V. Advanced biofuels and developing countries: intellectual property scenarios and policy implications[58]

Chapter III analysed the commercial viability of second generation biofuels. This chapter focuses on related intellectual property rights (IPRs) aspects. Three hypothetical scenarios in the context of the intellectual property protection of second generation biofuels are developed, with each scenario representing a different level of strictness of protection. Therefore, each scenario translates into a different level of potential access to advanced biofuel technologies by developing countries.

Second generation biofuels can be classified in terms of the process used to convert biomass into fuel: biochemical or thermochemical. Second generation ethanol or butanol would be made via biochemical processing. Second generation thermochemical biofuels may be less familiar to readers, but many represent fuels that are already being made commercially from fossil fuels using processing steps that in some cases are identical to those that would be used for biofuel production. These fuels include methanol, Fischer-Tropsch liquids (FTL) and dimethyl ether (DME) (Larson, 2007).

Second generation biofuels are currently not being produced commercially anywhere. Many efforts are going on worldwide to commercialize second generation biofuels made by both processes. In the case of biochemical fuels, breakthroughs are needed in the research and engineering of micro-organisms designed to process specific feedstocks, followed by demonstrations preceding commercial implementation. It is expected that 10 to 20 years may be needed before commercial production could begin on a substantial basis. In the case of thermochemical fuels, relatively modest additional development and demonstration efforts would enable commercial production, expected to begin in 5 to 10 years (Larson, 2007). Many of the equipment components needed for biofuels production through the thermochemical process are already commercially established for applications in fossil fuel conversion and processing is relatively indifferent to the specific input feedstock.

A possible trajectory that the biofuels industry may follow is that of the agricultural biotechnology industry. Through divestitures, mergers and acquisitions, there has been a process of consolidation in the global agribusiness in recent years. The outcome is a few major integrated companies, each controlling proprietary lines of agricultural chemicals, seeds and biotech traits. Beginning in the late 1990s, intellectual property ownership has increasingly consolidated in this dwindling number of large multinational corporations.

The application of second generation technologies will entail greater systems complexity, integrated engineering design and other technical parameters (especially in the case of biochemical technology) that may limit the diffusion of such technologies to most developing countries, and this for two reasons: advanced technologies will be proprietary and consequently costly to obtain; they may also be too complex for developing countries to easily absorb and adapt to local needs. Therefore – as happened in the agricultural biotechnology sector – the risk

[58] This chapter was prepared by Calestous Juma, Professor of the Practice of International Development and Director of the Science, Technology and Globalization Project at the Harvard Kennedy School of Government, and by Bob Bell, Jr, Ph.D. student in Information Management and Systems at the University of California, Berkeley, United States.

exists that there would be limited technology transfer to developing host countries. In that sense, it remains important for developing countries to invest in their own innovation systems.

In this chapter we argue that a restrictive IPR regime for advanced biofuel technology will likely prevail. The chapter first analyses recent patenting and investment trends in advanced, second generation biofuels. Subsequently, it presents three hypothetical scenarios based on extensive access, restricted access and limited access to proprietary biofuel technologies. Specific mechanisms that developing countries could use to access technology within the framework of each scenario are presented. Finally, the chapter addresses issues related to innovation systems and presents policy options for developing countries to fast-track innovation into their national policies.

It is worth noticing that the analysis here presented is limited both by the lack of empirical literature on the specific topic and by the difficulties inherent in considering a diversity of hypothetical scenarios. In particular, evidence regarding biotechnology-related intellectual property issues in the developing country context is almost entirely lacking, with almost no empirical work on patenting in the industrial biotechnology sector (Herder and Gold, 2007).

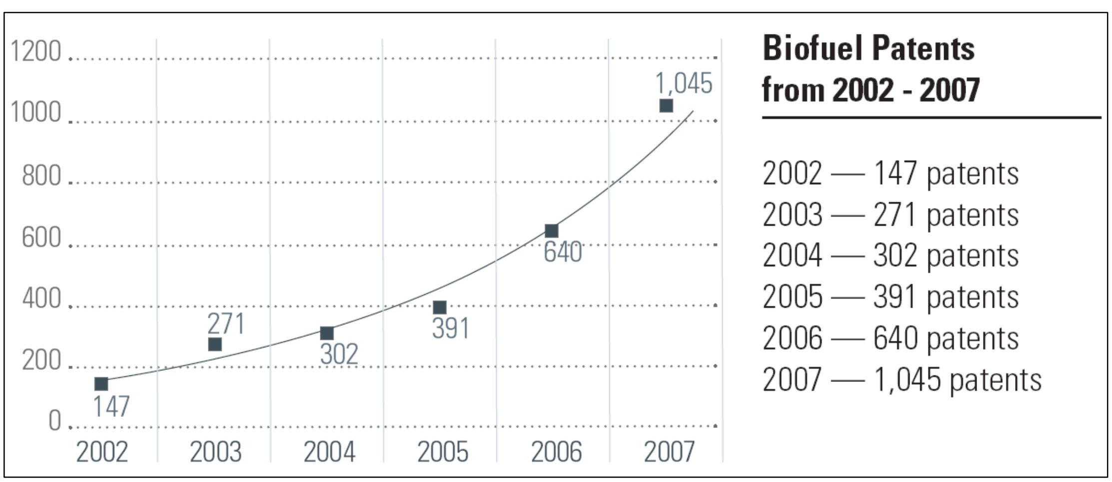
A. Trends in biofuels patenting

Though first generation biofuels are long off-patent, there is increasing patenting activity in second generation technologies (UNCTAD, 2007; Barton, 2007). This section analyses the patenting trends with respect to developing countries' accessibility to advanced biofuel technologies.

1. The United States

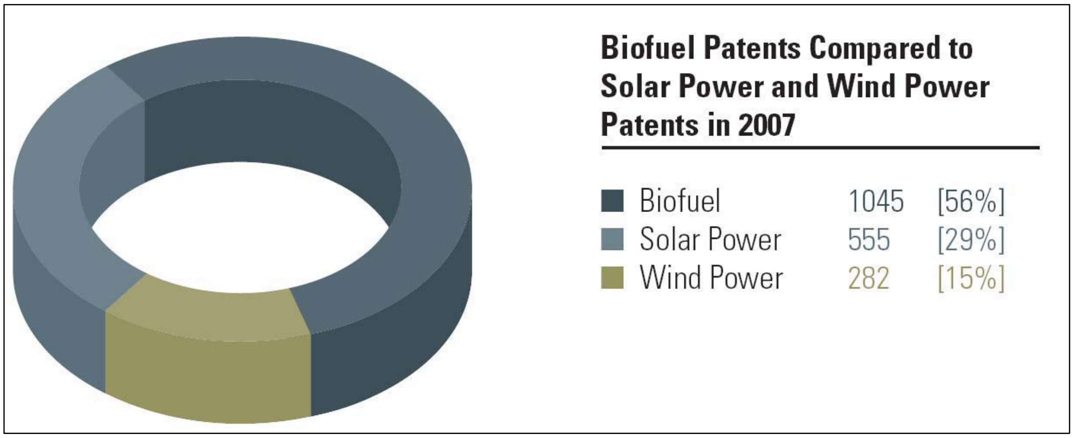
In the United States, biofuel patenting activity is booming. In the 2002–2007 period, 2,796 biofuel-related patents were published, with an increase of 610 per cent from 2002 to 2007 (figure 5.1). In 2007, the number of biofuel patents exceeded the combined total of solar power and wind power patents published (figure 5.2).

Figure 5.1. United States biofuel patents 2002–2007



Source: Kamis and Joshi (2008).

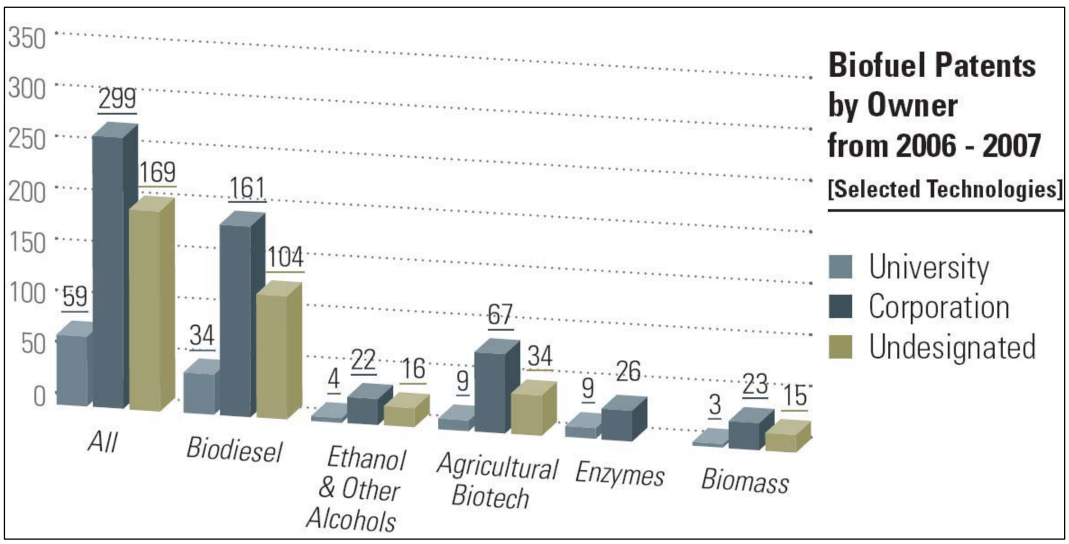
Figure 5.2. United States biofuel patents as compared to other renewable energy patents in 2007



Source: Kamis and Joshi (2008).

Categorized by ownership entity, the patents published in selected technologies in 2006–2007 were 57 per cent owned by corporate entities, 11 per cent owned by universities or other academic institutions and 32 per cent undesignated[59] (figure 5.3) (Kamis and Joshi, 2008). A similar distribution exists for biodiesel or ethanol patents only.

Figure 5.3. United States biofuel patents by ownership categories, 2006–2007



Source: Kamis and Joshi (2008).

Many of the changes in patent policy in the United States during the past two decades have been a result of court decisions, especially those of the Court of Appeals of the Federal Circuit, and to a lesser extent to the Supreme Court (Hall, 2007). *KSR International v. Teleflex Inc*. (No. 04-1350) 119 Fed. Appx 282, on non-obviousness, and *eBay Inc, et al. v. MercExchange, L.L.C.* (No. 05-130) 401 F. 3d 1323, on the four-factor test for injunctions, have raised the bar for obtaining patents on new products that rely on new combinations of existing, publicly known elements (Hall, 2007). In the recent case of *KSR International, Co. v. Teleflex, Inc*., 127 S. Ct. 1727 (2007), the most important patent ruling in years, the Supreme Court of the United States stated:

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[59] A significant number of patents are listed as undesignated because the United States' published patent applications often do not list the patent owner.

> We build and create by bringing to the tangible and palpable reality around us new works based on instinct, simple logic, ordinary inferences, extraordinary ideas, and sometimes even genius. These advances, once part of our shared knowledge, define a new threshold from which innovation starts once more. And as progress beginning from higher levels of achievement is expected in the normal course, the results of ordinary innovation are not the subject of exclusive rights under the patent laws. *(as quoted by Herder and Gold, 2007).*

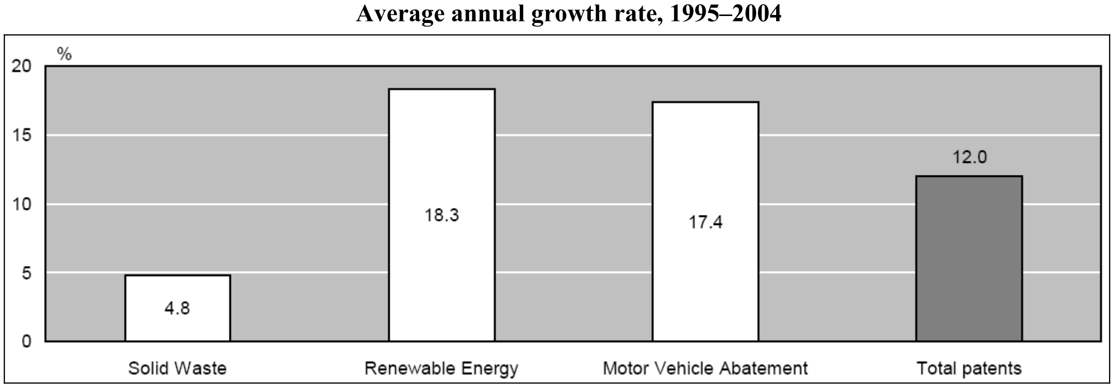
If the combination results from nothing more than "ordinary innovation" and "does no more than yield predictable results", the court reasoned, it is not entitled to the exclusive rights that a patent conveys. "Were it otherwise," Justice Kennedy wrote for the unanimous court, "patents might stifle, rather than promote, the progress of useful arts".

Because most inventions combine previously known elements, the court's more liberal approach to determining "obviousness" will almost certainly make American patents harder to obtain and defend in litigation. "Granting patent protection to advances that would occur in the ordinary course without real innovation retards progress", Kennedy wrote. He added that such patents (based on only incremental improvements) were also undesirable because they might deprive earlier innovations of "their value or utility". It is very possible that the effects of the more stringent patentability standards may be felt and that biofuels patenting could slow down as a result (Raciti et al., 2008). Other senior courts such as the House of Lords have espoused similar reasoning[60] (Herder and Gold, 2007).

2. Europe

In recent years, the growth rate in the area of renewable energy technologies has been higher than the growth rate of total European Patent Office (EPO) applications (Johnstone et al., 2008). The late 1990s saw the emergence of patents related to progress in energy-related technologies. Among environmental technology patents, inventions relating to renewable energy and motor vehicle abatement evolved rapidly since the mid-1990s (around 18 per cent a year on average, as can be seen in figure 5.4) (OECD, 2007).

Figure 5.4. Trends in patents filed in selected environmental technologies[61]
Average annual growth rate, 1995–2004



Source: OECD, Patent database, OECD (2007).

[60] *Synthon BV v. Smithkline Beecham* plc [2005] UKHL 59.
[61] Patent counts are based on the priority date, the inventor's country of residence and fractional counts. Patent applications filed under the Patent Cooperation Treaty (PCT), at the international phase, designating the EPO.

B. Trends in funding of biofuels research and development

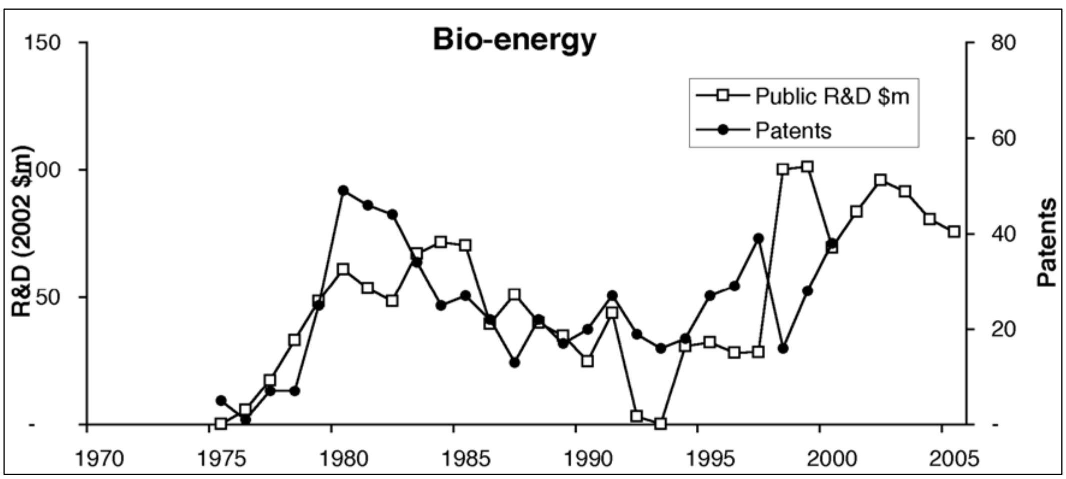
1. United States

Some of the contributing factors to the increasing patenting trends in biofuel technology are United States Government funding of research and development in biofuels and increasing United States venture capital funding in the biofuels sector. In the United States, there is a strong correlation between public research and development spending and patenting across a variety of energy technologies, including bioenergy (figure 5.5) (Nemet, 2007).

Moreover, the United States Federal Government has allocated, for the period 2008–2015, $500 million in grants under the Energy Independence and Security Act of 2007, to promote the development of advanced biofuels. Grant monies have also been appropriated for the research and development of commercial applications of biofuel production technologies, for research and development of cellulosic ethanol and biofuels and for a pilot programme for the establishment of refuelling infrastructure corridors for renewable fuel blends (Hill, 2008; Kamis and Joshi, 2008).

Furthermore, government-funded research results are increasingly transferred to the private sector under exclusive patent rights, made possible by the Bayh-Dole Act of 1980.[62] Because some bioenergy technologies are not yet inexpensive enough to be used for general application and firms are hesitant to invest in substantial research on their own, much of the research in these areas is funded by the United States Government and such subsidized research will almost certainly be transferred to the private sector under exclusive patent rights (Barton, 2007; Maskus and Reichman, 2005).

Figure 5.5. Patenting and federal research and development



Source: Nemet (2007).

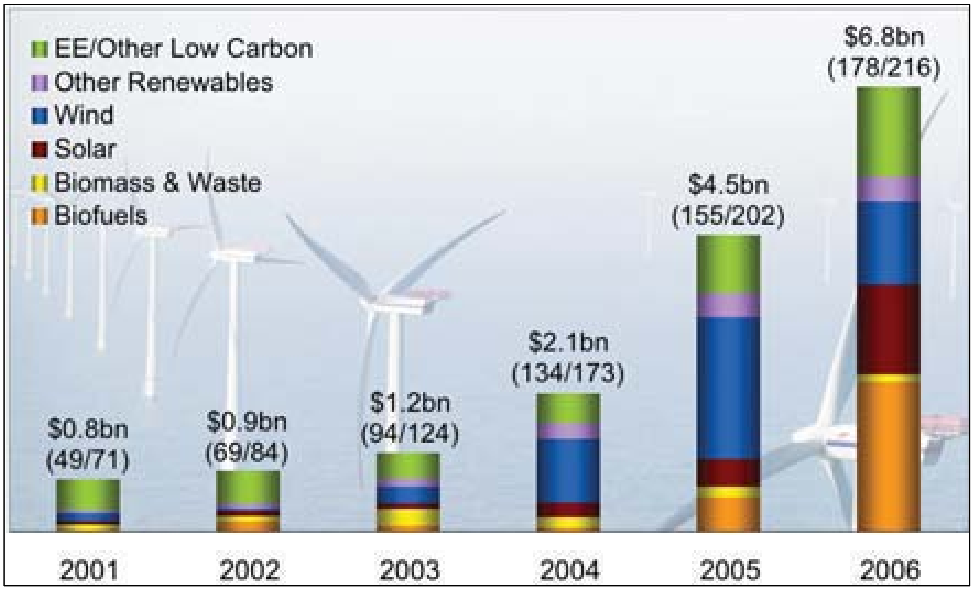
Increased United States venture capital funding in the biofuels sector is also probably influencing patent trends. Based on high energy prices, concerns about global warming and a growth of subsidies in the renewable energy industries, some venture capital-funded firms are entering the industry. The United States leads in venture capital investment, with over 60 per cent of the world's venture capital in clean energy during 2006, including biofuels, much of which was for developing and commercializing technologies for converting cellulose to ethanol (REN21, 2008).

Venture entities invested $2.9 billion in the biofuels industry sector in 2007, with more expected in the coming years (Kamis and Joshi, 2008). Venture capital firms prefer to invest in

[62] It requires that the licensee of technology developed under the grant commit itself that the relevant products "be manufactured substantially" in the United States.

start-ups having a strong proprietary position, with an emphasis on patents developed by the entrepreneurs themselves or technology obtained from a university or the government under license (Barton, 2007). As venture funding and government funding in the United States and outside the United States increase in the coming years, the number of biofuel patents (and specifically agricultural biotechnology biofuel patents) will likely increase as transgenic plant technology is directed to biofuel applications.

Figure 5.6. Venture capital/private equity investment by sector, 2000–2006 (global)



Source: SEFI, New Energy Finance as shown in Greenwood et al. (2007).
Note: Grossed-up values based on disclosed deals. The figures include private equity buyouts, but exclude OTC (over-the-counter) and PIPE (private investments in public equities) deals. Figures in brackets refer to (disclosed deals / total deals).

2. Canada

All across Canada, more and more funds are being established for clean and alternative energy technology companies. Because bioproducts and renewable biomass resources are expected to amount to Can$100 billion (US$95.9 billion) of Canada's GDP by 2020, a commitment to renewable fuels continues to grow among federal and provincial governments (Mergent, 2007).

In March 2007, the Canadian Federal Government announced an additional Can$10 million (US$9.6 million) in funding for the Biofuels Opportunities for Producers Initiative (BOPI), which doubled the total BOPI funding up to Can$20 million (US$19.2 million) over two years.

3. Global

Global venture capital financing for renewable energy boomed during 2006/2007, particularly for solar PV (photovoltaic) and biofuels, exceeding $3 billion worldwide in 2006 (figure 5.6). Individual venture capital sums now exceed the $100 million level, either in single funding rounds or spread over extended technology development periods (REN21, 2008).

C. Biofuels intellectual property scenarios

Policymakers and stakeholders in developing countries frequently raise concerns about potential barriers that increased patenting and intellectual property policies may pose for access to renewable energy technologies and specifically biofuels. The intellectual property system is usually associated with a number of limitations related to the access and dissemination of technologies in certain fields. Examples of those limitations are high transaction costs for obtaining information, negotiating and acquiring protected technologies and a lack of clarity in defining what is (not) protected. Market failures can be exacerbated by these information asymmetries (Barton, 2007). Some groups, such as the Third World Network, are expressing concern that patents on the new technologies may be keeping prices high and restricting access by developing countries (World Intellectual Property Organization (WIPO), 2008).

The application of second generation technologies will entail greater systems complexity, integrated engineering design and other technical parameters that may limit the diffusion of such technologies to most developing countries.

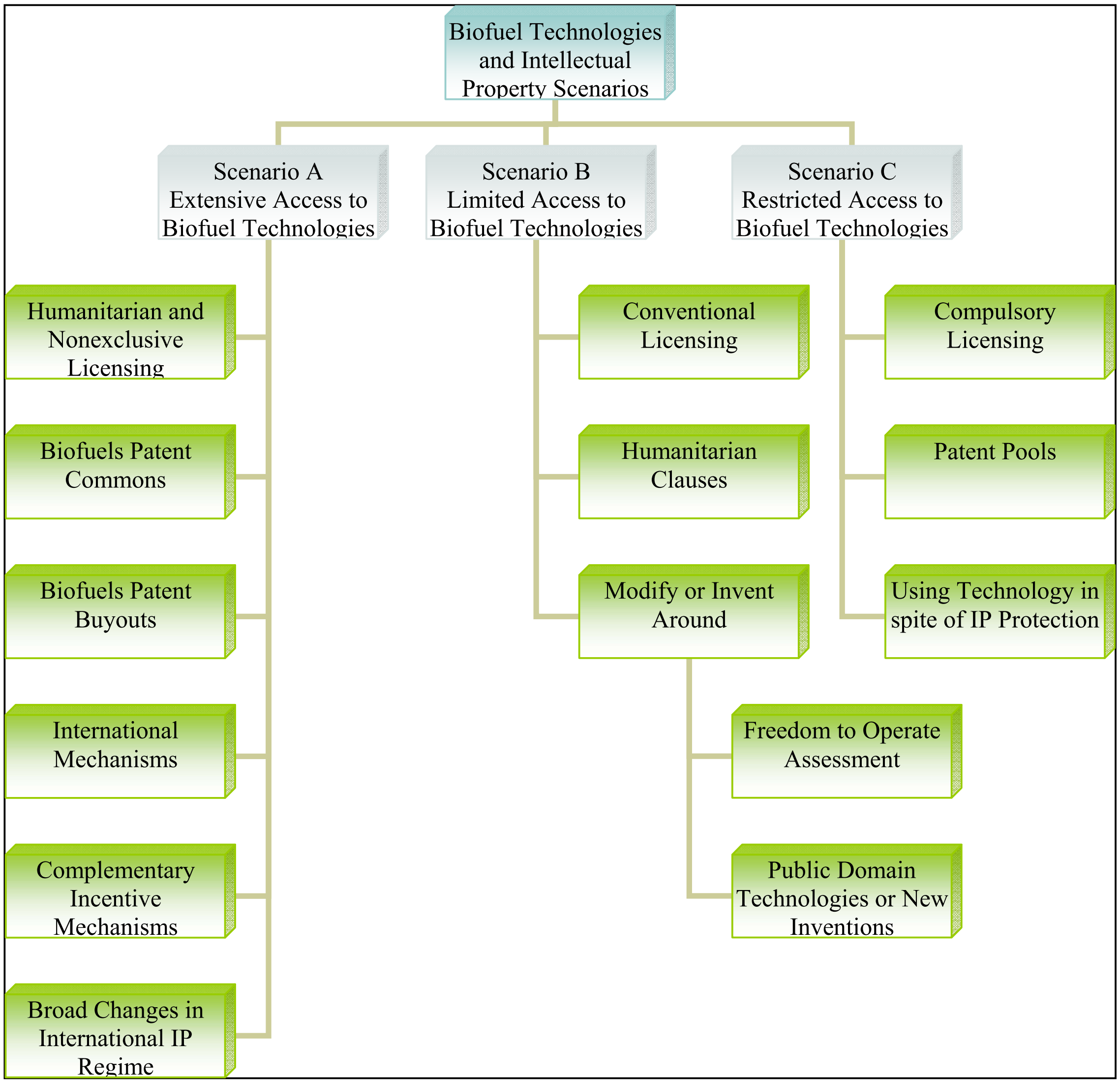
The United States and other developed country governments usually patent subsidized research with a preference for national firms in the licensing process. Indeed, technological developments are supported with the aim of assisting national manufacturers. In the United States, the law imposes favouritism for American manufacturers[63] (Barton, 2007). Some fear that the national preference may hinder developing countries from accessing biofuel technologies developed in the United States and other developed countries.

Others think that intellectual property is rarely an issue in accessing biofuel technology. The most serious patent issues, they say, may likely arise from broad patenting of new technologies, potentially complicating the development of a major category of more efficient and less expensive technologies. From their perspective, trade and tariff barriers and other restrictions associated with international sugar and ethanol markets, not intellectual property, pose the greatest threats to the access of biofuel technologies for developing countries (Barton, 2007).

Because the future of the intellectual property landscape in advanced biofuels is highly uncertain, this chapter maps out three hypothetical scenarios (figure 5.7), including extensive access, restricted access and limited access to biofuel technologies. Each section below lays out the context and likelihood of each scenario, as well as mechanisms that developing countries could use to access technologies within the framework of each scenario.

[63] According to section 204 of the Bayh-Dole Act, the key legislation on intellectual property related to government grants to universities.

Figure 5.7. Scenarios and mechanisms for accessing intellectual property



Source: authors.

Scenario A: extensive access to biofuel technologies

The "extensive access to proprietary biofuel technologies" scenario is a situation in which the developed world freely makes available all or most of its biofuel technologies at little or no cost to the public domain and specifically to the developing world.

Unfortunately, nothing indicates that this is likely to happen. In the context of the United Nations summit on climate change in Bali, Indonesia, in December 2007, a senior representative of the United States, Ambassador C. Boyden Gray, voiced potential disagreement ahead over the intellectual property rules governing the transfer to developing countries of technologies like carbon capture and storage (CCS) and second generation biofuels. He worried that if industries were forced to make these technologies freely available to other countries, it would discourage them from developing such technologies, as they might not be able to recoup their investments (Europolitics, 2007).

Furthermore, some American clean energy companies are reluctant to deploy their most cutting edge technologies in Asia for fear that their know-how will be copied. "It's a concern for anybody trying to export advanced and novel technology to markets where they don't have strong regulatory systems around patent issues", says Benjamin Phillips, president of Emery Energy, the Salt Lake City (United States) start-up that is marketing a proprietary system that can create a biofuel from the organic waste in municipal garbage (Spencer, 2007). Therefore, it seems particularly unrealistic that innovative firms will transfer technology to help a potential licensee become a competitor in the global market (Correa, 2005).

Perhaps a potential slowdown in biofuels patenting due to the stricter patentability requirements could make some biofuels technologies (primarily built upon existing knowledge with modest technological changes) more accessible for developing countries. However, this will not necessarily affect patent filings on brand new, disruptive technology that fundamentally changes the biofuels market. Below, we discuss particular mechanisms that would be reflective of this scenario and facilitate the access to widely available biofuels intellectual property.

1. Humanitarian and nonexclusive licensing of biofuels intellectual property

Universities and research institutes developing biofuel technologies can explicitly reserve rights to support humanitarian applications of such technologies. Though many universities routinely use a reservation of rights to guarantee continued use of licensed technologies within the ongoing research or educational programmes of the university, clauses included in license agreements to reserve rights for humanitarian use of technology are still rare (Bennett, 2007).

In the context of non-exclusive licensing, the licensor retains the freedom to license the technology to other parties in addition to the primary license agreement. Some institutions (e.g., the United States National Institutes of Health) wish to use non-exclusive licensing or to license to multiple companies whenever possible. If an institution can accomplish technology transfer to the private sector through non-exclusive licensing, it has the liberty to subsequently license the technology for humanitarian applications (Brewster et al., 2007).

2. Biofuel patent commons

Developed nations and their respective technology institutions could go even further by devoting a portion of their biofuel technology development to the special needs of the developing nations and to the public domain in general (Barton, 2007; Herder and Gold, 2007). One possible approach is the creation of a Knowledge Fund as the repository of patents dealing with technologies that are critical to the fundamental needs of developing countries, such as environmentally sound technologies or technologies related to food and drugs.

Patent holders would thus be encouraged to deposit patents of interest to developing countries in the Knowledge Fund. Patents could be made available to developing countries by placing patents in the public domain or by granting developing countries automatic and royalty-free licences for the patents listed in the Knowledge Fund. The Knowledge Fund could help ensure that the tacit knowledge required to work these patents locally is also transferred (Mytelka, 2007).

Some of the world's biggest companies have joined together to create a public online database for sharing patents for environmentally responsible products. The new Eco-Patent Commons was created to encourage researchers, entrepreneurs, and companies to develop more ecofriendly practices and incorporate them into their work, according to the World Business Council for Sustainable Development, a coalition of some 200 leading companies, which helped launch the project (Herro, 2008). Massachusetts Institute of Technology (MIT) scientists involved with the Registry of Standard Biological Parts have created the BioBricks Foundation, which might serve to coordinate a synthetic biology "commons".

Placing synthetic biology in the public domain may help developing countries access techniques that could assist in the production of industrial materials, including biofuels such as hydrogen and ethanol (Rai and Boyle, 2007). The limiting factor with respect to the concept of a patent commons is that many leading companies and research and development institutions will probably not be willing to relinquish technologies that are an essential source of competitive advantage in the renewable energy sector. Also, defensive termination provisions may effectively limit third party rights to the technologies provided.[64]

3. Biofuel patent buyouts

Developed countries could purchase patents on key biofuel technologies for free use in developing countries, potentially maintaining the incentive to invest in research and development while lowering the cost of acquisition for poor countries (Hoekman et al., 2004; Herder and Gold, 2007). Some suggest that patent buyouts could be facilitated as part of overseas development assistance (ODA) provided by developed to developing countries. Potential benefits include reduced litigation costs and exoneration from charges of "economic imperialism" (Kingston, 2005). Patent buyouts would not impede innovation because the innovating firm would be well paid for its research. Indeed, the patent buyer could easily increase the incentive to innovate by raising the buyout price.

4. International mechanisms for biofuel technology transfer

At the international level, Noordwijk Medicines Agenda, the World Intellectual Property Organization (WIPO) Development Agenda and recent work by the Intergovernmental Working Group on Public Health, Innovation and Intellectual Property at the World Health Organization (WHO) all point to the need to create and disseminate new models for the licensing and sharing of intellectual property. Though working models have not yet been developed, they would likely include mechanisms for bundling intellectual property (e.g., through pools, clearinghouses and public–private partnerships), willingness not to enforce certain patent rights, developing consortia and other collaborative measures for knowledge and information sharing (Herder and Gold, 2007).

The development of the United Nations Adaptation and Technology Funds may also help countries cope with the consequences of climate change and enable them to cut emissions by harnessing new technologies (Europolitics, 2007).

5. Complementary incentive mechanisms for biofuels intellectual property

Another option to explore could be setting up complementary incentive mechanisms, such as direct government grants to the private sector, "advance market commitments" and "prize funds" in lieu of traditional patenting mechanisms for protecting biofuels intellectual property. With the exception of a few pilot studies currently under way, there is presently no empirical data as to whether these mechanisms provide sufficient or comparable incentives to encourage researchers and firms to engage in research and development projects intended to address the needs of developing countries.

Where such mechanisms do guarantee net profits, they still may not be sufficient to encourage larger Western firms because of the "opportunity costs" of forgoing other areas of

[64] According to Rosen (2006), "Defensive termination is a form of implicit cross licensing of patent or other intellectual property rights. Consider a case where company A licenses patent A to company B. One of the conditions of the license agreement is that if company B should ever sue company A for infringing one of company B's own patents, such as patent B, then company A can terminate the license to patent A. Thus company A would be able to counter sue company B for infringing patent A. This is a strong incentive to prevent company B from suing company A for any future patent it might receive after it has licensed patent A."

research and development with Western markets. Furthermore, there exists less (or virtually no) evidence about the effect of these alternative mechanisms on industrial biotechnology (including biofuels) in developing countries, and there has been minimal effort to adapt these alternative mechanisms to the industrial biotechnology (and biofuels) sector (Herder and Gold, 2007).

6. Broad changes in the international intellectual property regime

Several broad, fundamental changes in the international intellectual property regime could have implications for making second generation biofuels more accessible to developing countries. The first is a global recommendation for governments to forgo favouritism in licensing biofuel patents to national manufacturers, similar to the "humanitarian clauses" being considered in the medical and agricultural areas.

For example, section 204 of the United States Bayh-Dole Act could be waived by the Government of the United States. There is history of such waivers by the United States National Institutes of Health Office of Technology Transfer with respect to licenses of tropical disease technologies to developing nation entities (Barton, 2007). Others suggest that modifying the provision of regulations such as the Bayh-Dole Act that favour local manufacturing may be more practical for countries that lack research-intensive industries or manufacturing capability (Boettiger and Bennett, 2006). Another proposal is to create a formal gatekeeping mechanism to weed out patents on foundational, broadly enabling platform technologies with significant social value (Herder and Gold, 2007).

Scenario B: limited access to biofuel technologies

The "limited access to proprietary biofuel technologies" scenario is a situation requiring some effort on the part of developing countries to gain access to technologies and reasonable substitute technologies. Though intellectual property may be protected by a diversity of firms (both large and small), universities and other research institutes, technology transfer could be facilitated through conventional (and unconventional) licensing mechanisms as well as alternative product development schemes (e.g., inventing around). Below we discuss a few mechanisms for accessing intellectual property in the context of this scenario.

1. Conventional licensing mechanisms

In the context of second generation technologies, methods, enzymes and new micro-organisms for cellulosic breakdown will likely be patented. However, it is also probable that the patent holders will be willing to license their technology for use everywhere because of the costs of biomass transport and the need to decentralize production. In other words, biofuels and feedstock production is expected to take place in many different countries and regions. The licensing fees for these technologies are unlikely to be kept at a high level for very long, due to competition. Intellectual property plays a considerably different role in the renewable energy industries than it does in the pharmaceutical sector where the basic approaches to solving the specific technological problems have long been off-patent and what is usually patented are specific improvements or features.

Thus, there is competition between a number of patented products and also between the sectors and alternative energy sources, ultimately reducing the licensing fees. In other cases where there are patent disputes, cross-licenses among firms may permit each to use some of the technological features developed by others or product modifications can be implemented in a non-monopolistic way. Thus, licensing fees alone are unlikely to be an impediment to developing nations' access to technologies to produce biofuels. Where there are direct private technology transfers from a developed nation firm to a developing country firm, a patent with clearly defined rights can actually help facilitate the negotiation of a license (Barton, 2007).

2. Humanitarian clauses

If a commercial licensee insists upon an exclusive license, the university or research institute licensors can limit the exclusive license to developed country markets and for specific product applications. The opportunity as well as the challenge with developing humanitarian clauses is the issue of market segmentation. With a market segmentation (or dual market) approach, an exclusive license might give a private sector entity the sole right to use a technology in profitable markets, while allowing others to use the technology at no cost or reduced royalties to serve market segments that do not interest the private sector.

The primary challenge is the containment of the intellectual property within the targeted markets. This poses a challenge to many developing countries who are considering developing second generation biofuels not only for their domestic markets but for the emerging global biofuels market. Market segmentation, unfortunately, is most successful where non-commercial markets can be sharply delineated by region, which makes it easier to exclude spillovers to non-targeted markets. Furthermore, market segmentation often requires intense negotiation, the development of trust between partners, and the capacity to enforce agreements (Brewster et al., 2007).

3. Modifying or inventing around patented technologies

An alternative to licensing is to change the product specifications, either by modifying the product with technologies available in the public domain or by inventing around the patented technology with new technologies altogether. These strategies are preceded by a “freedom to operate” assessment, which provides an analysis of the intellectual property opportunities and challenges related to the use of certain technologies. It must be noted that the costs of working around patents may actually limit who is able to participate in the second generation biofuels technologies (Herder and Gold, 2007).

4. Freedom to operate

Freedom to operate (FTO) assessment is a process whereby an institution conducts thorough due diligence to gain a clear picture of the patent rights supporting its technology (Boettiger and Bennett, 2006; Raciti et al., 2008). Due diligence helps mitigate the risks of litigation. If an FTO assessment is conducted later in the commercialization stage, it can create a situation where proprietarily-owned technologies are embedded and re-engineering the innovation to use other technologies may be financially or technically infeasible. Many Western commercial firms evaluate promising research projects early on for intellectual property considerations, providing greater flexibility and allowing FTO information to be accounted for in weighing the costs and benefits of commercialization (Boettiger and Bennett, 2006).

Because many developing countries do not have well-trained intellectual property management staff in the area of agricultural technology, the Public Intellectual Property Resource for Agriculture (PIPRA)[65] serves to address FTO issues, delivering services that individual universities are not designed to provide. One PIPRA programme involves building an intellectual property database. Using the database, patents are searchable with respect to various parameters, including licensing status.

The goal of the database is to inform public sector researchers about their freedom to operate and help them clear all intellectual property barriers to bring a new product to the market. The software also finds ways to invalidate patents and minimize the chances of patent blocking.

[65] PIPRA is a non-profit organization whose aim is to improve technology transfer to developing countries: http://www.pipra.org/en/about.en.html.

The database and PIPRA's analytical services are free for academic research and humanitarian purposes (Eiss et al., 2007). This patent database could perhaps be helpful where new agricultural biotechnological innovations are being developed for feedstocks for second generation biofuels.

5. Identifying alternative public domain technologies

One way to avoid potential intellectual property infringement issues identified in the FTO analysis is to locate alternative technologies in the public domain that would satisfy the technical requirements for the technological process(es) (Krattiger, 2007a). Published scientific literature, trade journals, conference proceedings, abandoned patents, expired patents and public domain technologies (e.g., Biofuels Patent Commons) are all potentially viable sources for finding public domain technologies. With respect to expired and abandoned patents, overlapping claims from other patents may still be active and could affect the freedom to use the technology (Krattiger, 2007b).

6. Inventing around

Another option following the FTO exercise is to "invent around" intellectual property by creating a similar technology that does not infringe on any existing patents (Mahoney and Krattiger, 2007). Choosing the "invent around" option would require a research team to search for alternative ways to develop the product in question. Though this could delay biofuels product development, it could lead to significant benefits in terms of new inventions, new intellectual property for cross-licensing and perhaps even better products. The main challenge is the actual capacity to invent new technological processes and the costs (both in terms of time and money) that may not be feasible for developing country public sector organizations. The costs of licensing versus the costs of inventing a significantly new product should be weighed using a risk/benefit analysis (Krattiger, 2007a).

Scenario C: restricted access to biofuel technologies

The "restricted access to biofuel technologies" scenario is one in which the most significant, foundational technologies to produce second generation biofuels are controlled by a few very large firms that restrict developing countries' access to the new technologies. This could happen if the trajectory of the global biofuels market follows the path of the agricultural biotechnology industry.

Through divestitures, mergers and acquisitions, there has been a process of consolidation in the global agribusiness in recent years. The outcome has been a few major integrated companies, each controlling proprietary lines of agricultural chemicals, seeds and biotech traits. Beginning in the late 1990s, intellectual property ownership has increasingly consolidated in this dwindling number of large multinational corporations.

Though small start-up companies still figure prominently as acquisition targets or as licensors to the large corporations, by 2002 95 per cent of patents originally held by seed or small agrobiotech firms had been acquired by large chemical or multinational corporations. When a few multinational companies are backed by a broad portfolio of patents, including proprietary entitlements on key enabling technologies, it may impede access to technologies if they refuse to license (UNCTAD, 2006).

Currently, second generation biofuels are only in pilot production and there are no clear leaders in this emerging sector where technologies are still being tested for viability and cost-effectiveness. It is too early to predict if the market will mature into a few, large multinational companies with the essential portfolio of technologies to dominate the development of second generation biofuel technologies. However, the patenting trends in the biotechnology and other sectors and the possibility that large oil, gas and chemical companies will license or acquire new biofuel technologies (Raciti et al., 2008) are fanning the fears that access to second generation biofuel technologies may be restricted.

Another hypothetical restricted access scenario could emerge if many different patented technologies (for the agricultural and industrial processes) are required for producing second generation biofuels. Indeed, it would be extremely cost prohibitive to license all the technologies, especially in developing countries. This phenomenon, called the “tragedy of the anticommons”, occurs when multiple owners each have a right to exclude others from a scarce resource and no one has an effective privilege of use (Heller and Eisenberg, 1998).

An anticommons can result, in theory, in any technological field where a proliferation of patent rights has occurred, bringing attention to the patenting trends of biofuels (Herder and Gold, 2007). Despite the large number of patents and the numerous, heterogeneous actors (i.e., large pharmaceutical firms, biotech startups, universities and governments), studies examining the incidence of anticommons problems in academics and industry (including data from Australia, Germany, Japan and the United States) find them relatively rare (Caulfield et al., 2006).

Another aspect of this scenario could be “blocking” or “hold-up”. This is the case where no industrialized patent holders of second generation biofuel technologies are willing to license their technologies to manufacturers in developing countries or engage in alternative intellectual property transfer mechanisms (humanitarian clauses, non-exclusive licensing, etc.) because of exclusive licensing. Some assert that broad patenting and anticompetitive “strategic” use of patents could possibly result in expensive licensing, limited scientific communication for patent licensees and time-consuming measures to avoid patent infringement.

Broad patents may be filed or purchased not for the purposes of product development, but to enable “strategic use” of the patents to prevent competitors from developing products (Suppan, 2007). These fears may also be compounded by the reality that there is no special treatment or flexibility for access to environmentally sound technologies (like there is for health or nutrition) within the World Trade Organization Agreement on Trade-Related Intellectual Property Rights (TRIPS) (Barton, 2007).

Some policy analysts argue that there are not yet cases of “blocking patents” in the industrial biotechnology sector, though this does not mean that this problem does not exist or will not exist in the future. It may merely reflect the fact that, given its sensitivity, health issues are better tracked and analysed than other issues (Herder and Gold, 2007). Others, however, posit that patent lock-up is already happening with, for example, critical enzymes in the biofuels production process (Ortiz et al., 2006). Below we discuss a few mechanisms that could be used by developing countries to access second generation biofuel technologies in the context of this patent lock-up scenario.

1. Compulsory licensing

When there are no close substitutes for a biofuels technological product or process, compulsory licensing may be an option. A compulsory license is an authorization given by a national authority to a natural or legal person for the exploitation of the subject matter protected by a patent; the consent of the patent title holder is not necessary. Compulsory licenses may be required to import or produce a given product or to use a patented technology for research (Correa, 2007). Compulsory licenses are granted in order to attain various public policy objectives, including counteracting anticompetitive business practices.

Less technically endowed firms are unlikely to benefit from a mechanism that does not ensure access to required know-how and technical assistance, which may be essential for the absorption and putting into operation of the relevant technology (Correa, 2005). On the whole, compulsory licensing may be a blunt instrument that is unlikely to promote technological innovation.

2. Patent pools

Another approach is the potential use of patent pools. Some of the benefits of this option include: (a) increased speed and efficiency in obtaining rights to patented technology through one-stop licensing mechanisms; (b) distribution of risks associated with research and development; (c) avoidance of patent litigation through the elimination of blocking patents and stacking licenses; (d) significant decrease in research and administrative costs; and (e) institutionalized exchanges of otherwise proprietary know-how (trade secrets) through cooperative efforts.

Though patent pools have been established in the consumer electronics industry, patent pools in biotechnology have not developed as a response to fragmented patent ownership. In the case of agricultural biotechnology, for example, cross-licensing and mergers and acquisitions have been the common response (Clift, 2007; Krattiger and Kowalski, 2007). In fact, there are no examples of functioning patent pools in the life sciences or biotechnology (Herder and Gold, 2007; Rai and Boyle, 2007).

If patent pools are a possibility in the area of biofuels, they are probably unlikely to change the underlying structural barriers to technology transfer. Patent pools are difficult to establish because of the divergent strategic interests of industry players, and are effective for technology transfer only in partial or modified form (table 5.1). On a practical level, patent pools may assist with the process of licensing intellectual property but not necessarily with the sharing of know-how and trade secrets.

If biofuels represent a potentially profitable energy subsector in the future, it is unlikely that the most innovative technology will be used and traded globally without some legal recourse.

Moreover, depending on how a patent pool is organized and implemented, it either cuts through patent-thicket blockages to facilitate access to critical biofuel technologies or can lead to antitrust issues (e.g., where horizontal competitors abuse the system to form an anticompetitive cartel). Though patent pools can be a useful intellectual property management tactic with positive implications for access to technologies, they may not be the best way to achieve the transfer of technology (Krattiger and Kowalski, 2007). Table 5.1 presents a summary of the pros and cons of patent pools as discussed in Krattiger and Kowalski (2007).

Table 5.1. Pros and cons of patent pools

PROS	***CONS***
Integrates complementary technologies	Difficult to agree on the value of individual patents contributed to a pool
Reduces transaction costs	Complex to set up and avoid antitrust problems (collusion and price fixing)
Clears blocking positions	
Avoids costly infringement litigation	May inflate licensing costs through nonblocking or unnecessary patents
Promotes the dissemination of technology	Complex when many patents are under litigation, as is the case with biotechnology
Levels the playing field	May shield invalid patents and thus prevent much technology from entering the public domain

Source: Krattiger and Kowalski (2007).

3. Using technology irrespective of intellectual property protection

There are other ways that developing countries can address "blocking patents." One strategy is to develop and market the products in countries where patents have not yet been filed. If an expert opinion determines that the blocking patents might not withstand legal challenge, then one could possibly proceed without a license (Mahoney and Krattiger, 2007; Hall, 2007; Caulfield et al., 2006).

Case studies conducted by the Organization for Economic Cooperation and Development (OECD) in the early 1990s observed that even when clean technologies were under patent, these patents were not a major concern either to importers or exporters. In general, exporters were willing to accept the risk of patent infringements, because technological developments were moving so quickly that by the time a competitor could effectively copy a particular process, the technology was likely to have been overtaken by new technologies (Less and McMillan, 2005).

If biofuels represent a potentially profitable energy subsector in the future, it is unlikely that the most innovative technology will be used and traded globally without some legal recourse. Some intellectual property experts contend that the next wave of large patent litigation disputes will arise with respect to methods and processes for converting biomass into biogas, biodiesel and bioethanol and genetically engineered plants grown specifically for the purposes of energy production (Portfolio Media, 2007). Moreover, many poor countries are extremely reluctant to engage in expensive litigation in the case of patent infringement (Love, 2002).

D. Developing countries' capacity to participate in second generation biofuels

What will be the capacity of developing countries to effectively participate in the emerging second generation biofuels sector?

The 2006/2007 period marked the beginnings of commercial investments in advanced second generation biofuels plants in Canada, Germany, Japan, the Netherlands, Sweden and the United States. Much of this investment went beyond pilot-scale plants, with government support tied to private investment as an important factor. Canada created a Can$500 million fund to invest in private companies developing large-scale facilities for producing both ethanol and biodiesel from cellulose.

The United States announced in early 2007 that it would invest up to $390 million in six cellulosic ethanol production plants over the coming four years, with total capacity of 500 million litres (132 million gallons) per year. The world's first commercial wood-to-ethanol plant began operation in Japan in 2007, with a capacity of 1.4 million litres per year (0.37 million gallons). The first wood-to-ethanol plant in the United States was planned to be completed by 2008 with an initial output of 75 million litres (19.8 million gallons) per year. In Europe, a Dutch firm was building a $200 million plant that would produce 200 million litres (52.8 million gallons) per year from wheat chaff and other wastes by late 2008 (REN21, 2008).

However, developing countries are noticeably absent from this picture. The premise of the authors is that second generation biofuels will probably be commercialized in advanced developing countries where there is reasonable infrastructure, existing capacity in biofuels production and an enabling environment for innovation in general and in the biofuels sector in particular.

One way to forecast possible developing country actors in the second generation biofuel sector is to identify those countries that have the current capacity to produce biofuels and possibly become early movers in the emerging technologies. The Ernst and Young Biofuels Country Attractiveness Indices, ranking the attractiveness of global markets for investment in biologically derived renewable fuels, which include both ethanol and biodiesel, are a useful proxy[66] (Ernst & Young, 2008).

As noted in table 5.2, several developing countries rank quite high in the biofuels attractiveness indices. For the purposes of this report, we focus on Brazil, China and India. China held its position as the world's third largest producer of bioethanol in 2007, despite the stagnation of investment in the subsector caused by uncertainty over the political framework. The government has set targets of 2.5 billion litres of capacity by 2010 and 12.7 billion litres by 2020.

Table 5.2. All Biofuels Index at Q4 2007

*Ranking**	*Country*	*All Biofuels*	*Ethanol*	*Biodiesel*	*Infrastructure*
1 (1)	USA	75	80	69	86
2 (2)	Brazil	71	75	67	94
3 (4)	Germany	60	65	60	81
4 (3)	France	59	64	56	67
5 (5)	Spain	57	60	55	60
5 (6)	Canada	57	59	53	72
7 (9)	Thailand	53	56	50	47
7 (11)	China	53	56	50	47
9 (7)	UK	52	55	49	56
10 (8)	Sweden	51	54	48	66
10 (11)	Colombia	51	54	48	50
10 (11)	India	51	53	48	50
13 (14)	The Netherlands	48	50	48	48
13 (9)	Italy	48	49	47	47
13 (-)	Philippines	48	48	47	46

Source: Ernst & Young (2008).
*Ranking in the Q3 2007 All Biofuels Index in brackets.

However, research suggests that ethanol production capacity remained unchanged in 2007, at 1.3 billion litres (0.34 billion gallons) per year. China is now searching for a more manageable way to expand the industry, with its new policy framework giving incentives to new feedstocks and processing technologies. Though China may never be an exporter of bioethanol, it remains aggressive in acquiring foreign technology, particularly for cellulosic ethanol. Chinese biodiesel production is at a very early stage of development in part because biodiesel feedstocks are in short supply. The government has only recently decided to actively support the industry, trialling non-traditional biodiesel crops such as jatropha (jatropha is analysed in detail in chapter VI).

The greatest opportunities in the industry, however, stem from the programme to build coal-to-liquids plants, in which $20–25 billion is being invested. The Fischer-Tropsch process, the dominant technology used in the plants, can also produce synthetic diesel from gasified biomass. It is envisaged that China's biodiesel production will hit 6.5 billion litres (1.7 billion gallons) per year by 2020, of which more than half will be produced through the Fischer-Tropsch process. Because of China's dependence on coal and lack of domestic oil, it seeks to ensure its

[66] The Biofuels Index provides scores out of 100 and is made up of a Biofuels Infrastructure Index (35 per cent) and Fuel-Specific Indices (65 per cent). The Biofuels Infrastructure Index is an assessment by country of the general regulatory infrastructure for biofuels, considering on a weighted basis: market regulatory risk (29 per cent), supporting infrastructure (42 per cent) and access to finance (29 per cent). The Fuel-Specific Indices comprise two indices providing fuel-specific assessments for each country, namely ethanol and biodiesel. Each of the Fuel-Specific Indices consider, on a weighted basis: offtake incentives (25 per cent), tax climate (8 per cent), grants and soft loans (8 per cent), project size (8 per cent), current installed base (11 per cent), domestic market growth potential (15 per cent), export potential (15 per cent) and feedstock (10 per cent).

energy security with renewable energy playing a significant role. China is working to build a local equipment industry, foster the creation of competitive local suppliers and buy the best foreign technologies so that it can become a supplier of low-carbon technologies to the rest of the world (New Energy Finance, 2008; Greenwood et al., 2007).

Though other developing countries are establishing biofuel industries, most of them are not engaged in the development of advanced biofuel technologies. Brazil, home to the world's largest renewable energy market with its long-established bioethanol industry, is primarily engaged in first generation biofuels. The same can be said of India's well-established bioethanol industry and its nascent biodiesel industry (Greenwood et al., 2007). In poorer developing countries, and particularly in sub-Saharan Africa, investment in renewable energy is very low and only for first generation biofuel technologies.

E. Building an innovation system for biofuels

Transferring biofuel technology involves not only access to intellectual property per se but, most importantly, the capacity to understand the tacit knowledge embedded in technology. Without the soft knowledge that accompanies the technological hardware involved in technology transfer, it may not be easy to replicate technological change, including in the biofuels sector (Worldwatch Institute, 2007).

Any biofuels development strategy that focuses only on intellectual property issues is bound to fail and may even be counterproductive. Efforts to promote compulsory licensing, for example, aiming at making biofuel technologies available in developing countries at low prices, must overcome not only intellectual property difficulties but also the obstacles presented by other components of innovation. These include the existence of manufacturing facilities that meet international standards, the availability of funds to procure the products for both domestic and international distribution and the cost of obtaining regulatory approval for products manufactured under compulsory licenses (Mahoney and Krattiger, 2007). While licensing is an important source of technical transformation, successful transfer generally requires the capacity to learn, improve information flows and make adaptive investments (Hoekman et al., 2004).

The licensing of technological products and processes has in some ways become a substitute for learning and innovation. Historically, current "developed" countries complemented the importation of foreign technology with local initiatives to recreate the technology (Bell and Pavitt, 1992). In the chemical and shipbuilding industries, Japan licensed the technology and made substantial investments in developing the capabilities to diffuse, modify and innovate upon the imported technology. Technology transfer in Japan, as well as in other developing countries having similar strategies in place, was viewed in the context of building the capacity to innovate technologically (Mytelka, 2007).

A country's general economic situation, the strength of its educational system as well as its communication infrastructure and quality of government might impact the extent and quality of technology transfer to a far greater extent than the particular level of intellectual property protection under which the transfer of technology takes place. In the case of India, the mathematical, information and language skills of Indian programmers probably have contributed more to its success as an outsourcing country than the intellectual property protection granted under Indian copyright law to computer programmes (Dreier, 2007). Similarly, one of the drivers of Brazil's success in biofuels – through its "Proálcool" programme – was its strong foundation in research, education and training, providing a knowledge platform that was able to develop technology and absorb, adapt and improve upon transferred technologies. Creating the domestic capacity to understand, utilize and replicate existing biofuel technologies requires a broader system of innovation that can facilitate knowledge and technical flows among different stakeholders (Worldwatch Institute, 2007).

1. National system of innovation for transfer of biofuel technology

Governments can reduce the technological "distance" between local and foreign firms by establishing national or regional innovation systems that encourage local research and development and transfer of knowledge from universities and public laboratories to domestic firms (Hoekman et al., 2004). As mentioned above, such an innovation system is one of the key reasons for the success of the Brazilian ethanol programme. Other developing nations who wish to follow the Brazilian example should establish or enhance such a national system (Larson, 2007).

Figure 5.8 illustrates the concept of an innovation system, sketching all the actors and activities in the economy that are necessary for industrial and commercial innovation to take place and to lead to economic development (Arnold and Bell, 2001). In an innovation system, the domestic capacity to engage in innovation depends not only on knowledge-producing institutions (universities and research institutes) or technology centres, but also on other institutional factors such as financial infrastructure, availability of human resources, physical infrastructure, network linkages and synergistic collaboration, innovation support services, and demand and framework conditions (UNCTAD, 2007).

In the sections below, we discuss the role of some of the actors and institutions involved in the process of helping developing countries build innovation systems for biofuels.

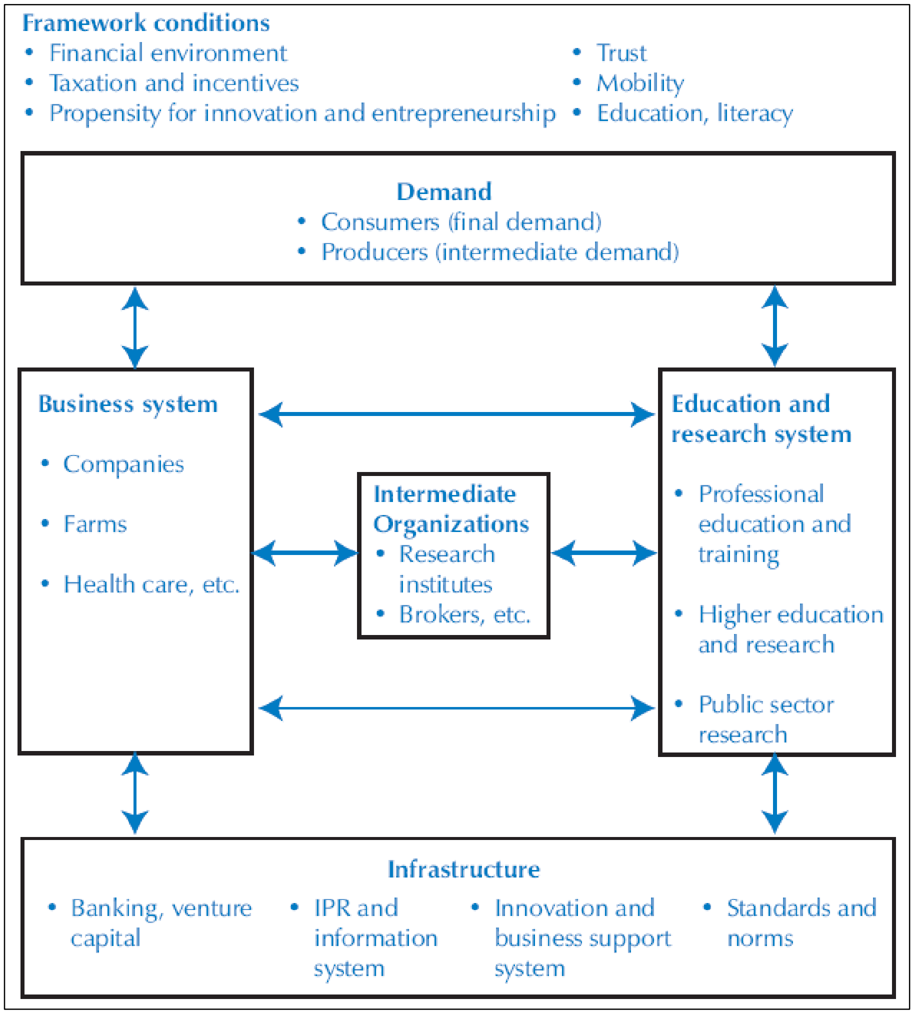
2. National governments

Governments can support the development of a robust biofuels industry through long-term investments in research and development and infrastructure, policies that provide incentives for biofuels production and use (such as the mandatory blends analysed in chapter I) and strategic diplomacy to promote transfer of biofuel technology.

Strategic diplomacy through bilateral and multilateral technological cooperation can also promote the transfer of biofuel technology. For example, Brazil's ethanol technology was developed in the context of collaborative agreements between Brazil and a host of other developing countries (Worldwatch Institute, 2007). Ministries of foreign affairs can promote international technology cooperation and forge strategic alliances with countries holding a leading position in biofuel technology, as well as engage and coordinate transnational diasporic communities in biofuel technology development programmes (Juma and Serageldin, 2008).[67] Bilateral and multilateral information sharing between countries can also play an important role in information dissemination and technical exchange (Worldwatch Institute, 2007; Kartha et al., 2005).

[67] The Indian and Taiwanese diasporic communities in Silicon Valley played a critical role in establishing IT and semiconductor industries in their home countries, respectively (Saxenian, 2006).

Figure 5.8. Elements of a national system of innovation



Source: UNCTAD (2007) and Arnold and Bell (2001).

3. Knowledge institutions

Research is needed specifically to improve feedstock production as well as technologies for harvesting, processing, transporting and storing feedstocks and fuels. Research and development is also required to better understand the potential environmental and societal impacts of biofuels throughout the entire supply chain (table 5.3) (Worldwatch Institute, 2007).

Knowledge institutions can collaborate with international partners for research and development training abroad and/or research cooperation. In the late 1970s, Copersucar (a major cooperative of mills in Brazil) sent a dozen Brazilians to Mauritius for one year to learn sugar and ethanol production. Upon returning, this group became the core of the industrial unit of Copersucar's research centre, Centro de Tecnologia Copersucar (CTC), which focused on sugar cane cultivation in São Paulo (SP varieties). Copersucar also led an international consortium of groups from Australia, South Africa, the United States and other countries. In 2001, these developments led, for the first time in Brazil, to the genetic mapping of the sugar cane plant (Worldwatch Institute, 2007).

Table 5.3. Research and development agenda for biofuels development

Research Area	*Specific Research Initiatives*
Feedstock production	Improve conventional feedstocks Develop next-generation feedstocks Advance alternatives to chemical inputs Assess the risks of genetic modification Supplement environmental life-cycle studies Develop metholodology for measuring life-cycle greenhouse gas (GHG) emissions
Feedstock collection and handling	Improve equipment and harvesting practices Ascertain sustainable residue removal rates Improve waste-handling practices Optimize feedstock storage and transport methods
Processing	Maximize efficiency of input use Advance the biorefinery concept
Fuel distribution and end use	Advance fuel and power train development Optimize vehicles Develop materials Develop fuel additives

Source: Worldwatch Institute (2007).

4. Private sector

Because technology flows are typically driven by the private sector, the business community can play a critical role in diffusing biofuel technologies to developing countries. The Proálcool programme was successful in part due to the Brazilian private sector's willingness to receive and adapt foreign technologies to local conditions (Worldwatch Institute, 2007). The setting up of joint ventures is a way to transfer technology, using foreign private sector actors who have experience, technical expertise and investment capital to contribute to the project.

One example is of a Swedish firm that formed joint ventures with small companies in Estonia, Latvia and Lithuania for manufacturing biomass feedstock. The joint ventures eventually expanded the use of biomass in the heating and agroprocessing sectors, reaching markets that neither the Swedish firm nor the small firms could have reached on their own (Kartha et al., 2005).

Developing countries can use their favourable climates for biomass production as a bargaining tool to engage in international joint ventures, contributing host sites for demonstrations and first commercial plants as well as avenues for entering local biofuels markets (Larson, 2008).

Consulting firms and private laboratories can also facilitate the transfer of biofuel technology through consulting services and analysis, convening training for capacity-building and mobilizing professionals from various sectors for collaboration (Ueki, 2007). Centro de Tecnologia Copersucar's industrial unit transferred foreign technologies, in part, through contracts with foreign and Brazilian companies, consultants, research centres and universities. In the 1970s and 1980s, Australian and South African consultants helped develop the Brazilian roller mill (Worldwatch Institute, 2007).

5. Financial institutions

Government financing of sugar cane and ethanol production in Brazil was critical for the success of the Proálcool programme (Worldwatch Institute, 2007). Various financing initiatives can be pursued to stimulate biofuels production and use, as described in the earlier section on infrastructure. However, governments can also support capacity-building activities within financial institutions to support an emerging biofuels industry, with a focus on: understanding biofuel technologies and their levels of commercial maturity; appreciating the financial benefits of using biomass resources; understanding feedstock procurement risks and mechanisms for risk mitigation; accounting for the effects of supply seasonality on cash flow in negotiating repayment terms; considering similar projects as candidates for bundling into larger loans with lower transaction costs; and understanding policy incentives (e.g., renewable portfolio standards, power purchase agreements and carbon offset arrangements) that contribute to biofuels project viability (Kartha et al., 2005).

6. Intellectual property regime

The actual effect of intellectual property regimes on transfers of environmentally sound technologies is difficult to measure, and there is a lack of empirical data to support literature (Less and McMillan, 2005). Much uncertainty remains regarding the effects of intellectual property on technology transfer to developing countries, with the effects probably depending on the level of development of a receiving country, the specific technological fields involved, the behaviour and absorptive capacity of single local firms and the general macroeconomic environment of the host country (Roffe, 2005).

7. Regional innovation communities

In the case of smaller developing countries with inadequate human, financial and social capital to build national innovation systems for biofuels, regional innovation communities can help overcome “institutional thinness” through regional collaboration. Regional cooperation in science and technology can take various forms, including joint science projects, sharing of information, conferences, building and sharing joint laboratories, setting common standards for research and development, and exchange of expertise.

Some of the potential benefits of regional innovation communities include access to new knowledge; foreign skills and training opportunities that may not be available at the national level; access to large and often expensive research facilities; enrichment of political and social relations between countries; larger groups that are more attractive for major international grants; and building or strengthening domestic research and development institutions (Juma and Serageldin, 2008). A starting point for regional innovation is the development of comprehensive regional biofuels policies, strategies, and research and development agendas (Jumbe and Msiska, 2007).

F. Concluding remarks

The future of biofuels, especially second generation technological systems, will be characterized by technological complexity and integration of a diversity of engineering subsystems. In addition, these technologies are being developed in a period when there is increased interest in strengthening intellectual property protection activities.

These trends may be coupled by business models that follow the approach of the biotechnology industry, therefore allowing limited technological spillovers in countries that provide feedstocks. Given this outlook, this chapter assumes a rather restricted intellectual property regime that will demand greater technological effort by developing countries wishing to enter the second generation biofuels phase.

Because of increased patenting and venture capital investments in the advanced biofuels sector, probably only the most advanced developing countries with existing biofuels capacity and innovative strength will be able to forge ahead into second generation biofuel technologies.

Though a number of mechanisms exist for accessing advanced biofuel technologies irrespective of the future intellectual property landscape, the capacity to innovate will effectively determine the countries that are able to participate in this emerging field. All developing countries, however, can make efforts to strengthen their innovation systems to eventually take advantage of the latest biofuel technologies for domestic use and global trade of renewable energy.

Technological developments also have a role to play in expanding the number of feedstocks available for conversion into biofuels, and increasing their energy yield. The last chapter of this volume analyses a specific feedstock, jatropha.

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