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Intellectual Property and Access to Clean Energy Technologies in Developing Countries

An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies

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ACRONYMS

AC	Alternating current
ADM	Archer Daniels Midland
CDM	Clean development mechanism
CTI	Climate Technology Initiative
CTP	Climate Technology Program
CO	Carbon monoxide
CO_2	Carbon dioxide
CRESP	China Renewable Energy Scale Up Program
DC	Direct current
EU	European Union
GEF	Global Environment Facility
H_2	Hydrogen
IP	Intellectual property
MTBE	Methyl tert-butyl ether
NIH OTT	US National Institutes of Health Office of Technology Transfer
OECD	Organisation for Economic Co-operation and Development
PURPA	Public Utilities Regulatory Policies Act
PV	Photovoltaic
SBSTA	Subsidiary Body for Scientific and Technical Advice
TCAPP	Technology Cooperation Agreement Pilot Program
UNFCCC	United Nations Framework Convention on Climate Change

FOREWORD

Energy-related emissions account for more than 80 percent of global carbon dioxide (CO_2) emissions responsible for climate change. Hence, improvements in energy efficiency and the development of low-carbon sources of energy offer great potential for reducing emissions in the future. The International Energy Agency projects that policies that encourage more efficient production and use of energy could contribute 78 percent of avoided CO_2 emissions by 2030. Another 12 percent reduction could come from renewables and ten percent from additional nuclear power.

The Kyoto Protocol (Art 2.1) to the United Nations Framework Convention on Climate Change (UNFCCC) expressly encourages parties to take measures to achieve energy efficiency enhancements and to develop and increase the proportion of new and renewable forms of energy. Beyond climate change objectives, the Johannesburg Plan of Implementation (JPOI) points to the enhancement of international and regional cooperation "to improve access to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services, as an integral part of poverty reduction programmes".

As the world steps up efforts to combat global warming, developing nations, especially the largest emitters among them, are likely to face increasing demands to take greater action to reduce their emissions of greenhouse gases, and particularly carbon dioxide (CO_2). They may have to obtain or develop new technologies in order to do so. On numerous occasions, policy makers and stakeholders in developing countries have raised concerns about potential barriers that intellectual property policies may pose for access to clean energy technologies. Some have even suggested considering the need for intellectual property right (IPR) flexibilities in the context of clean energy technologies.

The intellectual property (IP) system provides the regulatory framework where most commercially valuable technologies work and get developed. The IP system and more specifically the World Trade Organization Agreement on Trade-Related Intellectual Property Rights (TRIPS) does not provide for any special treatment or flexibilities for access and dissemination of environmental sound technologies as occurs in the field of health or nutrition. In addition, the IP system has been associated with a series of limitations to access and dissemination of technologies in certain fields. The most important ones include: high transaction costs of obtaining information, negotiating and acquiring IP protected technologies and a lack of clarity in defining what is protected and what is not. Thus, these limitations enhance potential market failures related to asymmetric information.

To address these concerns and facilitate developing countries' access to climate-friendly technologies, the UNFCCC (Article 4.5) calls on developed nations to assist developing nations through technology transfer. In addition, as part of the means of implementation of the JPOI adopted at the World Summit on Sustainable Development, the international community agreed to "support existing mechanisms and, where appropriate, establish new mechanisms for the development, transfer and diffusion of environmentally sound technologies to developing countries and economies in transition".

This study seeks to contribute to the debate on asymmetry of information as it relates to the potential role of intellectual property in the development and diffusion of clean energy technologies. It explores whether or not there will be IP barriers to access clean technologies and know-how in developing countries. In order to assess IP implications for developing countries, the paper examines the technology and industrial structure of three clean energy sectors: solar photo-voltaic (PV), bio-mass for fuel and wind energy technologies. The paper concentrates on three technologically advanced developing countries including Brazil, China and India.

It must be noted that licensing the capability to produce products is one of several possible modes of technology transfer. Others include gaining access to products incorporating the technology, or the development of national capability to research and produce the products independent of a licensor (or at least in a relatively equal position with the licensor). In general, IP protection plays quite a different role in the renewable energy industries than it does in the pharmaceutical sector, the source of many developing nation perspectives on IP. In the pharmaceutical sector the patent holder of a drug that may not have any substitutes is in a very strong market position and may be able to charge a price well above production cost. In contrast, in the three renewable sectors considered here, there is competition between a number of patented products with the result that prices can be brought down to a point at which royalties and the price increases available with a monopoly are reduced. There is also competition among the sectors, as well as between clean sources of energy and other alternatives.

Conclusions regarding the impact of IP vary accordingly to the sector, but in general, it appears that in all three sectors, rather than basic technologies, what are usually patented are specific improvements or features. In the PV sector, the developing nations are facing a loose oligopoly with many entrants. Thus, developing countries have been able to enter the industry as demonstrated by firms such as Tata-BP Solar in India and Suntech in China. For biofuel technologies, IP does not appear to be barring developing countries for accessing the current generation technologies as shown by developments in many countries including Brazil, Malaysia and South Africa. The harder question is about future or second generation biofuel technologies where methods, or enzymes, or new microorganisms for breaking down lignin are likely to be patented. At present, the most significant obstacles relate to trade barriers and distortions. The wind sector appears to be the most concentrated of the three sectors examined. However, the industry is competitive enough for developing nations to be able to build wind farms with equipment from the global market without enormous IP costs. The challenge for developing countries here is to enter the global market for wind turbines. The existing industry leaders are strong and hesitant to share cutting-edge technology out of fear of creating new competitors. In spite of these barriers, two developing nations, China and India, have succeeded in building important firms over the last 10 years.

The paper examines other questions of importance to developing nations including the benefits of strengthening IP protection in order to make foreign investors more willing to transfer technology and asking whether or not local trade barriers are proving helpful or harmful in developing these industries. The author concludes with specific suggestions for developing countries themselves, lenders and donors, and international negotiations.

The development and diffusion of renewable energy technologies is only one part of the challenge of bringing down emissions from the energy sector. Much needs to be done to harvest the largest potential in energy efficiency improvements. Nevertheless, it is our hope that this study will contribute to informing policy processes and negotiations related to technological cooperation and intellectual property in the energy, climate change and trade arenas.

John H. Barton is Professor of Law, Emeritus at Stanford Law School where he began teaching in 1969. His teaching fields include international trade and high technology law. He has published extensively on the pharmaceutical development process, on patent-antitrust issues and on the transfer of technology to developing nations. He was a member of two working groups of the Commission on Macroeconomics and Health (the Sachs Commission), and the U.S. National Research Council study of the patent system. He chaired the 2001-2002 UK Commission on Intellectual Property Rights and he spent the 2004-05 academic year as a Visiting Scholar in the Department of Clinical Bioethics at the US National Institutes of Health. He is a graduate of Marquette University (1958) and Stanford Law School (1968).

This paper is part of ICTSD’s *Trade and Sustainable Energy* series, published under its programme on Trade, Climate Change and Sustainable Energy in collaboration with the programme on IPRs and Sustainable Development. ICTSD’s programme on Trade, Climate Change and Sustainable Energy aims to generate policy-oriented and solutions-focused knowledge on key issues at the interface between the multilateral trading system and various regimes and initiatives promoting the transition to a sustainable energy future.

Ricardo Meléndez-Ortiz
Chief Executive, ICTSD

EXECUTIVE SUMMARY

As part of the world's move to combat global warming, developing nations are likely to seek to reduce their emissions of greenhouse gases, and particularly of carbon dioxide (CO_2).They may have to obtain new technologies in order to do so. This paper explores whether there will be barriers, particularly intellectual property (IP) barriers, to access those technologies. To do so, it examines the industrial structure of three sectors, photo-voltaic (PV), bio-mass and wind energy. It concentrates on the more scientifically advanced developing countries such as Brazil, China, and India.

There are several modes of technology transfer. One is to provide products incorporating the technology, e.g. ozone-layer-safe coolant compounds or photovoltaic panels for off-grid electrical supply. Another is to license the capability to produce such products, perhaps to an indigenous firm or perhaps to a joint venture. And a final one is to support developing national capability to research and produce the products independent of a licensor (or at least in a relatively equal position with the licensor).

Intellectual Property (IP) protection generally plays a quite different role in the renewable energy industries than it does in the pharmaceutical sector, the source of many developing nation perspectives on IP. In general, in the pharmaceutical sector, an individual patent may have a very substantial impact because a specific drug may not have any substitutes. In such circumstances, the patent holder is in a very strong market position and may be able to charge a price well above production cost. In contrast, in the three renewable sectors considered here (and in many other industrial sectors), the basic approaches to solving the specific technological problems have long been off-patent. What are usually patented are specific improvements or features. Thus, there is competition between a number of patented products – and the normal result of competition is to bring prices down to a point at which royalties and the price increases available with a monopoly are reduced. This will be particularly the case for the products considered here, where there is competition not only between the firms in the specific sector but also between the sectors and alternate sources of fuel or electricity. In effect the benefit of the technologies is shared with the ultimate customers.

There are several different markets for renewable energy capabilities for developing nations. The most obvious one is the market for enabling the nation itself to reduce its CO_2 emissions (not currently required by international law but possibly required in the future). The second is the market for providing carbon offsets under the clean development mechanism (CDM) system of the Kyoto accord. And the third is the market for exporting renewable products, such as biofuel (or conceivably electricity), and equipment, such as wind turbines, in which the developing-world industry becomes integrated into the global industry as a supplier.

It is clear that some of the renewable energy technologies, particularly PV technologies, are not yet inexpensive enough to be used for general application. Because of this, economics firms have been hesitant to invest in substantial research on their own, save where there are significant subsidies, as in the current ethanol boom in the United States. Hence, much of the research in these areas is funded by the government. At least in the case of the United States, such subsidised research will almost certainly end up protected by patent rights. And when such research is licensed, certain favouritism is, by law, to be shown to US manufacturers.

In the PV sector, the developing nations are facing an oligopoly structure. But it is a somewhat loose oligopoly with lots of entrants. Thus, the benefits of the basic (silicon-slice) technology are likely to be available to developing nations even in the face of patents. But, even if they face patent issues in entering the field as producers, they are likely to be able to obtain licenses on reasonable terms, because of the large number of firms in the sector. The possibility of entry is demonstrated by Tata-BP

Solar, an Indian firm, based on a joint venture, and Suntech, a Chinese firm, based on a combination of its own technologies and of purchases of developed world firms.

At this time, it appears as if developing nations also have good access to the current generation of biofuel technology. The technologies are quite traditional, and there are many firms interested in bringing the technologies to developing nations. The harder question is with future biofuel technologies. It is likely that methods, or enzymes, or new micro-organisms for breaking down lignin will be patented. It is also likely that the holders of these patents will be willing to license their technology for use everywhere, and the licensing fees for these technologies are unlikely to be very high for very long. Thus, the key barriers are not likely to be associated with patents but rather associated with the tariffs and other restrictions related to the international sugar and ethanol markets.

The wind sector is competitive enough that developing nations will be able to build wind farms with equipment from the global market without enormous IP costs. However, it is much more difficult for developing nations to enter the global market for wind turbines; the existing industrial leaders are strong and hesitant to share their leading technology out of fear of creating new competitors. Moreover, a new firm that seeks to create its own technology must face the pricing problem of recovering its research and development costs. Initially, new firms are likely to have a smaller number of sales than their global competitors. In spite of these barriers, two developing nations, China and India, have succeeded in building important firms over the last 10 years.

With respect to access to the benefits of the technology, i.e. for the markets for reducing CO_2 emissions or for providing emission offsets to developed nations, there seem to be insignificant IP barriers to developing nation access. For the exporting markets, including PV cells, ethanol (or other renewable fuel) or wind engines, the picture is slightly more mixed. Certainly, for ethanol, the key concerns will be tariff and similar barriers, not IP barriers. For PV, the IP system is still unlikely to be a significant barrier. For wind energy, the issue is slightly less clear, but there will still probably be little IP problem. However, because of the global concentration in some of the industries, all countries should be alert to the risks of cartel behaviour.

There are other questions of importance to developing nations exploring these industries. Should developing nations strengthen their IP protection in order to make foreign investors more willing to transfer technology? The evidence suggests a possibility that stronger IP will help in the more scientifically-advanced developing nations, and offers little indication of risk associated with such strengthening. The answer may be different in poorer nations.

Are local trade barriers proving helpful or harmful in developing these industries? A confident analysis here requires much more detailed economic data, but the data here suggests that the argument against such tariffs is more likely to win. The available evidence is inconclusive on the benefit of nationally-funded research programmes oriented toward helping national firms gain the technology needed to compete globally. Clearly, there have been major benefits of such research in the developed world, but the success of the developing-world programmes is less clear.

For lenders and donors, a group of key issues arises in the "software" area – i.e. in designing the subsidies or legal requirements needed to make renewable energy economical. It is important to ensure that these subsidies, and particularly research subsidies, take developing-nation needs into account.

Of particular importance in this sector is public support of technologies. Developed nation governments are likely to seek to ensure that patents are gained on the results of the research and then seek to ensure that national firms are favoured in the licensing process. In essence, part of the political basis for the technology support is the hope of helping national manufacturers. It is possible to resolve this problem by asking developed nations to agree to forego their national favouritism in licensing publicly-funded inventions, at least with respect to technologies of global environmental importance. This is quite similar to the "humanitarian clauses" being considered in the medical and agricultural areas.

It would be far better for developed nations to to go even further and commit themselves to devote a portion of their technology development to the special needs of developing nations. They could also ensure that firms in developing nations have an opportunity to participate in such efforts. In any such arrangement it is crucial that the various research programmes leave space for many different strategies to bloom. An arrangement could be negotiated in either of two ways. One would be as part of climate change negotiations, in which the commitment to make the technology more readily available would be included, perhaps as a quid-pro-quo for stronger environmental constraints upon developing nations. This would require a stronger commitment than has been typical of global environmental agreements. The other approach would be as part of a stand-alone technology arrangement, with the quid-pro-quo based on reciprocity among research funders. This is envisioned in the proposed Treaty on a Global Scientific and Technological Commons.

Almost certainly the most important need is to remove unnecessary barriers to trade in the area, such as those that restrict Brazilian ethanol. In a sector such as renewable energy, it is economically wise to maintain some subsidies for the sake of the global environment (assuming the world does not move toward a carbon-tax or its economic equivalent). Although the subsidies serve environmental goals, they are often designed in response to domestic concerns, particularly domestic agricultural concerns, and may end up discriminating against developing countries. It would be ideal to design the subsidies in ways that do not distort trade or discriminate against developing nation firms. This would be a very difficult negotiation, but an extremely valuable goal to seek.

1. INTRODUCTION: THE ISSUE

As part of the world's move to combat global warming, developing nations are likely to seek to reduce their emissions of greenhouse gases, and particularly of carbon dioxide (CO_2). They may have to obtain new technologies in order to do so. This paper explores whether there will be barriers, particularly intellectual property (IP) barriers, to access those technologies. To do so, it examines the industrial structure of three sectors, photo-voltaic (PV), bio-mass and wind energy. Each of the three sectors, as it turns out, is extremely different from the others.

The paper emphasises IP and industrial structure issues, rather than the "nuts and bolts" of human education and understanding that are at the heart of technology transfer. Mainly because of the availability of data, the study concentrates on the more scientifically advanced developing countries such as Brazil, China and India. And the situation with respect to other technologies to combat global warming may be quite different.

2. THE INTERNATIONAL CONTEXT

There are a number of international programmes designed to assist developing nations in obtaining environmental technologies in general. This section reviews the underlying international negotiations, and the current pattern of international technology transfer in the renewable area, including the role of IP in these areas of technology.

2.1 Negotiations on Climate Change and the Likely Future of Developing Nation Obligations

The key international agreements on climate change are the original United Nations Framework Convention on Climate Change (UNFCCC) (signed in 1992 and entered into force in 1994) and the Kyoto Protocol (signed in 1997 and entered into force in 2005), so far the most important implementation of the UNFCCC. Neither places binding greenhouse gas emission reduction targets on developing nations. Whether such targets will be placed in current negotiations is still a matter of heated debate.

However, Article 12 of the Kyoto Protocol does create a "clean development mechanism" (CDM), under which entities in industrialised nations can satisfy their domestic CO_2 reduction obligations through facilitating an emissions reduction in a developing nation. Among the requirements spelled out in this provision are that the arrangement be voluntarily approved by each nation involved, that it provides "real, measurable, and long-term benefits related to the mitigation of climate change," and that the reductions be "additional to any that would occur in the absence of the certified project activity." This is not the only kind of international exchange authorised in the Kyoto Protocol, there are also joint implementation programmes and emissions trading, leading to a supervised market in "carbon credits," organised under the UNFCCC. In addition, there are less formal voluntary markets organised by a number of institutions including banks.[1] Where these procedures are available, developing nations can obtain financial support for emissions reductions.

2.2 Treaties Calling for Technology Transfer and Programmes to Assist Developing Nations

The UNFCCC calls on developed nations to assist developing nations through technology transfer. Article 4.5 states that:

[t]he developed country Parties . . . shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties.

In order to assist in the implementation of this provision, the UNFCCC conferences have created an Experts Group on Technology Transfer, whose reports are available on the UNFCCC website: (http://unfccc.int/2860.php). This group reports to and makes recommendations to the Subsidiary Body for Scientific and Technical Advice (SBSTA), a group created under the UNFCCC to deal with a variety of scientific issues. Judging from its current reports and work programme, the expert group has been concentrating on providing broader access to the information needed to achieve technology transfer.[2]

There are a large number of programmes implementing such technology transfer. One of the most important is the Global Environment Facility (GEF), which is designed to subsidise developing nations' actions to respond to environmental concerns in those situations in which the developing nation making the expenditure will obtain little benefit for itself even though the action will, on net, benefit the rest of the world. Dealing with climate change is one of several specific goals of this fund, because activity to reduce emission of greenhouse gases benefits the entire world, while possibly being, on net, costly to the nation involved. The GEF is a partnership of the World Bank and the UN system with a complex governance structure designed to reflect both donor and developing nation interests. Although much of the activity of the GEF is in other environmental areas, such as the protection of biodiversity, the GEF has been involved in the renewable energy area and has, in particular, supported wind and photovoltaic projects. It has also catalysed some of the regulatory changes (to be discussed in Section III) needed to implement renewable energy.[3]

The World Bank has a Renewable Energy Division, which supports a variety of programmes including one on Photovoltaic Market Transformation and the Asia Alternative Program. It has, for example cooperated with the GEF, combining World Bank money, GEF money and Chinese co-financing, to provide institutional strengthening in both the windfarm and the PV areas, as well as direct support in the PV area.[4] A second phase project of the Bank with China was inclusion of finance for a large scale wind project.[5] In 2005, the Bank approved a "Chinese Renewable Energy Scale Up Program," (CRISP), looking particularly to technical assistance, capacity building and policy assistance.[6] More broadly, the Bank committed itself in 2004 to a 20 percent average annual growth in new-renewable energy and energy efficiency commitments between 2005 and 2009.[7]

And there are many bilateral programmes specific to the climate change area. These include, for example:

- The US Technology Cooperation Agreement Pilot Program, created in 1997 (TCAPP);
- The Climate Technology Partnership (CTP), a US programme that replaced the TCAPP in 2001;
- The Climate Technology Implementation Plan (CTIP), created under the Climate Technology Initiative (CTI) in 1995 by a group of OECD countries together with the EU.[8] This provides a global network of coordination activities for the technologies considered in this paper as well as for a number of other technologies;[9] and
- The various EU mechanisms for the CDM, finance, and technology cooperation, e.g. EU-Latin America Clean Development Mechanism Co-operation, and bilateral programmes in Asia.[10]

2.3 Current Patterns of Technology Transfer in Clean Energy Technologies

There are several modes of technology transfer. One is provision of products incorporating the technology, e.g. ozone-layer-safe coolant compounds or photovoltaic panels for off-grid electrical supply. Another is licensing the capability to produce such products, perhaps to an indigenous firm or to a joint venture. Examples appear below in both the PV and wind sectors. A final mode is supporting developing national capability to research and produce the products independent of a licensor (or at least in a relatively equal position with the licensor).

In some cases, the relations between local market size, transportation costs and economies of scale will lead to preference for a particular form of technology transfer. Obviously, donor nations will often prefer the first or second of these options because their own industries will receive some of the benefit from any subsidies they provide. In fact, "tied aid," meaning aid contingent on its use to purchase donor-nation goods, has been used in the renewable energy area. The developing country will, depending on its size and research capability, usually prefer the third approach to the second and the second to the first, because of the benefits to national employment and industrial capability.[11]

In general, the public sector programmes described above are implemented through an initial agreement between the donors and the developing country. This agreement lays out a framework for cooperation at the intergovernmental level, typically looking toward an analysis of the developing country's needs and a choice among the specific areas in which the nation's energy programmes are to be assisted. Then, the transfer of the chosen new materials, equipment or technology is implemented through a package; this package is likely to include such approaches as support for training, development of market incentives and project finance.[12]

The CDM process works in a different way. Although there are several patterns, one involves an agreement between a specific developed world entity that wishes a carbon credit and a specific developing nation entity able to provide one. The arrangement is then reviewed by the Executive Board of the CDM system, a Board that is organised under the UNFCCC. That review seeks to guarantee that the carbon reduction created in the developing nation is actual and real. Then, the process goes ahead and the developing nation is assisted by the developed-world entity in implementing the specific reduction. This implementation may include technology transfer. An example is a recent wind-energy park in China, supported by a Japanese electrical power firm and the Swedish Energy Agency.[13] The project documents, available on the web, describe the proposed wind energy park, present the history of the negotiations involving the various organizations and their governments, and present a careful analysis of the amount of CO_2 emissions prevented using methodologies laid out by the CDM Executive Board. It is noteworthy that in this particular case the wind turbine manufacturer, Vestas, a Danish company, was chosen by public bidding.

There can also be direct private technology transfer in the relatively traditional pattern of a license from a developed nation firm to a developing nation firm (and such a transfer can form part of a more elaborate project funded privately or under one of the above mechanisms). In this case, the existence of a patent defining the exact rights held by a technology supplier facilitates the negotiation of a license (even though know-how may also be licensed along with the patent). Although the magnitude of the effect of national IP legislation is hard to evaluate,[14] technology holders are also more willing to license their IP if they believe that the technology can be protected against copying. And there are now several examples of developing-nation firms purchasing developed-nation firms in order to obtain access to their technology, and possibly also to their markets and their production capabilities. In these cases, of course, the IP system helps the developing-nation purchasing firm ensure that it really obtains the technologies it seeks. Thus, a patent may not only, as is often the concern, be a bar to developing nation use of a technology; it can also facilitate that use.

Intellectual Property protection generally plays a quite different role in the renewable energy industries than it does in the pharmaceutical sector, the source of many developing nation perspectives on IP. In general, in the pharmaceutical sector, an individual patent may have a very substantial impact, for a specific drug may not have any substitutes. In such circumstances, the patent holder is in a very strong market position and may be able to charge a price well above production cost. In contrast, in the three renewable sectors considered here (and in many other industrial sectors), the basic approaches to solving the specific technological problems have long been off-patent. What are usually patented are specific improvements or features. Thus, there is competition between a number of patented products – and the normal result of competition is to bring prices down to a point at which royalties and the price increases available with a monopoly are reduced. This will be the case particularly for the products considered here, where there is competition not only between the firms in the specific sector but also between the sectors and alternate sources of fuel or electricity. In effect the benefit of the technologies is shared with the ultimate customers. Moreover, in some cases, there will be cross-licenses among firms, permitting each to use some of the technological features developed by others. This healthy result is not always the case, because sometimes firms are able to find a specific niche of a technology or a related product that may be needed by many and these can be the basis of significant exclusivity. An example of such exclusivity of an enzyme used in certain bio-ethanol processes is discussed below, but it should be noted that this is rare.

The UNFCCC and its Expert Group have considered the role of UNFCCC in technology transfer. In its early study, 'Methodological and Technological Issues in Technology Transfer',[15] serious patent and restrictive business practice problems were noted in the Republic of South Korea's imports of environmentally-sustainable technologies. The report emphasised the benefits of IP and stated that the costs of licensing are small, and suggested production-sharing contracts, under which technology suppliers would license technology in return for a share of the production. A later paper prepared for a workshop organised at the recommendation of the Expert Group, however, was drafted by Tata Energy Research Institute in India, and presented a somewhat different perspective, building on the work of the UK Commission on Intellectual Property Rights.[16] It presents no specific conclusions, but sets forth both pros and cons of IP from a developing nation perspective.[17]

3. THE ECONOMIC CONTEXT OF IMPLEMENTING ENERGY CONSERVATION AND PROMOTING ALTERNATIVE ENERGIES

As implied by the above discussion, there are several different markets for renewable energy capabilities for developing nations. The most obvious one is the market for enabling the nation itself to reduce its CO_2 emissions (not currently required by international law. but which may be required in the future). The second is the market for providing carbon offsets under the CDM system of the Kyoto accord. And the third is the market for exporting renewable products, such as biofuel (or conceivably electricity), and equipment, such as wind turbines, in which the developing-world industry becomes integrated into the global industry as a supplier. In general, the competition (and therefore the prices) in each of these markets will be different.[18] In the first market, the economic comparison is with alternative energy sources (including energy conservation). In the second, the competition is with alternative sources of offsets, which may be in other developed nations. And in the last, the competition is with other suppliers of the particular internationally-traded product. In the first two cases, it is the IP protection in the host nation that is of greatest importance, for the activity is essentially entirely domestic – and the IP issues are essentially the same for these two markets. In the last case, IP issues in the market nations are also important, for competitors' IP may bar the export.

Looking in particular at the first of these markets, it must be recognised that many renewable technologies are unlikely to be successfully applied unless they are subsidised or required by regulation. In the developed world, a significant portion of the motivation to use renewable energy technologies has derived from restrictions on electrical grids or on the transportation sector. This section reviews those arrangements, and it is essential that they be, in some way, duplicated in the developing world for renewable energy technologies to be economically feasible. Many of the arrangements were initially created in the 1970s during the energy crisis that followed the oil price rises that began in 1973. Many were then eliminated during the long period in which oil prices fell in real terms. And new versions have been created more recently, particularly with the high oil prices of the early 21st century and with growing recognition of the risks of global warming. There will need to be analogous arrangements in the developing world, which may, of course, differ in many respects. One example is China's Renewable Energy Law which entered into force on January 1, 2006. This law builds on earlier legislation and provides an overall framework, particularly for renewable energy sources supplying the grid and for CDM projects within China.[19]

3.1 Issues Associated with Electricity Grids

A major thrust for renewable energy, particularly in the wind sector and in the use of waste heat from industrial processes (cogeneration) has come from requirements on electrical utilities that they use renewable sources for a certain percentage of their energy, or that they buy renewable energy, often on favourable terms set up in a "feed-in tariff", from anyone who may be able to produce it and be interested in selling to them. These were the principles underlying US federal legislation, the Public Utility Regulatory Policies Act of 1978 (PURPA), which required utilities to buy electricity from private individuals and developers. Many states have other requirements. For example, California added a requirement in 2002, the "Renewable Portfolio Standard," which requires that by 2017 utilities must obtain at least 20 percent of their energy from clean energy sources. In addition, there have been a variety of 'production tax credits,' that encourage development of wind power in the United States.[20] There are also loan guarantees and subsidies authorised in the US Energy Policy Act of 2005. The new California Global Warming Solutions Act of 2006 requires a cap on greenhouse gases for 2020 at the 1990 level, which may lead to further incentive arrangements. Similar arrangements are, of course, found in many nations, as exemplified by the European Union (EU) Renewable Electricity Directive of 2001.[21]

3.2 Issues Associated with Transportation Fuel

A similar arrangement is associated with the various arrangements for special fuels for transportation. Thus, in Brazil, there were a series of activities in the nation's early (1974) move to encourage ethanol. This included credit guarantees and low-interest loans for construction of refineries, favourable purchasing arrangements by a state trading enterprise and investments by the state-owned oil company for distributing ethanol throughout the nation. In addition, in 1979, the government made agreements with auto manufactures for producing agreed numbers of 100 percent ethanol cars. In today's regime, the primary direct interventions are a requirement that all gasoline contain a fixed proportion of ethanol, and a slight tax preference for the purchase of new "flex-fuel" cars which can use both gasoline and ethanol.[22]

In the United States, there are subsidies for the production of ethanol. The key traditional US subsidy was an exemption from the motor fuels excise tax.[23] In addition, ethanol can be used as a substitute for methyl tert-butyl ether (MTBE), a chemical additive used to help meet emissions standards. Some states are now phasing out the use of MTBE because of fear of health risks; the result is to increase ethanol use.[24] The 2005 Energy Policy Act adds tax credits for purchase of certain alternative fuel vehicles, as well as credits for producing ethanol and for installing the refuelling equipment needed for handling biofuels.

3.3 The Role of Public Funding in Research and Development in Clean Energy Technologies

It is clear that some of the renewable energy technologies, particularly PV technologies, are not yet inexpensive enough to be used for general application. Because of this, economics firms have been hesitant to invest in substantial research on their own, save where there are significant subsidies, as in the current ethanol boom in the United States. Hence, much of the research in these areas is funded by the government. The basic economic justification for such an approach is that the social benefits of the alternative sources of energy (e.g. in the reduction of the emission of green house gases) are not capturable by industry. In the absence of, say, a carbon tax that would create private incentives, the government must fund the research.

Among the most important such funders is the US Department of Energy – to provide approximately 356USD million for the three technology sectors considered in this paper, at least as proposed in the 2008 budget.[25] And for an older example with an interesting title, consider the US Solar Photovoltaic Energy, Research, Development, and Demonstration Act of 1978. But the public sector is not important in the United States alone. A study performed for the European Union found that the public sector conducted slightly more than half of the renewable energy research performed in the EU – the total, for 2002, was 349.3Euros for the public sector and 340Euros for the private sector.[26] The three sectors considered in this paper were among the leading sectors of public expenditure. Solar energy, presumably in non-PV forms was also high.

At least in the case of the United States, such subsidised research will almost certainly end up protected by patent rights. And when such research is licensed, a certain favouritism is, by law, to be shown to US manufacturers. For example, Section 204 of the Bayh-Dole Act, the key legislation on IP aspects of government grants to universities, requires that the licensee of technology developed under the grant commit itself that the relevant products 'be manufactured substantially' in the United States. This is, however, a condition that can be waived by the government, and there is history of such waivers by the US National Institutes of Health Office of Technology Transfer (NIH OTT) with respect to licenses of tropical disease technologies to developing nation entities.[27] There are also arrangements to enable US firms to avoid certain antitrust issues associated with cooperation in research; certain of the protections do not apply at the production level unless the production takes place within the United States.[28] Such rules will be barriers to entry into the industries by foreign firms, including those in developing nations; they will not, of course, be barriers to purchaser of the products developed by the licensees or research co-operators. For this paper, the existence of analogous provisions in other nations was not explored – but certainly nations frequently seek to ensure that it is their national firms that receive the benefits of their research subsidies.

Finally, especially in the current burst of enthusiasm for renewable energy technologies, based both on high energy prices and on concern about global warming, (and, of course, also, as a result of the growth of subsidies to the renewable energy industries), a variety of venture-capital funded firms are entering the industry. The venture-capital firms prefer to invest in start-ups that have a strong proprietary position; thus patents are often emphasised by the start-ups. In some cases, the entrepreneurs themselves have developed the technology; in other cases, they obtained the technology from a university or the government under license. The university may have developed the technology under government grant.

4. PHOTO-VOLTAIC

4.1 The Technology

Photo-voltaic technology is the most novel of the three technologies focussed upon in this paper. It involves a panel which produces electricity when exposed to sunlight. Of the three technologies considered here, PV is also the most expensive in terms of cost per installed kilowatt or kilowatt-hour and is, in general, currently more expensive than traditional means of producing electricity. However the costs are declining; a 2004 paper presented at the IEEE Power Engineering Society Summer Meeting in California estimates the cost of PV energy as 20-40 cents per kilowatt-hour, and notes that the cost has declined by a factor of 10 over the previous two decades, and by a factor of two over the previous decade.[29] Because the installed capacity is increasing rapidly, one can expect a continued decline in cost. Because of the cost of the technology, its most common application has been in off-grid applications, such as rural electrification and pumping or lighting in remote areas. In such situations, it can be far less expensive than efforts to extend a grid, and far more environmentally friendly than alternatives such as diesel generators or kerosene lamps. But, as the cost drops, PV is beginning to be used in on-grid situations.

The first generation of the technology was based on crystalline silicon, much the same material used in semi-conductors for computers, although the quality demands are somewhat less severe. Silicon slices were treated with surface modifications that made them better acceptors of light, with doping in various layers to ensure that the electrons generated when a photon struck the device could be collected, and with conducting interfaces to carry off the electricity.

The improvement process has emphasised development of less expensive and more readily produced forms of PV cell.[30] The newer technologies that are being explored involve thin films of various semiconductors that are applied to the surface of a material like glass. This permits significantly reduced manufacturing costs, and the production of much larger single units.[31] The new thin-film technologies accounted for about 9 percent of the market in 2005.[32] There are also efforts at more fundamental modifications of the process to achieve higher efficiencies.[33]

In order to operate effectively, the panels have to be combined with other equipment. If power is required during night time, or when the sun is not shining, batteries are needed.[34] And, if power is to be supplied to the grid or to local alternating current (AC) devices, inverters are needed to convert the direct current (DC) power produced by the panels into AC power. The inverters are extremely important, and coming to reflect an increasing share of the overall cost of the system, as the PV cells themselves become less expensive. Typically, the inverters not only convert DC to AC, but also include control mechanisms designed to ensure that the solar panels operate under the most efficient electrical conditions possible and also satisfy the various requirements of connecting to the grid.[35]

As in the other sectors discussed, there is significant public sector support. As an example, the US Department of Energy has recently granted support to some 13 solar energy projects, primarily in areas of new chip technologies and manufacturing and fabrication processes.[36] Almost certainly, that support will lead to patented inventions.

4.2 Industrial Structure and IPR Issues

The production of PV panels is expensive and requires large-scale precision manufacturing capability. Nevertheless, the industry is quite decentralised, as shown in Table 1., which lists all firms shipping over 50 MWp in 2005, as well as firms shipping smaller amounts in developing nations.

Table 1.[37] Photo-voltaics: Region, Total Shipments, Leading Firms and Shipments

REGION	TOTAL SHIPMENTS	LEADING FIRMS	THEIR SHIPMENTS
Europe	397 MWp	Q-cells	128
		Schott Solar	63
		+8 other firms	
Japan	635	Sharp	292
		Kyocera	109
		Mitsubishi	77
		Sanyo	96
		+ 1 other firm	
United States	119	7 firms	
China	116	Suntech Power	63
		+ 2 other firms: Ningbo Solar Cell and Shenzhen Topray.	
Rest of world	133	4 firms, including 2 developing nation firms: Motech (Taiwan) and BP Solar (India)	

This is a moderately concentrated industry; the four leading firms produce about 45 percent of the market. Another study, also using 2005 data, lists five firms, Sharp, Kyocera, Shell Solar, BP Solar and Schott Solar, as holding 60 percent of the market.[38]) The industry consolidated heavily in the 1990s.[39] Today's firms are concentrated in the developed world, but there are five firms in the developing world, each producing at least 10 MWp.

There are also a number of manufacturers of PV manufacturing equipment, e.g. Baccini, Meyer Berger, Spire and GT Solar.[40] The Baccini website describes its equipment and notes that it holds more than 30 patents; the websites of the latter two promise turnkey sale of assembly lines.[41] And there will, of course, be other patents on parts of the production processes. For example, Solaixc, which has technology to improve the production of silicon wafers, notes that it is seeking patents on its technology.[42]

A European Patent Office expert sees a substantial rise in the number of PV patent applications: a total of about 1,000 in 1997, up to over 2,000 in 2002.[43] Each of the major firms has a somewhat different technology, and, in general, each of the firms will patent its technology. There was at least one case of patent litigation among developed-world firms in 1992.[44] The patents involved, dating as early as 1977, were issued to David Carlson, the inventor of the amorphous silicon PV cell at RCA, and the question raised was whether or not ARCO's solar cells were within the scope of the patent. (Both plaintiff, Solarex, and defendant, ARCO, were ultimately acquired by British Petroleum, the former in 2001, and the latter in 2000.[45]) There has also been litigation over such PV applications as hand-held calculators and night-vision equipment.[46] It is very likely that the newer thin-film technologies will be subject to much more extensive patenting than the older silicon-slice technology. Although such litigation might affect the positions of particular firms, it seems unlikely to affect the economics of large-scale power production from a developing nation perspective.

It should further be noted that patents on inverters may be an issue. The inverter industry has many small firms, but appears to be a little more concentrated than the PV industry. Although there are a large number of firms making inverters,[47] the three leading ones in the United States (SMA, Xantrex and Sharp) hold 73 percent of the market and the three leading ones in Europe (SMA, Fronius, and Studer) hold 69 percent of that market.[48] Part of the reason for the differences among the different firms is because of differences in regulatory requirements in different markets.[49] Due to the need for PV costs to decline to ensure penetration of the market, it is possible that the royalties may not be significant.

4.3 Implications for Developing Nations

In China, the industry has long been encouraged by the government, primarily through support for research into all forms of PV cells and through encouragement of the import or design of PV production equipment. The import of certain of the fabrication technologies was accomplished in part by a programme with the US Department of Energy in the early 1980s. According to a 2003 study, most of the actual production line equipment (or at least the key equipment) was imported from the United States or Canada, but one firm, GoFly Green Energy Co., built its own production equipment, while inverters and controllers were made locally.[50]

The 2003 report, however, does not even mention China's key recent success story in the area: Suntech Power Co., Ltd. This is a firm that was founded in 2001, started its first assembly line in 2002, and produced 60 percent of China's PV cells by 2005. The firm went public in New York in December 2005. The firm has its own Research and Development Centre. Its founder and CEO, Shi Zhengrong, studied in Australia, and is said to have brought a number of patented inventions on his return to China.[51] In 2006, the firm acquired a Japanese PV firm, MSK.[52] The same year, it became the world's 4th largest PV producer (superseding the data in the chart above),[53] and it exports 90 percent of its production.[54] Its corporate prospectus makes no mention of concerns about obtaining technology; rather it emphasises concerns about access to the silicon supply needed for continued expansion.[55]

In contrast, India's leading firm is a joint venture between BP Solar (51 percent) and Tata (49 percent). The joint venture has a solar manufacturing plant in Bangalore.[56] It is serving both the Indian and the export market, including a sale to Bhutan for a small project funded by Danida.[57] Clearly, its future role will depend on BP Solar's overall strategy.

The developing nations are certainly facing an oligopoly structure in this industry. But it is a somewhat loose oligopoly with lots of entrants. Hence the benefits of the basic (silicon-slice) technology are likely to be available to developing nations even in the face of patents. It is not clear whether the various patents involved have been taken out in developing nations as well as in developed nations, so that it is possible that developing-nation firms could copy the technologies for local application. But, even if they face patent issues in entering the field as producers, they are likely to be able to obtain licenses on reasonable terms because of the large number of firms in the industry. The possibility of entry is demonstrated by Tata-BP Solar, based on a joint venture, and Suntech, based on a combination of its own technologies and of purchases of developed world firms.

5. BIO-MASS FOR FUELS

5.1 The Technology

Biomass can derive from many different sources and be treated in a variety of ways. Some traditional crops such as corn (maize) or sugar are used as sources of bio-mass. The bio-mass derived as waste from the production of other products can be used as a source of energy. Biomass can be directly burned for conversion into heat energy, either for industrial uses or for steam generation to make electricity. It can also be converted into a fuel for transportation use.

There are two currently important technologies for production of transportation fuel from biomass. One is the production of ethanol for use in automotive fuel. It is produced quite efficiently from sugar-cane in Brazil, and much less efficiently from corn in the United States. The alternative process, emphasised in Europe, is diesel fuel (bio-diesel), manufactured from a variety of forms of bio-mass This is a quite different process in which there is no sugar intermediate.[58]

The ethanol process in the United States is based on corn, and involves a grinding of the corn, treatment to produce sugar, fermentation of that sugar into ethanol, and then distillation of the ethanol to produce an additive that can be included as part of fuel. In contrast, the Brazilian technology involves production of sugar from cane in the traditional way, and then the parallel fermentation and distillation.

As mentioned, the biofuel technology used primarily in Europe is quite different from the US and Brazil and, in general, does not involve a step of going through sugar and ethanol. Rather, the starches of the grain are partially oxidised to yield a mixture of CO_2 and H_2, which is then reacted to produce synthetic diesel. A significant amount of energy is, however, lost in the process.[59] There are also ways to produce similar fuels from oil-rich crops such as soya and rapeseed (canola).

In addition to these relatively traditional technologies, there are new approaches. There could be much greater yields from a particular area of land if it were possible also to convert not just the starches but also other components of the plants into energy. This requires the breaking down of cellulose, a method which is currently the topic of significant research and public research support.[60] So far, this has happened only on a demonstration scale, and the apparent leader is Logen, an Ottawa-based Canadian corporation..[61] This firm’s website indicates that the enzymes it is using will be available for sale in connection with technology licenses in the future.[62] Another approach is to engineer new organisms to manage the chemical pathways needed for these new feedstocks.[63] Note also that there might be special plant crops, other than corn or sugar cane used for making fuel, and that the plants might be bioengineered. In addition, there is the possibility of using algae to provide the biomass.

There are also significant government programmes. For example, the US Department of Energy has recently awarded 23USD million to four corporations and a university for work on fermentative organisms to convert biomass to ethanol, and has a much bigger programme for building plants for the same purpose.[64] Certain of these programmes were in response to specific Congressional authorisation.

For biofuels, it is essential to consider the parallel technology of the automotive engines that use the fuel. Special designs are needed, and there also may be a need for special additives to enable engines to use particular new fuels.[65] An example of special design is the Brazilian "Flex Fuel" vehicle, an approach that allows cars to shift back and forth from gasoline to ethanol which is used on a large portion of new cars in Brazil.[66] The engine automatically changes timing and fuel injection according to the level of ethanol in the fuel, with the control based on a measurement of oxygen in the engine exhaust.[67] There are patents in this area.[68]

5.2 Industrial Structure and IPR Issues

The industrial structure here is very different from that for PV energy. Here, for the current technologies, the basic conversion of biomass occurs in individual conversion operations, in which the plant matter is trucked in and then converted to fuel. The economics of bringing the biomass to the production plant favour decentralised conversion.

There is, however, significant concentration at the ownership level. In the United States, for example, one company, Archer Daniels Midland (ADM), holds 17 percent of the US ethanol capacity and the top five firms hold 37 percent.[69] According to a different source, ADM produces 25 percent of the US ethanol.[70] And there are international contractors, sometimes themselves large international firms, who offer the service of designing and constructing the local conversion operations. For example, ADM, together with Cargill, another large US commodity firm, is investing in Brazil.[71] But there are also local developing-world firms offering to build ethanol plants. For example, Dedini, an indigenous engineering firm, is a major supplier of sugar and ethanol equipment for Brazil, and reports on its website that it is able to provide complete plants on a turnkey basis for sugar and ethanol.[72]

The Brazilian programme began after the 1973 oil crisis, as the Brazilian National Alcohol Program of 1975, but has been significantly revised since. In 2003, for example, a requirement was imposed that Brazilian gasoline include 25 percent ethanol, and the nation currently produces two types of fuel ethanol: anhydrous, that is blended with gasoline, and hydrous, that is sold for direct use by consumers, who may then blend it in their engines.[73] It is now proceeding to produce its own advanced technologies, as exemplified by the H-BIO process, a way of incorporating fuel derived from biomass into diesel.[74]

There are substantial ethanol industries in a number of other developing nations, including China (which has built the world's largest plant), India, Pakistan, Japan, Thailand and Malaysia.[75] In addition, there are efforts by both the United States and Brazil to invest in ethanol production in other Latin American nations.[76] This suggests that there are few technological difficulties in entering the sector.

The same is true in the biodiesel context, where the major producers are European. In this case, there is also production in Thailand, India, Indonesia and Malaysia.[77] Argentina is also building a substantial industry.[78] For these nations, the technology issues are adaptations of the processes to use the local feedstocks, which may be based on crops and tropical oils different from those used in Europe. The firms are seeking to export their production to the developed world, and are typically facing trade barriers based on tariffs, subsidies and standards.[79]

Patent issues are likely to arise primarily with the newer technologies, because the older ones are long off-patent, and there is enormous patenting activity in the new areas. For example, a recent study of bio-diesel technology found an increase in patenting in the area from two patents in 1998 to 88 in 2005.[80] A firm in the area, CPS Biofuels Inc., emphasises its patent rights on its website.[81] And a new University of Georgia (US) process for producing biofuel from pinechips may become the basis of a patent application.[82] In addition, there are efforts to advance the more traditional technologies; these efforts may also be subject to intellectual property. For example, a new firm, Catalin, has licensed technology from Iowa State University to use waste grease and other oils as feedstocks for the production of biofuels, suggesting that Iowa State is interested in patenting.[83]

There also appears to be a technology race in the use of algae as a source for fuel. Several firms, e.g. Solix Biofuels, LiveFuels and XL Tech-Group, are interested in the area, and both Colorado State and Arizona State Universities are offering technology.[84] Solazyme, a California based company, has already entered an agreement to provide biodiesel feedstock from algae to a research partner.[85] The company's technology is based on attempting to shape the evolution of algae, and the company emphasises its proprietary position on its website.

As noted above, patents are likely to apply to the technologies developed under government support, as will the licensing restrictions associated with US government-sponsored technology. In fact, on its website, one of the DOE recipients, a start-up called Mascoma emphasises technology capabilities based on an exclusive license from Dartmouth.[86] And a search on "patent" on the Department of Energy Biomass Document Database leads to approximately 25 patents, on processes or specific organisms useful in the processes.

Moreover, some of the processes need continuing inputs and these can give rise to relevant patent positions. There have been at least two cases involving ethanol production processes, both relevant to corn-based processes, as used in the United States, and not to sugar- based processes. One of these involved trade-secret information for a "raw starch hydrolysis process."[87] The other involved industrial enzymes used to break down certain of the starch molecules in grain and convert them into glucose (sugar) molecules. This industrial enzyme industry is highly concentrated with only two firms in the United States; and one, Genencor, a US firm owned by Danisco, was dominant until the entry of Novozymes, a Danish firm. Novozymes came in with a new technology, which it patented in 2004, and successfully sued Genencor for patent infringement, winning very substantial damages in 2007. Genencor was ultimately required to pay a 20 percent royalty on its infringing sales of the enzyme.[88] This amounts to about 0.1 cents per liter of fuel. [89] (In another major fuel royalty case, Unocal obtained a jury verdict in 1997 giving it a .5.75 cents (USD) per gallon license in connection with a method of reformulating gasoline to meet emissions control regulations, but was eventually forced to give up its demands for such a fee as part of a settlement of antitrust proceedings.[90])

5.3 Implications for Developing Nations

At this point, it appears as if developing nations will have adequate access to the current generation of technology. The technologies are quite traditional, and there are many firms interested in bringing the technologies to developing nations. There will, of course, be problems in exporting biofuel to global markets, as reflected, for example, in the US tariff on Brazilian ethanol. Considering the incredible protectionism and market management of the global sugar economy, it is not surprising that there is protectionism in the product of the sugar!

But the hard question will be with future technologies. It is likely that methods, or enzymes, or new microorganisms for breaking down lignin will be patented, as those for converting corn into sugar discussed above. It is also likely, however, that the holders of these patents will be willing to license their technology for use everywhere; this is an implication of the costs of transporting bio-mass and consequent need to decentralise production. Based on the analysis above, the licensing fees for these technologies are unlikely to be very high for very long. There will certainly be competition among biofuels and with other fuels, so that the licensing fees are unlikely to be so great as to bar access to developing nations for use of the technologies to produce biofuels for their own markets or for export, if their systems are adequately efficient and they are not barred by tariffs.

Thus, the key barriers are not likely to be not those associated with patents, but rather with those linked to tariffs and other restrictions associated with international sugar and ethanol markets. The recent US-Brazil Memorandum of Understanding to Advance Cooperation on Biofuels, March 9, 2007,, covers both technology cooperation and market development and standards. Technology exchange is also included in a Brazil-Venezuela agreement of approximately the same period.[91] It does not significantly affect the analysis just presented.

6. WIND

6.1 The Technology

Windmills go a long way back, so, again, the basic technology is not new. But there are many recent improvements in the technology. These include design of much lighter and more efficient blades, design of systems (for some styles of mill) to orient the windmill to changing wind directions, mechanisms to protect the system during high winds, and engineering choices needed to decrease long-term maintenance costs. Because the systems are often sited where maintenance is expensive, the latter is a particularly important issue.[92] Much of the improvement has come in areas suggested by experience based on problems early on.[93] Technology has also been evolving in the design of appropriate systems to enable connection to the electricity grid.

Typically, the wind-driven rotor will travel at a variable speed that depends on the wind. The rotor will normally drive a generator directly (or through a fixed-ratio gearbox) so the frequency of any alternating current produced by the generator will vary with wind speed. Somehow, the electricity produced by the generator must be brought to the frequency needed by the grid and must satisfy the grid's standards designed to protect against failures that might derive from the mill.[94] This process usually uses an inverter, like that used in PV technology, for converting direct current to alternating current. As will be seen, these various control processes have been an important area of patent activity.

6.2 Industrial Structure and IPR Issues

A number of competing firms have emerged, each interested in producing windmills for sale. The 2006 leaders are shown in Table 2; there has been significant merger activity in the 2006-07 period, so this table may quickly become obsolete. The firm in fifth place is Indian while that in tenth place is a Chinese firm.

Table 2. Leading Firms In Wind Turbine Manufacture[95]

FIRM	NATIONALITY	MARKET SHARE
Vestas	Denmark	28.2 %
Gamesa	Spain	15.6 %
GE Wind	United States	15.5 %
Enercon	Germany	15.4 %
Suzlon	India	7.7 %
Siemens	Germany	7.3 %
Nordex	Germany	3.4 %
REPower	Germany (acquired in 2007 by Suzlon)	3.2 %
Acciona	Spain	2.8 %
Goldwind	China	2.8 %

As with ethanol production, there are intermediate firms that specialise in building large-scale wind-energy parks, assembling the real estate, the capital and equipment, and making all the necessary arrangements with the electrical grid. An example is Acciona Energia, a Spanish firm said to be the "world's foremost wind-park developer."[96] Its website indicates that it has installed 163 wind-parks in 10 countries; the only developing country on the list is Morocco.[97]

The industry is the most concentrated of the three analysed here; the top four firms serve almost three-quarters of the market.[98] And there has been significant consolidation, with a number of mergers in 2003.[99] There have been a number of publicised patent disputes and licensing discussions, all primarily affecting the US market. In 1996, Enercon was barred from importing wind turbines into the United States through a proceeding before the US International Trade Commission.[100] (This is through a procedure under which a firm's imports to the United States can be barred if it is shown that the firm's product violates a US patent.) The patent involved covered a particular method of controlling the inverter in order to provide power most effectively to the grid, and was held by Kinetech, a "technology investment and patent holding" company managed by Lachman Goldman Ventures.[101] More recently, Gamesa sought to enforce a patent on a strategy of controlling the turbine speed against GE[102]

In recently publicised licensing discussions, GE Energy, which controls a number of patents on the variable speed technology to use with wind turbines granted a license to REPower (a German firm now owned by the Indian firm Suzlon) to enable the latter to enter the US wind market.[103] GE's press release emphasised that it "is actively engaged in licensing its key patents for wind turbine control technologies." GE also recently licensed technology to Composite Technology Corporation's subsidiary, EU Energy.[104] It is noteworthy that GE was able to obtain a waiver from the government to protect its patent position under a government contract.[105]A USPTO patent search on "'variable speed' and 'wind turbine'" yielded 173 patents, most of which looked relevant from the titles. GE is mentioned in 18 of the patents; in at least some of these cases, it is the assignee, i.e., corporate holder of the patent. Clearly, GE Wind is seeking to use its patent strategy as an important competitive tool, and some foreign firms have had to design around the US patent in order to market in the United States.[106] Nevertheless, GE does not have a monopoly on the US market, and its market share has declined from 59 percent in 2005 to 44 percent in 2006.[107]

As for the other technology sectors considered in this paper, there are government research programmes, and it is likely that the products of such research will be patented. For example, the US National Renewable Energy Laboratory lists six patents available for licensing.[108] These include patents on airfoil design (some of which may have derived from a joint programme with a private consulting firm, Airfoils, Inc.)[109] and on variable speed power and generator systems.

6.3 Implications for Developing Nations

There is enough competition that developing nations will be able to build wind farms with equipment from the global market without enormous IP costs. However, it is much more difficult for developing nations to enter the global market for wind turbines as the existing industrial leaders are strong. They are hesitant to share their leading technology out of fear of creating new competitors.[110] Moreover, a new firm that seeks to create its own technology must face the pricing problem of recovering its research and development costs. Initially, it is likely to have a smaller number of sales, compared to its established global competitors. And, in the United States, there is a patent barrier; this may be a situation unique to that nation. Perhaps as a result of these concerns about protecting technology and the economic demands of reaching different markets, there is a range of licensing patterns balancing the licensor's and the licensee's interests in different ways.[111]

In spite of these barriers, two developing nations, China and India, have succeeded in building important firms over the last 10 years.[112] China has succeeded in serving its own market, but is not, at this point, a significant exporter. It appears to be able to produce wind turbines about 20 to 40 percent less expensively than developed-world firms. As of 2003, all Chinese technology in the area appeared to originate from agreements with US and European firms, and in none of the cases was state-of-the-art technology transferred. Older technology was transferred, which is typical for windmills with smaller total power per unit.[113] The Chinese Ministry of Science and technology, however, has subsidised wind turbine research.[114]

The leading Chinese firm is Goldwind, which initially obtained its technology from Jacobs, a German firm, for a royalty of 10,000 DM per machine.[115] Considering that the "standard" approximate cost of an onshore turbine is 1000USD/KW,[116] and that the typical Goldwind machine is about 750 KW; this amounts to roughly a 1 percent royalty. But Goldwind only had some of the technology needed; as of 2003, Goldwind was not manufacturing the entire turbine in China. It had begun to acquire blades locally, but not the entire product.[117] A more recent study indicates that Goldwind was also a licensee of REpower and of Vensys.[118] Goldwind is seeking proprietary protection of its technology, perhaps in the hope of achieving a position in China like that of GE Wind in the United States.[119]

Of several smaller Chinese firms, one (Zhejiang Yunda Windey) is developing some of its own technology, according to the same recent study. The study lists eight foreign (four wholly-owned and four joint-venture) firms (including industry leaders such as Gamesa, Vestas and GE) manufacturing in China, mainly manufacturing blades and nacelles.[120] Harbin Electric Machinery Co. is also described as developing its own technology and claiming full intellectual property rights over it.[121] Nevertheless, there is evidence that China's technology is still lagging. The Vestas turbines chosen for the Gansu Datung Yumen CDM project discussed above were described as having superior technology to that of any Chinese manufactured turbines. In particular, they have "Optitip" pitch regulation using micro-controllers to maintain the blade pitch at the best angle for the wind, and "Optispeed" generator technology to allow the rotor speed to vary in relation to the speed that is synchronous to the grid. [122]

It is not clear how much of China's technology lag is based on the need for Chinese firms to gain experience and how much is based on the unwillingness of the technology licensing firms to provide particular technologies. Part of the problem has been restrictions in tied-aid programmes that require use of the donor-nation's products.[123] China is attempting to help develop the missing technologies, and is considering not only local content requirements but also local intellectual property requirements.[124] It has often undertaken such efforts to encourage technology transfer.[125]

India has been more successful. It has the world's fourth largest installed park of wind power facilities.[126] The Indian Wind Turbine Manufacturer's website lists nine manufacturers in the nation, of which five are associated with a global firm.[127] The leading Indian firm, Suzlon, although essentially indigenous, acquired initial technologies by license.[128] But then it expanded by acquiring developed world firms. For example, it acquired a German firm, REpower, in mid 2007.[129] It has also acquired a Belgian wind turbine gearbox producer and established a rotor blade facility in the United States.[130] This will, of course, give it access to developed-world technology and turn it into a global firm competing in the developed world as well as the developing world. The REpower transaction involves arrangements under which integration of other smaller European firms into the restructured company appears likely. Even as early as 2003, Suzlon was exporting 13 percent of its production, primarily to the United States, and it has set up a manufacturing plant in China and is setting one up in the United States.[131] The firm's website emphasises its own research and mentions facilities in Europe, India and also new sales in the United States.[132] Based on its own research and its global acquisition strategy, it appears to have solid access to technology and is likely to be a technological leader.

7. OVERALL IMPLICATIONS

The conclusions are summarised in Table 3:

Table 3. Intellectual Property Implications: PV, Biofuel and Wind

TECHNOLOGY	PV	BIOFUEL	WIND
IP access limitations on current market for energy (For reducing emissions or participating in CDM).	Few concerns over IP.	Essentially no concerns over IP.	Possible concerns over IP, but likely to involve at most a small royalty.
Major developing country concerns in future market for energy	Possible difficulties in obtaining advanced IP-protected technologies.	Possible barriers or delays in obtaining cellulosic technologies.	Possible risk of anti-competitive behaviour given concentration of industry.
IP access limitations on entering the industry as a producer of key components or products	Possible barriers or delays in obtaining or creating the highest quality production systems.	Possible concerns over access to new enzymes and conversion organisms – but at most a royalty issue.	Possible difficulty in obtaining most advanced technologies.
Most important overall concerns in area.	Access to government-funded technologies, Standards.	Global trade barriers in the sugar/ethanol/ fuel context. Access to government-funded technologies, Standards.	Access to government-funded technologies, Plausible anti-competitive behaviour, Standards.

7.1 For Developing Nations Themselves

With respect to access to the benefits of the technology, i.e. for the markets for reducing CO_2 emissions or for providing emission offsets to developed nations, there seem unlikely to be significant IP barriers to developing nation access. Each of the sectors is organised as an oligopoly at a key level of technology supply. Each of the oligopolists may have IP for which it would like to charge a high royalty, but it will be constrained by competition from the other members of the oligopoly, and, even more, by competition with alternate means of producing electricity or fuel. There may be exceptions in such areas as PV power for isolated applications, where the competition may be weaker.

For the third type of market, that of exporting PV cells, ethanol (or other renewable fuel), or wind engines, the picture is slightly more mixed. Certainly, for ethanol, the key concerns will be tariff and similar barriers, not IP barriers. For PV, the IP system is still unlikely to be a significant barrier. For wind energy, the issue is slightly less clear, but there will still probably be little IP problem. In all three of the sectors, developing nation firms have succeeded in entering industry leadership. Indeed, in some cases, patents may have worked to facilitate technology transfer. The patent disputes have typically been resolved by cross-licenses or product modifications in a pattern common in non-monopoly industries.

The likelihood that the oligopoly will pull ahead of new small competitors will probably be the most important barrier to access by new smaller firms and those in smaller nations. And, precisely because of the global concentration in some of the industries, all companies should be alert to the risks of cartel behaviour. It should be emphasised that there have been no serious public allegations of such collusion in the industries considered here, but there has been prosecution in the related energy industry area of gas-insulated switchware as well as an investigation in power transformers.[133]

There are other questions of importance to developing nations exploring these industries. Should developing nations strengthen their IP protection in order to make foreign investors more willing to transfer technology?[134] The case of wind power in China described above certainly argues in this direction, but it is not clear how much the concerns in those cases are really general concerns about transferring core technologies. Additionally, investor concerns about protecting home markets can certainly be met by IP protections in the home markets. The evidence suggests a possibility that stronger IP will help in the more advanced developing nations and offers little indication of risk associated with such strengthening. The policy balances with respect to IP are very different from those for pharmaceuticals and may also be different for poorer nations.)

Are local trade barriers proving helpful or harmful in developing these industries? Both India and China have tariffs on PV and wind technology in the order of eight to 10 percent in China and 15 percent in India. These tariffs may produce economic inefficiency.[135] They may also, however, have served as infant industry protection for local firms. A confident analysis here requires much more detailed economic data, but the data here suggests that the argument against such tariffs is more likely to win. In China, the production cost advantage was described above as being much greater than eight to 10 percent and quality issues have probably dominated cost. In India, there is enough move toward exporting that the protective benefit of the tariff seems doubtful.

The available evidence is inconclusive on the benefit of nationally-funded research programmes oriented toward helping national firms gain the technology needed to compete globally. Clearly, there have been major benefits of such research in the developed world, but the success of the developing-world programmes is less clear. The Brazilian programme helped in Brazilian biofuels; but in PV and wind technologies, technology supply by foreign firms appears to have been much more important than technology supported by the governments. And data are not yet in on China's effort to help its wind industry. In any event, any nation considering such a research and technology transfer programme should be careful to use IP in a way that encourages technology transfer to the national industry rather than hindering it.[136]

7.2 For International Lenders and Donors

For lenders and donors, one group of key issues is in the "software" area i.e. in designing the subsidies or legal requirements needed to make renewable energy economical. This was the role of the legislation and regulation discussed above in Part III. Obviously, it is important to decide wisely when such arrangements should be used and when the developed world should contribute to the cost of the subsidy that is often implicit. It is also important to make sure that the need for these arrangements is taken into account in the privatization of electrical grids.

These donors should ensure that their subsidies, and particularly their research subsidies, take developing-nation needs into account. New research is probably not a significant issue in the windpower area, but is certainly significant in PVs, where off-grid applications will probably be much more important than in the developed world. It is crucial in biofuels, where different nations are likely to have different feedstocks.

7.3 For International Negotiations

In general, there are no special new issues in the IP area, per se. This is because the competition among different suppliers in the various sectors implies that royalties are likely to be minimal. The most serious plausible patent issues are likely to arise from the new technologies, where there is a risk that some broad patent might complicate the development of a major category of new more efficient or less expensive technologies. The riskiest area, as noted above, is the wind energy area, where patents have already been used to attempt to protect markets from foreign competition, and where the industry is the most concentrated, compared to the other three sectors studied.

Concentration itself presents a most significant issue, should the relative small number of suppliers (of PV cell manufacture or manufacturing equipment, of biofuel manufacturing requirements such as enzymes, or of turbines or turbine equipment) cooperate in a way that would violate competition-law principles. Thus, there should be consideration of ways to ensure detection of possible violation of competition-law principles, especially in industries such as these where each nation may want to help its national champions.

Of particular importance in this sector is public support of technologies. Developing nation governments are likely to seek to ensure that patents are gained on the results of the research and then seek to ensure that national firms are favoured in the licensing process. In essence, part of the political basis for the technology support is the hope of helping national manufacturers. (This is also an implication of tied aid.) But there are obvious possibilities of resolving this problem by asking developed nations to agree to forego their national favouritism in licensing publicly funded inventions, at least with respect to technologies of global environmental importance. This would be very similar to the "humanitarian licenses," discussed in the medical and agricultural areas.[137]

It would be far better to go even further and for developed nations to commit themselves to devote a portion of their technology development to the special needs of the developing nations and to ensure that developing nation firms have an opportunity to participate in such efforts. In any such arrangement it is crucial that the various research programmes leave space for many different strategies to bloom.[138] An arrangement could be negotiated in either of two ways. One would be as part of climate change negotiations, in which the commitment to make the technology more readily available would be included, perhaps as a quid-pro-quo for stronger environmental constraints upon developing nations. This would require a stronger commitment than has been typical of global environmental agreements. The other approach would be as part of a stand-alone technology arrangement, with the quid-pro-quo based on reciprocity among research funders. This is envisioned in the proposed Treaty on a Global Scientific and Technological Commons.[139]

There is a serious possibility, raised in many of the materials reviewed above, although not analysed in the text, that technical standards could be helpful in facilitating international trade – and, therefore, perhaps market entry – in all three areas.[140] Consider the needs, for example, for standards for the silicon to be used in manufacturing PV cells, for various grades of biofuel, and for requirements for coupling wind systems to power grids.

Almost certainly, the most important need is to remove unnecessary barriers to trade in the area, such as those that restrict Brazilian ethanol. In a sector such as renewable energy, it is economically wise to maintain some subsidies for the sake of the global environment (assuming the world does not move toward a carbon-tax or its economic equivalent). Although the subsidies serve environmental goals, they are often designed in response to domestic concerns, particularly domestic agricultural concerns, and may end up discriminating against developing countries. It would be ideal to design the subsidies in ways that do not distort trade or discriminate against developing nation firms.[141] This would be a very difficult, but also very valuable.

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