. There are many, but at least three should be specifically considered – all pose somewhat similar IP issues. These are the Cooperative Research and Development Agreement (CRADA) model, the subsidized research model, and the governmental purchaser model.

In the CRADA, a private firm and a government laboratory undertake a cooperative agreement to undertake a particular research project. Each will bring a contribution; the government contribution is primarily in the form of technology

[43] J. Herrick, Federal Financing of Green Energy; Developing Green Industry in a Changing Energy Marketplace, *Public Contract Law Journal* 31: 257-275 (2002).
[44] See, e.g. US. National Institutes of Health, Office of the Director, Determination in the case of petition of Cell-Pro, Inc., Aug. 1, 1997.
[45] See B. Sampat, Patenting and US academic research in the 20th century; The world before and after Bayh-Dole, *Research Policy* 35: 772-789 (2006).

or access to particular facilities or skills. The private entity naturally receives control of technology it develops; it may also have rights to an exclusive license to government developed technology. There are, of course, requirements that the arrangement be in the public interest. Nevertheless, at least in the United States, it is extremely difficult to obtain accurate data on these projects, because the agreements themselves are confidential.[46] Moreover, data arising from a CRADA can be protected for up to 5 years.

In the subsidized research model, the government will work with industry using a combination of public and private resources so as to help industry achieve a desired goal. These are often organized under specific statutes. Among the most obvious examples are the US. efforts to help the automotive industry in designing new generations of automobile through the Partnership for a New Generation of Vehicles (PNGV), now the Freedom Car Initiative, and the US efforts to help its semiconductor industry through the Semiconductor Manufacturing Technology (SEMATECH) consortium.

The details of these approaches differ from case to case, and will certainly differ further from nation to nation. There may be a separate entity (such as SEMATECH) which is created by the group, or the pattern may be one of direct government cooperation with several firms. Several IP and organizational issues are common. First, the different firms must be interested in collaboration – this typically means that the government must contribute to the costs of the research. It also typically means that the firms involved will gain substantial rights over the intellectual property generated during the research, and will normally view it as a contribution to their competitive capability. Second, the project must encourage horizontal collaboration among the partners. For example, for the approach to be effective there must be enough industry interest in the cooperative project that firms will send some of their best people (rather than keep them at home working on proprietary projects). And it is clear that antitrust issues are posed by the cooperation – this tends to mean that the approach will be used with a subset of the firms in the industry, that it will be used to favor a national industry in competition with foreign industries, or that it will be restricted to basic "pre-competitive" technologies. The commercialization of the results will ultimately depend on the extent to which the member firms have incentives to use the

[46] See Stiglitz & Wallsten, supra.

technology and to diffuse it by licensing it or gaining market share in products that embody the technology.

Finally, there are contexts in which government has chosen to work with industry to develop new products that it wants, as the primary ultimate customer. This is the pattern of the defense industry. Because of widespread privatization of electrical utilities, it is unlikely now to be a pattern in the energy area, but it was certainly part of the basis of the nuclear power industry in a number of nations where electricity production was a national activity. In these sectors, a government entity will ultimately purchase the product, so it will, of course, arrange for itself to have full rights to use the technologies developed under contract. But the private contractors are likely to have rights to use the technology commercially –and, in particular, the rights to export products containing the technology. This, in fact, may then become a form of industrial promotion.

Experience with the PNGV illustrates a number of the issues considered above. This project involved the US. government, and the three leading US. auto firms (GM, Ford, and Chrysler). The goals of this program explicitly included national competitiveness, as well as implementing current technologies and developing new ones. According to a National Academy of Sciences study, certain of the public research expenditures – which were primarily made at government laboratories – were very effective and certain were not. And much of the private sector research expenditure was expenditure that would have been made anyway, but not necessarily in the same time frame. Nevertheless, the study found a net benefit.[47]

It was clear that the auto companies generally created “firewalls” between their proprietary work and their cooperative work to ensure that they would not lose control of crucial technologies – it is not clear precisely what happened in this case, however, where the technologies (primarily diesel-hybrid) proved closer to commercialization than expected.[48] A review of the program at the time of conversion into the FreedomCAR initiative (an effort of the Bush administration to refocus the program on hydrogen fuel cells) noted that one of the successes of the program was to identify a hybrid electric power train as likely to be most

[47] National Research Council, *Energy Research at DOE; Was it Worth it? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Academy Press, 2001.
[48] D. Sperling, supra.

efficient.[49] Interestingly, however, the first such vehicle actually to reach the mass market came from Toyota, not a member of the consortium. Indeed, one of the studies suggested that the most important effect of the partnership was to encourage the foreign research that led to the new foreign products.[50] From an IP perspective, it is significant that the consortium was not able to exclude the Toyota product.

Even after a technology is developed, it may be necessary to undertake public-sector efforts to ensure that it is shared, and this may be difficult even if subsidized. (This issue is quite similar to that of the transfer of renewable energy production technologies discussed above in Part I.) An example that demonstrates some of the problems of this phase of technology transfer is the Global Environment Facility's China Efficient Industrial Boiler Project." This project, started in 1994, was designed to obtain technology for more efficient boilers from developed world firms and then to transfer that technology to Chinese boiler manufacturing firms. There were significant difficulties in persuading the global firms to tender and then license their technology. The issues appear to have been concern by the technology licensors about the relatively small magnitude of the payment they offered, about giving up core technologies, and about whether the technologies would be spread within China further than they had been licensed. The result was not only delays, but inadequate funding for capacity building.[51] Clearly, these are issues that will arise in any effort to encourage firms to share their technology with potential competitors. Such efforts will be difficult in any event (although it may be less difficult to encourage entry into the Chinese market or to encourage joint ventures in which the technology suppliers envision a possible long-term benefit); making them successful will require care in defining the rights that are to be transferred and the availability of a legal system that can be expected to enforce those rights (although this concern may sometimes be overstated).[52] The issue is not just one of patents and their enforceability, but one of license agreements and their enforceability.

[49] V. Roan, The Future of DOE's Automotive Research Programs, House Science Committee, Feb. 7, 2002.
[50] Sperling, supra.
[51] Global Environment Facility, *Report of the STAP Selective Review of "China Efficient Industrial Boiler Project*, GEF/C.18/Inf.12, Nov 29, 2001; S. Birner & E. Martinot, Promoting energy-efficient products; GEF experience and lessons for market transformation in developing countries, *Energy Policy* 33 (2005) 1765-1779.
[52] J. Watson et al, *International Perspectives on Clean Coal Technology Transfer to China; Final Report to the Working Group on Trade and Environment, CCICED* (August 2000).

B Through development of prototypes

In some cases, programs such as those just considered emphasize government support of a prototype to demonstrate feasibility and to provide a focus for dealing with the various difficult engineering and materials questions that may be posed in a new area. Here there is the important issue of how the knowledge gained from the prototype can be effectively diffused and whether the firms involved in the prototype will have an impregnable position based on IP or other factors. Under what circumstances will they have the incentive to share or spread the expertise they gain during the demonstration project phase?

One sector where this pattern has been quite significant is that of civilian nuclear power. In the initial days of the US. civilian nuclear program, the government, by statute, owned all patents in the area. This provision was amended in 1954,[53] and a prototype civilian light water reactor was built at Shippingport in 1957, with Westinghouse as the prime engineering contractor. Westinghouse contributed about 1 % of the cost of the construction, the local utility contributed about 10 %, and the government paid the rest.[54] It seems very likely that its role in building this prototype contributed to Westinghouse's leading position in nuclear power, although Westinghouse had had earlier experience building naval nuclear reactors.[55] Even within the United States (and as early as 1947, before the patent laws were changed), it has had competition from GE, which also had naval reactor experience and built a civilian prototype reactor at Vallecito, CA, also completed in 1957.[56]

Somewhat similar patterns were followed in France, where the industry was heavily under government control, operated by a combination of the Commissariat à l'Ėnergie Atomique (CEA) and Ėlectricitė de France. A gas-graphite design was chosen, and it was clear that industrial contractors were chosen in the hope that the firms would acquire know-how, which they could use as a basis for future exports of technology.[57] Following major diplomatic discussions as to choices of reactors for nuclear power, however, this design was

[53] B. Boskey, Some Patent Aspects of Atomic Power Development, *Law and Contemporary Problems* 21: 113-131 (Winter, 1956).
[54] L. Clarke, The origins of nuclear power: A case of institutional conflict, *Social Problems* 32:474-487 (1985); Shippingport reactor starts, *Science* 126:1280-1281 (20 Dec 1957).
[55] Argonne National Laboratory, www.anl.gov/Science_and_Technology/history
[56] American Society of Mechanical Engineers, The Vallecitos Boiling Water Reactor, Oct. 7, 1987.
[57] G. Hecht, Political Designs: Nuclear Reactors and National Policy in Postwar France, *Technology and Culture* 35: 657-685 (Oct 1994).

rejected as a basis for large-scale civilian development, and France ended up licensing in Westinghouse technology for its civilian program.[58] This was partly a result of a much broader nuclear safeguard and nuclear weapons diplomacy that led to a 1958 agreement between the US. government and Euratom (now effectively integrated into the EU).[59] But, as just noted, the agreement went further to lead to building plants using the US. light water technologies under US. patents. Part of what motivated the arrangement was the expectation that there would be steep learning curves and associated network externalities associated with the new technologies. This is exemplified by an expectation that doubling of the number of plants built by a firm would decrease both construction time and capital cost by about 10%.[60] The result is that leading firms are able to underprice entrants who have produced fewer reactors. The market is encouraged to follow one design or manufacturer.

Clearly, the factors raised by this example will be relevant to many of the contemporary programs. They include: national efforts by funding entities to support their own firms, the fact that the builders of prototypes have an unavoidable advantage over others, the likelihood that network externalities will favor those who have substantial market share, and the linkage of technical decisions with political decisions. One clear response is to attempt to ensure that there is more than one firm building prototypes and competing for global market share afterwards. There may be enormous political dispute over the support of Boeing and Airbus, but the fact that there are two such firms in competition, rather than one monopolist, is beneficial to the global economy.

This prototyping mechanism is exemplified by several broad internationally parallel programs to develop methods to use coal for energy production without contributing to the emission of CO_2. Just as with cement, there are two levels of technology: one to carry out the basic energy production process in an efficient a way as possible, and a second to further reduce CO_2 emissions by preventing release of the gas into the atmosphere and then sequestering it. Although there are several possible processes, one of the leading ones, Integrated Gasification Combined Cycle (IGCC) involves gasification of the coal, through a number of possible chemical reactions, and then burning this gas in a turbine to produce

[58] International Atomic Energy Agency, *Country Nuclear Power Profiles* (2000).
[59] H. Nieburg, Euratom; A Study in Coalition Politics, *World Politics* 15: 597-622 (1963).
[60] R. Cowan, Nuclear Power Reactors: A Study in Technological Lock-in, *The Journal of Economic History* 50: 541-567 (1990).

electricity. The waste heat from the gas can be used to heat a boiler to generate further electricity. This process has been used in a number of developed countries, including the Netherlands, Spain, and the United States.[61] China started a plant of this type in the 1990s at Yantai, but found that costs were higher than expected, and the project appears to have failed with the nation's 2002 breakup of its State Power Commission. Although China is starting a new effort at IGCC, called Greengen, and this plant is targeting a 2010 date, an expert at the Chinese Coal Research Institute doubts that IGCC will be applied in earnest until 2020.[62]

In spite of the fact that a number of these plants have already been built, the technology really has been slow to spread. In the United States, for example, there have been two facilities, a 262 MW unit in Indiana and a 250 MW unit in Florida. Both were built in the mid 1990s, with government support for about half the capital cost. Both have operated effectively from both efficiency and environmental perspectives.[63] But they have not been imitated. A 2004 US. study of the reasons, based in part on an industry survey, found that the issues were primarily economic, e.g. higher capital costs and the increased engineering costs and risks of new designs. It also noted regulatory problems in that permitting processes designed for other forms of electricity production did not adapt well to the IGCC plant. Although this study gave specific consideration to legal and regulatory issues, IP questions were not even mentioned.[64] And the same conclusion was reached by a draft report of the US. Advanced Coal Technology Work Group, a group created by the Clean Air Act Advisory Committee.[65] It should be recognized, however, that there are many patents in the area; a search on the US PTO patent website yields over 200 patents that mention "IGCC," and almost 2000 mentioning "syngas," i.e., synthetic gas such as that used in many IGCC concepts. (There are other applications.) A more recent U.K. study, looking at transfer to India, did suggest technology transfer problems. This analysis states that the economics do not favor IGCC over other technologies unless there is a strong restriction (equivalent to a high carbon tax)

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[61] Z. Yu, A. Black, & R. Rardin, The Role of IGCC in the Global Energy Markets: Part I: Technology Progress and Applications, (IEEE, 2005); S. Batoo for Prof. J. Doucet, *Clean Coal Technology Transfer to China and India*, Alberta School of Business, April 12, 2007.
[62] P. Fairley, China's Coal Future, *Technology Review*, Jan 1, 2007.
[63] J. O'Brien & J. Blau, *An Analysis of the Institutional Challenges to Commercialization and Deployment of IGCC Technology in the US. Electric Industry: Recommended Policy, Regulatory, Executive and Legislative Initiatives*. Global Change Associates, March 2004.
[64] Id.
[65] *Draft interim Report of the Advanced Coal technology Work Group; Clean Air Act Advisory Committee* (June 27, 2007).

on CO_2 emission. It notes that developing countries have had trouble gaining access to information on operating experience with IGCC, and that firms holding key technologies are likely to be unwilling to share core technologies, e.g., those for the design and manufacture of the first row of turbine blades.[66] In as much as there are only a few private sector suppliers (GE is the leader),[67] the second of these points is quite plausible and likely. The first is surprising, however, for it goes against the obvious commercial interest of the firms (unless the performance is really bad!). Nevertheless, it is significant that the private sector recognizes the issue and is dealing with it – EPRI has organized a program, the "CoalFleet for Tomorrow®" project in which performance date is being assembled and standardized specifications developed.[68] The history makes it clear that planners should be concerned about access to performance data and that, as with wind turbine technology, it will be easier to obtain access to products embodying the technology (and thus to lower CO_2 emissions) than to enter the industry of producing the advanced generation systems.

IGCC is not the only reasonable approach to increasing the efficiency of electricity production from coal. Among the others is pressurized fluidized bed combustion (PFBC). It is significant that data here on performance have also been hard to obtain, perhaps because there has been a dominant supplier, once ABB Carbon of Sweden (the ownership of the technology has since devolved to Alstom and/or Siemens).[69]

As noted above, in efforts further to reduce CO_2 emissions, the CO_2 can be stripped from the gas stream, and then sequestered, in a process often known as carbon capture and sequestration (CCS). There are a number of alternative processes for stripping the CO_2, both before and after combustion.[70] Among them are capturing the CO_2 after combustion with an amine solvent that can then be regenerated and there are many pre-combustion methods (some applicable to IGCC) involving a gas produced from coal in which the CO_2 can be separated. In all cases, there is an energy penalty involved in the separation, and the

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[66] D. Ockwell et al, *UK-India collaboration to identify the barriers to the transfer of low carbon energy technology* , Sussex Energy Group, TERI, IDS, March 2007.
[67] Morgan Stanley, *Capital Goods; Clean Coal: Opportunities; Alstom, GE and Siemens* (Jan 24, 2006).
[68] SPRI, Accelerating the Deployment of IGCC Plants; N. Holt, Preliminary Economics of SCPC & IGCC with CO_2 Capture & Storage; 2nd IGCC & XtL Conference, Freiberg, Saxony, Germany, May 9-10, 2007.
[69] J. Watson, Advanced Cleaner Coal Technologies for Power Generation; Can they deliver? (2005 BIEE Academic Conference, Oxford); Morgan Stanley, supra.
[70] S. Batoo, supra.

separation is generally the most expensive part of the sequestration process. [71] Such separation will be involved in the prototype low emissions programs discussed below; there is both publicly- and privately-sponsored work being carried out in the area, including support by EPRI and ALSTOM for construction of a pilot plant designed to serve as a test-bed for evaluating specific capture technologies.[72]

There are many projects on sequestration. Possible sites include natural reservoirs, such as depleted oil and gas fields, deep saline strata, and possibly the deep ocean.[73] Pumping into a depleted oilfield is currently the economic favorite, for it can contribute to enhancing the oil recovery, and thus provide a positive benefit. Among the early leaders is a North Dakota plant that was initially build to produce a synthetic natural gas from coal. During the early 1980s, the United States subsidized the construction of this plant, using non-recourse loans. Because of declining natural gas prices, the private consortium operating the plant defaulted in 1984, and the plant went into government ownership. Several years later, the plant was sold to a firm, now the Dakota Gasification Company, which used it to produce a variety of by-products, and also to supply CO_2 for shipment through a 205 mile pipeline to enhance oil recovery in Saskatchewan, Canada. The result is CO_2 sequestration.[74]

Among the newer examples are the British Petroleum CO_2 Capture Project, in which 8 energy companies are collaborating, and a global Carbon Sequestration Leadership Taskforce, which has a variety of taskforces on different aspects of CCS, including one on the legal issues. The IP issues do not yet appear strongly. Discussions in the legal taskforce just mentioned have been primarily on environmental issues rather than IP issues.[75] The MIT Coal Project, which discusses CCS, does not mention IP, but does emphasize legal issues in permitting and maintaining long-term stewardship over the areas in which CO_2 is

[71] J. Davison, Performance and costs of power plants with capture and storage of CO_2, *Energy* 32: 1163-1176 (2006); J. Stephens & B. van der Zwaan, CO_2 Capture and Storage (CCS): Exploring the Research, Development, Demonstration, and Deployment Continuum, Harvard Energy Technology Innovation Project, August 2005.
[72] J. Douglas, The Challenge of Carbon Capture, *EPRI Journal*, Spring 2007, pp 14-21.
[73] P. Freund, Making deep reductions in CO_2 emissions from coal-fired power plant using capture and storage of CO_2, *Proceedings of the Institute of Mechanical Engineers, Part A: J. Power and Energy*, 217.
[74] P. Fairley, Carbon Dioxide for Sale, *Technology Review* (July 2005).
[75] Intergovernmental Panel on Climate Change, *Carbon Dioxide Capture and Storage; Summary for Policymakers and Technical Summary*, (2005?); G. Unruh & J. Carillo-Hermosilla, Globalizing carbon lock-in, *Energy Policy* 24 (2006) 1185-1197.

placed.[76] Nevertheless, some 150 patents do mention “carbon sequestration,” mostly in the context of oilfields.

Although many of the individual steps in the process have already been carried out, there has not yet been an integrated prototype of the IGCC process that goes from coal to electricity production to CCS and is scaled up to a level that could begin to replace alternative forms of energy generation. The development of such a prototype is at the center of the UK-China cooperation mentioned at the beginning of this note. There is also a US. version, the FutureGen project, under which the US. Department of Energy is entering into a cooperative agreement with an alliance of private firms to build a prototype zero-emissions plant. Among the participants in the alliance are China Huaneng Group, and a variety of coal and energy firms from the United States, the UK, and Australia.[77] In this case, the private sector firms have created a non-profit alliance; this alliance receives funds from the Department of Energy, and then supports research at a variety of institutions. These institutions gain IP rights under analogues to Bayh-Dole. The Consortium offers membership to non-US. entities apparently on terms comparable to those offered US. entities, and its government advisory board offers participation to non-US. governments, with the degree of access to decisions and information dependent on the level of support. According to public documents, the IP arrangements are to “be structured to maximize the potential to commercialize the technology being developed,” and “sufficient non-proprietary data on the engineering, environmental, and cost performance of FutureGen must be made publicly available to enable all interested parties to evaluate the viability of coal-fueled, aero-emission energy plants.”[78]

In these contexts, as in other forms of government-industry cooperation, the members of the consortium will want a competitive advantage in return for the investments they make in developing the technology. (Note that access to government funding or technology may also be a key motivation.) It is not clear, however, that, in the IGCC context, this will necessarily make it difficult to apply the technology beyond the initial consortium. On the whole, the firms gaining the expertise are likely to be suppliers and engineering firms, not utilities. They will gain importance advantages in know how, experience, and information. They will,

[76] Massachusetts Institute of Technology, *The Future of Coal* (2007).
[77] www.FutureGenAlliance.org
[78] US. Department of Energy, A Prospectus for Participation by Foreign Governments in FutureGen, June 20, 2003.

however, generally have an incentive to market a product or service to all utilities, and depending on the competitive situation, they may be willing sometimes be willing to license their technology to other firms. The magnitude of the implicit or explicit royalties will depend on the competitive situation in the industry and on whether there are competing technologies. Nevertheless, it is important to ensure that performance data be as publicly available as possible.

It is hard and highly speculative to envision the structure of the electrical energy industry in a low CO_2 emissions world. Yet, it is also necessary if one is to get the IP issues as right as possible. The pattern will depend not only on economics but on regulatory structures, and, given the heavy capital investment in the industries, will be heavily path dependent. It may also depend on such broad questions as whether or not there is a significant move toward a hydrogen economy. Some may depend on the relative costs of long-distance transfers of coal, electricity, H_2, and CO_2; it is appearing that, because of the possibility of pipelines, CO_2 transmission may be cheaper than that of electricity).

The implementations of the zero-emission electricity production and of the sequestration seem likely to take place under separate economic auspices. The electricity production market is necessarily (at least for a long time) decentralized, and, until electricity transmission is very inexpensive, each production facility will be in only limited competition with others. It therefore seems likely that the industry will remain decentralized and that the utility developers of the new electricity production technologies will be ready to license their technologies to many facilities, and the supplier developers willing to market to all. Their bargaining power will depend on the regulatory structure of the electricity industry and on the number of competing technologies available. And, as with most other technologies, the suppliers will be much more interested in marketing their products (such as gasifiers and turbines to assist in reducing CO_2 emissions), than in sharing their technologies with firms who may become competitors.

The sequestration process, however, is likely to be more centralized, because of the relatively limited number of feasible sites, at least initially. This suggests that sequestration will be offered as a service to the electricity firms. It may also mean that those prototyping the sequestration methods will have especially strong economic positions -- whether or not there is competition in this market may depend on the number of sites and the economics of long distance transmission of CO_2. This is where it may be especially important for public funders to anticipate problems and to ensure that performance data is made as public as possible. (Note that such data may be inextricably mixed with geological data, some of which may be proprietary to those who extract petroleum.)

As usual IP cuts two ways. One the one hand and most immediately, the potential of IP rights will assist in encouraging the private sector to participate in the development programs. They may also assist in encouraging firms to apply their technologies in China, where, in the absence of rights, they may fear loss of technology to competitors. But, on the other hand, such rights may increase the effective costs of the technologies for widespread application. The magnitude of this last (negative) effect is hard to predict, because it depends on the competitive structure issues discussed above. It must be remembered that it is likely to be a long time before technologies such as IGCC are actually used in China or Europe on any substantial scale.

III STANDARDS

Both negotiated and regulatory standards will have intended or unintended effects on the competitiveness of particular firms and therefore on technology diffusion; the impact of both forms is significantly affected by IP. Whether the standards are formally negotiated within the private sector or formally set by government or international organization, they will always have a substantial political and strategic content. In all cases, affected firms will lobby heavily; in all cases, those issuing the standards will recognize the competitive implications of the standards they create.

A standard may increase the competitive importance of IP. It may be, for example, impossible to comply with a standard without infringing a particular patent – and the standard then provides enormous competitive advantage to the entity holding the relevant patent. This risk is the basis of rules typical in standards organizations that the participants in standards discussions disclose any relevant patents that may affect compliance with the standard, and sometimes that any such patents be licensed in a "reasonable and nondiscriminatory" pattern.[79] This risk has also been the basis for antitrust litigation against firms accused of deception about their IP holdings while standards discussions proceeded. Among the more significant such examples is the case of Unocal, accused of pursuing relevant patents without disclosing the fact in proceedings before the California Air Resources Board to adopt rules for reformulating gasoline to assist in reducing atmospheric emissions.[80] The issue in the case is moot because of the antitrust settlement, but the patents involved claimed broad categories of fuels blended to reduce emissions, defined in terms of a combination of a number of physical and chemical properties.[81] It is likely that there will be similar patents in other fuel areas and perhaps the syngas area.

A Standards designed to ensure interoperability

One group of standards, typically negotiated privately, includes those designed to ensure that different systems can operate together. The most obvious current examples of IP impact in this context are in the cellular telephony area and in the standards for DVDs and a number of other similar products. In general, in these cases, the negotiations lead to a combined license through which consumers purchasing the standardized product will pay a royalty (typically included in the price), which is then divided among the parties. Such agreements have, in a number of cases, been submitted for antitrust review; at least in the United States, the key grounds for review is whether there is a reasonable and fair procedure for deciding which firms have a right to a share in the royalty. The US. authorities have resisted any effort to determine whether the royalty is reasonable – but it seems plausible that, in an extreme case, they would do so, because, often, a large number of firms are involved in the arrangement, so the arrangement risks becoming a cover for collusion.

[79] See, e.g. Communication from the People's Republic of China, *Intellectual Property Rights (IPR) Issues in Standardization*, G/TBT/W/251 (25 May 2005); *Communication from the People's Republic of China, Background Paper for Chinese Submission to WTO on Intellectual Property Right Issues in Standardization (G/TBT/W/251*), G/TBT/W251/Add.1 (9 November 2006); M. Lemley, Ten Things to Do About Patent Hold-Up of Standards (and One Not to), *Boston College Law Review*, 48: 149-168 (2007).

[80] The case was settled in 2005, after the Commission issued a decision remanding the issue for a hearing. US. Federal Trade Commission Press Release, Dual Consent Orders Resolve Competitive Concerns About Chevron's $18 Billion Purchase of Unocal, FTC's 2003 Complaint Against Unocal, June 10, 2005. Another important recent case is *Broadcom v. Qualcomm*, DC-Civil No. 05-cv-03350 (3d Cir, Sept 4, 2007).

[81] E.g. US. Patent 5,837,126, *Gasoline Fuel*, Jessup et. al, Nov. 17, 1998.

Clearly, unless the pricing is collusive, such licensing arrangements are reasonable, because they allow a group of firms to bring a new product to the market in a situation in which each of the firms might have a veto over the final product. In some cases, there are several competing standards; in others there may be just one standard, making the situation more similar to a monopoly.

The most likely example with direct climate change effect is the standard for linking a PV or wind system to a grid. There certainly is IP governing, for example, particular mechanisms of coping with the problem that wind turbines may turn at variable rates while supply of a grid must be at a frequency very close to that of the grid. It is not clear whether grid requirements, which are not yet globally standardized, might be written in a way that favors particular suppliers. This is a technical question that will depend on the details of the particular standards. There are likely to be negotiations to permit greater linkage of national grids as well as greater ability of renewable sources to provide power to the grids.

The other area where this issue may arise is in standards relevant to manufacturing processes, such as those for PV manufacture. Here, it may be helpful to have standards negotiated among those who produce the silicon used in PVs, those who produce machines used in PV manufacture, and those who produce PV chips and arrays.[82] It is possible that there will be competing standards in this area (associated with different manufacturing processes) – and such competition will help avoid serious risks.

In these cases, and in any other similar ones, it is important to follow the emerging pattern that IP must be disclosed during negotiations (and that it is an antitrust violation to fail to do so), and, where IP issues are unavoidable, to require licensing at a reasonable royalty.

B Trade-oriented standards

Another similar form includes standards for fuels, ensuring interoperability between the fuels produced by various clean-energy mechanisms and the engines within which they are used. Here, there will almost certainly be arrangements that affect international trade in fuels and particularly in biofuels;

[82] See, e.g., SEMI (Semiconductor Equipment and Materials International), Photovoltaics; An Exploding Market Urgently Need Industry Standards, 2007.

whether particular standards will require recognition of particular IP rights is not clear. In general, these standards are likely to be negotiated politically; the task will be to ensure that governments, and not just firms, reveal IP issues that may be posed by new standards.

C Designed to protect safety or environment

Other important standards, more likely to be enacted by governments than agreed by private firms, are designed to protect society. They may, like other standards, be affected by IP. A clear example is the environmental standard for California fuels at issue in the Unocal case. Whether there will be similar issues with future climate change technologies is not yet clear – but is certainly likely, because there will probably be genuine regulatory issues with some of the new technologies. The most likely areas of concern are new fuels, but there may be others. And it must be recognized that nations will tend to favor standards that support their own firms, although, in this context, there are issues of compliance with WTO codes relating to the scientific basis of standards. Again, the key issue is transparency – and, if necessary and possible, use of antitrust principles to block use of undisclosed IP relevant to compliance with standards.

V OVERALL IMPLICATIONS

The world, and the EU and China in particular (as well as the United States) are seeking to encourage the development and spread of difficult and expensive new technologies that will assist in slowing global warming. Cooperation between public and private enterprises is essential, for private enterprises do not yet have optimal incentives to deal with climate change issues and are, at the same time, major sources of technology. All private enterprises are concerned with their competitive positions; all national governments (and, of course, the EU) are also concerned with the competitive positions of their economies. Yet, recognizing the global threat posed by climate change – and that that threat threatens all – they are seeking technology management and licensing approaches that will contribute to the global good.

The above analysis suggests several key principles to be used in making this technology development and diffusion as effective as possible:

1. It is essential that there be economic incentives for the private sector to deploy the desired technologies. This is a matter of regulation and CO_2 pricing – without such incentives, the IP issues will be irrelevant.
2. Technology transfer is primarily a human-to-human issue – IP is only part of the issue, and approaches focused on IP alone will not necessarily ensure technology transfer.
3. In general, the legal barriers deriving from the need to develop and modify environmental standards for new situations, e.g. IGCC and CCS, are likely to be more important than those deriving from IP.
4. In some cases, a strong IP regime will be valuable in encouraging incumbent firms to develop or share their technologies. This is not simply an issue of formal IP rights, but also an issue of the enforceability of those rights and of the enforceability of license and trade secrecy agreements.
5. It is important to balance IP considerations with antitrust considerations, something that may be difficult on a global level, because of the territoriality of national antitrust systems.[83]
6. In any effort to privatize the energy sector or to restructure it (e.g. to reduce vertical integration in the sector, as is being currently discussed in the EU), it is essential to consider the implications for the incentives to develop and apply new technologies.
7. When devising a regulatory-based incentive to conduct research relevant to global warming, the implications for the encouragement of research should be taken into account. The clear example is that feed-in pricing is probably more likely to encourage research than are market shares reserved for particular forms of energy.
8. When approving or disapproving a cross-license (and there may be antitrust law power to review such a cross-license or the power may be reserved in the terms of a technology grant

[83] See J. Barton, Antitrust, Patents, and Developing Nations, forthcoming under UCLA auspices.

or of a public-private cooperation agreement) it is important to take into account the balance between the way the cross-license decreases individual research incentives and the way it increases the diffusion of the technology. This balance depends on the structure of competition within the sector.

9. In the design of any program to encourage technology development and dissemination, it is crucial – right at the beginning – to include the equivalent of a business plan as to how the technology rights should be managed. There will be surprises, but a serious plan is essential.

10. When deciding what IP rights to provide a research grantee, it is wise to consider the benefits of making the technology broadly available through publication. Exclusivity is sometimes essential to bring forth the investment necessary to bring a product to market (and to market it effectively etc.), and it may sometimes be essential to bring forth private investment. But, often, publication and open availability are best.

11. In structuring collaborations with individual competitors or a consortium of such competitors – and this is an essential part of any prototyping effort – it is essential to balance the demands of these competitors to strengthen their own positions as part of their interest in participating in the project with the demands of society for broader access to the results of the publicly-sponsored research. Normally, but depending on the competitive structure of the relevant industry, the firms involved in the collaboration will have an incentive to make their product widely available or to license out their new technology for a reasonable royalty; if this does not happen, it may be necessary for the government to have the right to compel such a result.

12. It is possible to insist on making technologies available to developing nation firms on a low-royalty humanitarian basis, or to use “march-in’ rights more freely than they are currently used. This may not be wise if the developing world market is the primary one in which research costs would be expected to be recovered.

13. When designing programs based on prototypes, it is essential to recognize that the leaders have an advantage based

on access to information and on their position on the learning curve. It is wise to ensure that the performance data deriving from the operation of the prototype be as publicly available as possible, and it may be essential to have several prototypes.

14. In devising standards, it is essential to follow the emerging rules that require disclosure of IP rights that may affect compliance with the standard.

15. It is also essential in establishing any program designed to bring carbon control technologies to the developing world to deal realistically with national tendencies to ensure that nationally-subsidized research programs benefit national firms. Where possible, it is best to design the programs on the assumption that the world energy industry is inevitably globalized and interconnected and that we all benefit from any nation's reduction of CO_2 emissions. This will be a central issue if we move to global subsidization of research or a global research fund as part of a follow-on to Kyoto.