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Intellectual Property and Biofuels: The Energy Crisis, Food Security, and Climate Change

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Abstract

In light of larger public policy debates over intellectual property and climate change, this article considers patent practice, law, and policy in respect of biofuels. This debate has significant implications for public policy discussions in respect of energy independence, food security, and climate change. The first section of the paper provides a network analysis of patents in respect of biofuels across the three generations. It provides empirical research in respect of patent subject matter, ownership, and strategy in respect of biofuels. The second section provides a case study of significant patent litigation over biofuels. There is an examination of the biofuels patent litigation between the Danish company Novozymes, and Danisco and DuPont. The third section examines flexibilities in respect of patent law and clean technologies in the context of the case study of biofuels. In particular, it explores the debate over substantive doctrinal matters in respect of biofuels – such as patentable subject matter, technology transfer, patent pools, compulsory licensing, and disclosure requirements. The conclusion explores the relevance of the debate over patent law and biofuels to the larger public policy discussions over energy independence, food security, and climate change.

Keywords:

Patent Law, Biofuels, Energy, Food Security, Water Security, Biodiversity, Agriculture, Biotechnology, Clean Technologies, Renewable Energy, Climate Change.

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Introduction

Biofuels have a long and rich pre-history. At the World's Fair in 1900, Rudolf Diesel – the inventor and patent holder - and the Otto car company exhibited a diesel engine, which ran on peanut oil (Tomes, Lakshmanan, and Songstad 2011, 5). Recognising the value of food crops for fuel, Diesel observed that "power can... be produced from the heat of the sun, which is always available for agricultural purposes, even when all natural stores of solid and liquid fuels are exhausted" (Goodall 2009, 166). Similarly, the car manufacturer, Henry Ford, observed in 1925: "The fuel of the future is going to come from fruit like that sumach [a type of tree] out by the road, or from apples, weeds, sawdust – almost anything" (Goodall 2009, 166). He rhapsodized: "There is fuel in every bit of vegetable matter that can be fermented." (Goodall 2009, 166).

In his leading work, *Biofuels and the Globalization of Risk*, James Smith provides a definition and classification of modern "biofuels":

> Biofuel refers to energy derived from biomass through processes such as combustion, gasification or fermentation. These processes yield energy in the form of liquid or gas fuels. A range of biological sources can act as feedstock for these processes, including dedicated energy crops (such as grasses and trees), traditional crops (sugar cane and oilseed) as well as crop residues and degradable waste (for example, wheat straw, rice hulls, and organic waste). The resulting fuel can be used in cooking, heating, electricity generation and transport (Smith 2010, 15).

Biofuels are defined in terms of various generations. Smith thus observed that first-generation biofuels "rely on food crops that boast readily accessible sugars, starches and oils as their feedstock" (Smith 2010, 15). He noted: "The most common feedstocks are sugar cane… sugar beet, maize, wheat and other starchy cereals, such as barley, sorghum and rye" (Smith 2010, 19). Smith defined second-generation biofuels as those which "rely on bio-chemical and thermochemical conversion" (Smith 2010, 19). Second-generation biofuels rely on feedstocks – such as "perennial grasses such as switchgrass, trees such as poplar or willow and residues and wastes derived from agricultural production" (Smith 2010, 20). Moreover, Smith noted that "third-generation biofuels focus on improving the feedstock" (Smith 2010, 21). The third generation of biofuels has used algae, microalgae, and seaweed. There has been a discussion of whether there exists a fourth generation of biofuels focused upon biotechnology. James Smith observed: "Even more theoretically, fourth-generation technologies hypothetically offer entirely custom-made feedstocks and microbes to process fuel" (Smith 2010, 21).

There has been much public and private investment in the various generations of biofuels. James Smith observed: "Over the last decade, increasing awareness of the impacts of climate change and dwindling supplies of fossil fuels can be seen to have generated investment in fields such as biofuels, climate-ready crops and storage of agricultural genetic resources". In the United States, President Barack Obama has emphasized that biofuels are part of his energy independence policy: "Biofuels are an important part of reducing America's dependence on foreign oil and creating jobs here at home" (The White House 2011). There has also been much interest in the use of biofuels in Canada (de Beer 2011), and South American countries, such as Brazil (La Rovere, Pereira, and Simões 2011). In the *Garnaut Review 2011,* Ross Garnaut argued that "Australia has an important role to play in research and development on biofuels" (Garnaut 2011, 125). In 2011, the Gillard Government established the $20 million Australian Biofuels Research Institute (Ferguson 2011). The Institute's work is designed to provide "support for the potential of next-generation biofuels to increase Australia's energy security and diversify sources of liquid fuel supply" (Ferguson 2011). In the European Union, the European Commission has established a directive to promote the use of biofuels and other renewable fuels for transportation (European Commission 2013). There has also been interest in biofuels in Africa (Matondi, Havnevik, and Beyene 2011; Juma 2011). The Roundtable on Sustainable Biomaterials has sought to develop a global standard and certification scheme for the sustainable production of biomass and biofuels.

Achim Steiner, Executive Director of the United Nations Environment Programme, observed in 2009: "Biofuels are neither a panacea nor a pariah but like all technologies they represent both opportunities and challenges" (United Nations Environment Programme 2009). The Nuffield Council on Bioethics reflected that biofuels have become part of a larger policy debate over the energy crisis, food security, biodiversity, and climate change. The Council observed that the hope was that biofuels would provide "a new source of income for farmers and revenue from 'clean' technology, as well as renewable – and therefore endless – sources of fuel, leading to far less greenhouse gas (GHG) emissions than fossil fuels" (Nuffield Council on Bioethics 2011, xvii). The Council noted that investment in biofuels had been encouraged by "increasing worries over energy security in the face of growing demand, dwindling supplies of oil, and international conflicts and wars" (Nuffield Council on Bioethics 2011, xvii). Moreover, "the growing awareness of the dangers of global climate change reinforced the challenge to find alternatives to fossil fuels as the dominant form of energy" (Nuffield Council on Bioethics 2011, xvii).

Critics, though, have questioned whether biofuels should be classified as 'renewable energy' or 'sustainable'. Tony Seba (2014) from Stanford University contends that biofuels are obsolete and uncompetitive in comparison to solar energy and wind power. He also argues that biofuels are water intensive and damaging to food security. Seba is also critical of government subsidies of biofuels: “The only thing that’s renewable about the agricultural biofuels industry is the special-interest lobby groups that represents it in places like Washington, Brazilia, and Brussels” (Seba, 2014: 210).

This article considers the various legal and political debates over patent law and biofuels, and the concomitant implications for energy independence, food security, and climate change. Smith has observed that biofuels are the subject of much debate: ‘Biofuels fire the imagination of policy-makers, entrepreneurs, researchers and governments because of the possibility of being all things to all people’ (Smith 2010, 6). He warns that biofuels also risk becoming ‘objects of contestation, or ideas around which ideologies and politics are fought, much as agricultural biotechnologies were before them’ (Smith 2010, 6). The first section provides a network analysis of patents in respect of biofuels across the three generations. In particular, it highlights fundamental subject matter, clusters of biofuels, and influential patents. It also focuses upon the fragmented and diverse ownership in the field of patent law and biofuels. The second section looks at patent litigation over biofuels. As a case study, it considers the ongoing conflict between the Danish company Novozymes, and Danisco and DuPont in respect of biofuel patents. The third section examines patent law, policy, and practice in respect of clean technologies – focusing upon biofuels. In particular, it explores the debate over substantive doctrinal matters in respect of biofuels – such as patentable subject matter, technology transfer, patent pools, compulsory licensing, and disclosure requirements. The conclusion explores the relevance of the debate over intellectual property and biofuels to the larger public policy discussions over energy independence, food security, biodiversity, and climate change.

A Network Analysis of Biofuels

In September 2010, the United Nations Environment Programme, the European Patent Office, and the International Centre for Trade and Sustainable Development published a landmark report on *Patents and Clean Energy* (Karachalios *et al.* 2010). The study emphasized: "Despite the importance attached to the role of intellectual property rights in the transfer of climate change technologies to developing countries, it is only recently that empirical research has begun to appear on the issue" (Karachalios *et al.* 2010, 14). The study stressed that "the absence of an evidence-based approach has fed into the rhetoric and stalemate in the climate change negotiations" (Karachalios *et al.* 2010, 14). The report noted: "In order to move away from the abstract to an evidence-based approach, there is an urgent need for greater empirical analysis" (Karachalios *et al.* 2010, 14). The study concluded: "In terms of building on the empirical data gathered thus far and to move the debate forward, there is a need for additional research" (Karachalios *et al.* 2010, 67). In this context, this chapter seeks to make an original contribution to the literature on patent law and clean technologies by providing a network analysis of biofuel patents – across three generations.

A Literature Review of Patent Landscapes

There have been a number of previous studies – often sector-specific and country-specific – which have sought to provide patent landscapes in respect of clean technologies.

In a sophisticated discussion of methodological strengths and weaknesses, E. Richard Gold and Andrew Baker from McGill University review the use of patent landscaping as a means of understanding and analysing technology development, innovation policy and business strategy (Gold and Baker 2012). The pair commented that "patent landscaping is a method of understanding the interrelationship of data extracted from patent documents across a certain dimension, be that technological, geographical, or company" (Gold and Baker 2012, 77). Gold and Baker observed: "While a potentially powerful tool, patent landscaping has, to date, been conducted largely on an *ad hoc* basis" (Gold and Baker 2012, 77). The Canadian researchers comment that two common problems in patent landscaping are the failure to disclose justifications for methodological choices, and drawing conclusions from analytical methods that do not meet the norms for evidence-based policy making. Gold and Baker comment that "patent landscaping has come of age with the availability of large patent databases and the increasing sophistication of search and analytical tools" (Gold and Baker, 2012, 97). The scholars made a number of suggestions as to how to harmonise and standardise the use of patent landscaping methodologies in the future.

In 2007, Professor John Barton offered an analysis of patent law and biofuel technologies (Barton 2007). He commented: "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" (Barton 2007, 13–14). Barton observed: "There also appears to be a technology race in the use of algae as a source for fuel" (Barton 2007, 13–14). He also commented that "patents are likely to apply to the technologies developed under government support, as will the licensing restrictions associated with US government-sponsored technology" (Barton 2007, 13–14).

John Lazarus, patent expert for Foley Lardner, has conducted annual surveys of patents in respect of clean technologies (Lazarus 2009; Lazarus 2010; Lazarus 2011). One of his sub-categories of clean technologies is for the collective group of biomass, biogas and biofuel. In 2010, John Lazarus observed of biofuels: "The biomass/biogas/biofuel energy field in 2009 accounted for approximately six percent of patents in the cleantech landscape, which is a slight decrease from 2008" (Lazarus 2010). He suggested: "The biomass/biogas/biofuel technology area having the greatest potential white space under this indicator is 'system/process for making a biofuel'" (Lazarus 2010). Lazarus commented: "The biomass/biogas/biofuel technology area for which patent protection was most actively obtained in both 2009 (based upon number of claims granted) is 'ethanol production from biomaterial,' which was closely followed by 'system/process for making a biofuel'" (Lazarus 2010). He observed: "Individual inventors accounted for approximately 25 percent of the biomass/biogas/biofuel patents, indicating a fairly significant scope of new biomass/biogas/biofuel developments that may be available for access by licensing or acquisition" (Lazarus 2010). He also commented: "U.S. entities obtained approximately 77 percent of the biomass/biogas/biofuel patents, with a majority of those patents going to entities in the Midwest" (Lazarus 2010).

Lazarus commented that, given the statistics on examination of biofuel patents, "it may be advantageous to seek accelerated examination of particularly promising new biomass/biogas/biofuel technology developments" (Lazarus 2010). A number of jurisdictions around the world have introduced fast-track mechanisms in respect of the examination of clean technologies. San Diego patent attorney, Eric Lane, has argued that there should be an international system established to facilitate fast-track examination of patent applications for clean technologies (Lane 2012a). He envisages that the establishment of a "Global Green Patent Highway would be a powerful mechanism for fostering green innovation and should be employed as a tool in the battle to combat climate change" (Lane 2012a, 1170).

In 2008, Michael Ward, and Timothy Hall, lawyers at Morrison and Foerster, observed that "the biofuel patent landscape is increasingly crowded and fragmented" (Ward and Hall 2008). The pair noted: "A recent patent study found that there are at least 850 biofuel patents and pending applications in the United States, Europe, and Japan, divided among 285 companies, with only 35 companies owning more than five patents" (Ward and Hall 2008). Ward and Hall concluded that the patent thickets for biofuels raised issues in respect of the freedom to operate: "In such a congested intellectual property environment, freedom-to-operate issues become crucial to any entity in the space" (Ward and Hall 2008).

The trilateral study by the United Nations Environment Programme, the European Patent Office, and the International Centre for Trade and Sustainable Development provides a broad overview of patent law and clean technologies (Karachalios *et al.* 2010). The study provides some useful information about patents in respect of biofuels.

In a summary of its larger study of intellectual property and climate change, the Third World Network charted the patent field in respect of biofuels (Shashikant and Khor 2010, 26):

> Over the last six years, a total of 2,796 biofuel-related patents were published in the US, with the number increasing by over 150% in each of the past two years. Analysis of biofuel-related patents published in 2006 to 2007 revealed the following breakdown of patents: biodiesel (299), agricultural biotechnology (110), ethanol and other alcohols (42), enzymes (35) and biomass (41). Further broken down by ownership entity, the patents published in the selected technologies in 2006 to 2007 were 57% owned by corporate entities, 11% owned by universities or other academic institutions and 32% undesignated (i.e., the patent applications do not list the patent owner). Worldwide, the highest number of biofuel patents in 2006 to 2007 originated from the US (184), Germany (34), Japan (14), Italy (10), and France (10).

The study suggested that "as venture funding and government funding increase, the number of biofuel patents will continue to grow steadily" (Shashikant and Khor 2010, 26). The report maintained: "Future legislation directed towards climate change is also expected to strongly influence biofuel patents" (Shashikant and Khor 2010, 26).

Sandra Thompson has also undertaken a number of patent studies of biofuels for *Industrial Biotechnology* (Thompson 2010a; Thompson 2010b; Thompson 2010c).

Network Patent Analysis

A network patent analysis is a patent analysis process, which uses citation connections between patents to both group and rank patents. A network patent analysis can be deployed to analyse citation connections in order to determine the most important patent groupings and patents. Ambercite and Griffith Hack comment that a "network patent analysis" consists of "a set of analytical and visualisation tools that use citation links to both group patents of similar technologies and rank patents" (Lloyd, Spielthenner, and Mokdsi 2011). They maintain that "[l]arge numbers of patents can be analysed to ensure statistical reliability, with up to 250,000 patents and one million citation linkages being analysed in some studies" (Lloyd, Spielthenner, and Mokdsi 2011).

The technique of network patent analysis has been previously deployed in a number of contexts. The tool has been applied to the contested field of the smartphone patent wars (Lloyd, Spielthenner, and Mokdsi 2011), and has been used in the medical field to provide an overview of the leading patents, research and applicants in respect of patenting trends for the treatment of Alzheimer's disease (Lloyd, Mokdsi, and Spielthenner 2012). In the field of patent law and clean technologies, network patent analysis has been a powerful tool to understand the conflicts over hybrid car technologies (Lloyd and Blows 2009) – in particular, the dispute between Paice and Toyota (Lloyd and Spielthenner 2011).

In this study, the team sought to apply the methodologies and analytical tools of network patent analysis to the topic of biofuels. First, the research team conducted an initial traditional patent search, such as a keyword of International Patent Classification code search. This produced a set of 11,129 starting patents. Second, the research team added to the dataset all patents which were connected by citation to the starting patents, and were not already within the list of starting patents. There were 12,888 additional patents found through this method. This led to a total of 24,017 patents in the combined dataset. Third, the researchers applied Network Patent Analysis to this dataset and obtained 2,457 central highly connected patents. Fourth, the researchers prepared network diagrams based on these central patents. Fifth, the researchers categorised the patent records according to the generation of biofuels using keyword and International Patent Classification criteria.[i] The research team also cleaned up the assignee names using manual and automated techniques.

There are a number of methodological limitations to the patent landscape and the network analysis. First, the search of the collections took place on June 5th, 2012. The results of the search are dependent upon the records available at the time the search was conducted. Second, the applications are generally only published 18 months after they are first filed and it may take some additional time for applications to be reviewed and indexed for availability via the various collections. Third, there may be errors or omissions in the databases which prevent the location of potentially relevant records. Finally, the searches could only identify records indexed to an International Patent Classification mark, or related to other search criteria.

Network Patent Analysis: Generations

There has been much debate about the incidence of patent applications in technological fields. There has been much discussion about the issue of "patent thickets". Carl Shapiro famously described a "patent thicket" as a "dense web of overlapping intellectual property rights that a company must hack its way through in order to commercialise new technology" (Shapiro 2001, 119). Patent offices have been grappling with the phenomenon (European Patent Office 2012). The Nuffield Council on Bioethics commented: "Given the range of technologies likely to be involved in the production of new biofuels, the area seems particularly prone to patent-stacking and patent-thickets" (Nuffield Council on Bioethics 2011, 153). Michael Heller has used the term "the tragedy of the anticommons" to discuss the situation where multiple, overlapping patent rights block access to patented inventions (Heller and Eisenberg 1998; Heller 2008; Heller 2009). David Lametti has questioned whether the language about the "tragedy of the anticommons" is helpful or useful in describing patent landscapes or networks (Lametti 2013). Some commentators have also sought to develop language to describe situations where is an absence of patents. John Lazarus refers to "white spaces" where there are fields of technology with little or no patent applications (Lazarus 2009; Lazarus 2010; Lazarus 2011).

The patent landscape and the network patent analysis conducted in this study highlights that the field of biofuels is crowded with patents. The initial patent landscape review identified 11,129 patents in this area. The majority of the patents were filed after the year 2000, with an acceleration in patent filings after 2005, building up to a peak in 2007. However this growth was not evenly split between the three generations of biofuels. Keywords were used to try to assign the different patents to the three Generations, and this was used to classify almost 8,000 of the 11,129 patents by generation. This can be seen in Table 1.

Table 1 – Outcomes of classification of biofuels into different generations

Row Labels	Count of Patent Number
1st Generation	4,710
2nd Generation	2,907
3rd Generation	350
Other	3,162
Total	11,129

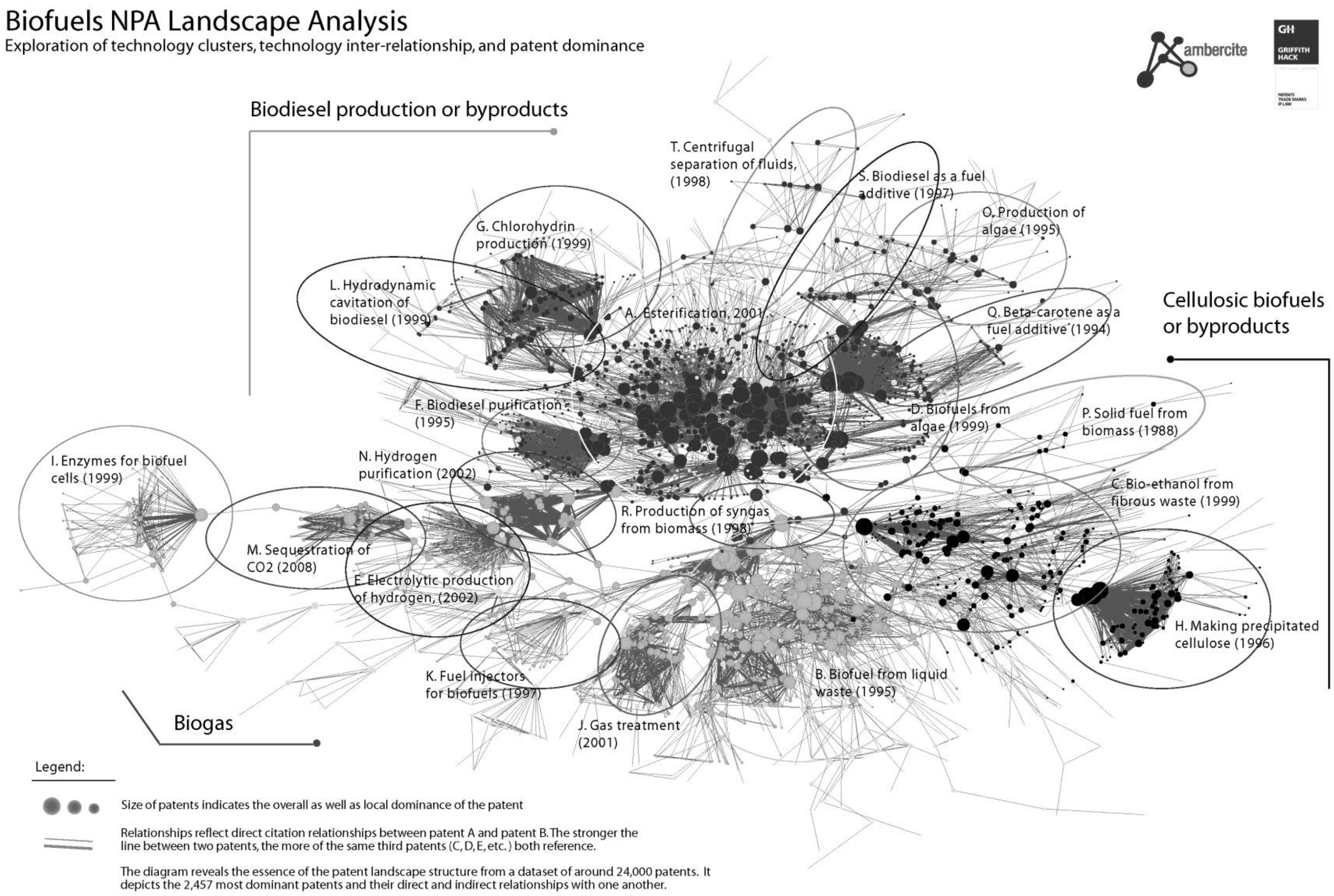
Clearly, when separated into generations, the first generation of biofuels is the most well represented in terms of patent filings. The patent register is crowded and cluttered in this sector. The second generation of biofuels is also represented by a significant number of patent filings. Patent filings relating to the third generation of biofuels are still only lightly represented. It is worth noting that there were a number of biofuels patents (3,162) which did not fit into the generation-based classifications. Biotechnology-based biofuels would also appear to be under-represented thus far in patent filings and could be an area of significant future patenting activity.

In his book, *A Blueprint for a Safer Planet*, Lord Nicholas Stern from the United Kingdom has argued that research and development should be focused upon later generations of biofuels, given the impact of the first-generation of biofuels upon food security and greenhouse emissions (Stern 2009, 166–7). The environmental leader and former United States Vice President, Al Gore, has observed: "The second generation for producing ethanol - when it becomes commercially available - has a significant advantage over the first generation technology: instead of using food crops, it will make liquid fuels from perennial grasses, fast-growing trees, and waste streams with a high cellulose content" (Gore 2009, 123; see also Gore 2013). Moreover, there is a third-generation of biofuels being developed by enterprising biotechnology companies. Gore reflected that "the main focus of the third generation is end products that are superior to ethanol, including new molecules (like biobutanol) that can be mixed directly with gasoline and diesel, eliminating blending problems” as well as “the production of transportation fuel from algae” (Gore 2009, 129).

Network Patent Analysis: Clusters

The patents connected by citation to the original data set, but not in the original data set, led to a total of just over 24,000 patents. The patents were clustered using the Network Patent Analysis process (represented in Figure 1). The Network Patent Analysis identified the most highly connected 2,457 patents, the vast majority which fell into 21 clusters, along with 568 broker patents (where there was no strong allegiance to any of the clusters).

Table/ Figure 1. Biofuels Network Patent Analysis



Biofuels NPA Landscape Analysis
Exploration of technology clusters, technology inter-relationship, and patent dominance
ambercite
GH
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PATENTS TRADE MARKS IP LAW
Biodiesel production or byproducts
T. Centrifugal separation of fluids, (1998)
S. Biodiesel as a fuel additive (1997)
O. Production of algae (1995)
G. Chlorohydrin production (1999)
L. Hydrodynamic cavitation of biodiesel (1999)
A. Esterification, 2001
Q. Beta-carotene as a fuel additive (1994)
Cellulosic biofuels or byproducts
F. Biodiesel purification (1995)
D. Biofuels from algae (1999)
P. Solid fuel from biomass (1988)
I. Enzymes for biofuel cells (1999)
N. Hydrogen purification (2002)
C. Bio-ethanol from fibrous waste (1999)
R. Production of syngas from biomass (1998)
M. Sequestration of CO2 (2008)
E. Electrolytic production of hydrogen, (2002)
H. Making precipitated cellulose (1996)
K. Fuel injectors for biofuels (1997)
B. Biofuel from liquid waste (1995)
Biogas
J. Gas treatment (2001)
Legend:
Size of patents indicates the overall as well as local dominance of the patent
Relationships reflect direct citation relationships between patent A and patent B. The stronger the line between two patents, the more of the same third patents (C, D, E, etc.) both reference.
The diagram reveals the essence of the patent landscape structure from a dataset of around 24,000 patents. It depicts the 2,457 most dominant patents and their direct and indirect relationships with one another.

The biofuels patents can be further broken into sub-categories. As can be seen in Figure 1, the clusters can be grouped into three main areas: biodiesel (Table 2); biogas (Table 3); and cellulosic biofuels and by-products (Table 4).

Table 2 – Clusters found in the Biodiesel Grouping of clusters

Row Labels (number of patents in cluster)	**Cluster name**	**Leading patent**	**Title and owner of leading patent**	**Owner of Strongest patent portfolio within cluster (% of cluster value)**
A (489)	*Esterification* (1999)	US5525126 (1994)	*Process for production of esters for use as a diesel fuel substitute using a non-alkaline catalyst*, Agricultural Utilization Research Institute, US	UOP, owned Honeywell, US, (20%)
D (155)	*Biofuels from Algae* (2004)	US8137555 (2011)	*Methods of and systems for producing biofuels*, Haliae, US	Haliae, US, (31%)
F (89)	*Biodiesel Purification* (1991)	US7998225 (2007)	*Methods of purifying biodiesel fuels*, Scott Powell, US,	Scott Powell, US, (45%)
G (80)	*Chlorohydrin Production* (1994)	US8106246 (2011)	*Process for the manufacture of dichloropropanol by chlorination of glycerol*, Solvay, Belgium	Solvay, Belgium, (62%)
L (45)	*Hydrodynamic cavitation of biodiesel* (1996)	US7754905 (2008)	*Apparatus and method for producing biodiesel from fatty acid feedstock*, Arisdyne Systems Inc, US	Five Star Technologies, US, (29%)
O (31)	*Production of algae* (1993)	US5534417 (1994)	*Microorganism growth apparatus*, University of Ben Gurion, Israel	Algae Systems, US, (18%)
Q (24)	*Beta-carotene as a fuel additive* (1992)	US5160506 (1990)	*Liquid fuel mixture, method for is production, and its use for two stoke engines*, Schure and Werner, Germany	Oryxe Energy International, Inc, US, (52%)
S (18)	*Biodiesel as a fuel additives* (1994)	EP0608149 (1994)	*Fuel additives*, Exxon Mobil, US	Exxon Mobil, US, (26%)
T (17)	*Centrifugal separation of fluids* (1996)	US7775961 (2006)	*Microwave assisted centrifuge and related methods*, Battelle Energy Alliance, US	Battelle Energy Alliance, US, (19%)

Table 3 – Clusters found in the Biogas Grouping of clusters

Row Labels (number of patents in cluster)	Cluster name	Leading patent	Title and owner of leading patent	Owner of Strongest patent portfolio within cluster (% of cluster value)
B (329)	*Bioenergy from liquid waste* (1992)	US8156662 (2009)	*Systems for prevention of HAP emissions and for efficient drying/dehydration processes,* EarthRenew, US	EarthRenew, US, (27%)
E (93)	*Electrolytic treatment of effluent* (2000)	US8075750 (2010)	*Electrolytic cell and method of use thereof,* McAlister Technologies, US	McAlister Technologies, US, (32%)
I (63)	*Enzymes for biofuel cells* (1996)	US7638228 (2003)	*Enzyme immobilization for use in biofuel cells and sensors,* University of St Louis, US	University of St Louis, US, (24%)
J (53)	*Gas treatment* (1999)	US5321946 (1992)	*Method and system for a condensing boiler and flue gas cleaning by cooling and liquefaction*, Fawzy Abdelmalek, US	SustainC, US, (39%)
K (47)	*Fuel injectors for biofuels* (1995)	US8074625 (2010)	*Fuel injector actuator assemblies and associated methods of use and manufacture*, McAlister Technologies, US	McAlister Technologies, US, (73%)
M (36)	*Sequestration of CO2* (2006)	US8006446 (2010)	*CO2-sequestering formed building materials,* Calera Corp, US	Calera Corp, US, (55%)
N (34)	*Hydrogen purification* (2001)	US6221117 (1999)	*Hydrogen producing fuel processing system*, IdaTech LLC, US	IdaTech LLC, US, (73%)
R (21)	*Production of syngas from biomass* (1996)	US4822935 (1987)	*Hydrogasification of biomass to produce high yields of methane,* Donald Scott, Canada	University of California, US, (56%)

Table 4 – Clusters found in the Biogas Grouping of clusters

Row Labels (number of patents in cluster)	Cluster name	Leading patent	Title and owner of leading patent	Owner of Strongest patent portfolio within cluster (% of cluster value)
C (161)	*Bio-ethanol from fibrous waste* (1997)	US7708214 (2006)	*Fibrous materials and composites,* Xyleco, US	Xyleco, US, (58%)
H (77)	*Making precipitated cellulose* (1994)	US4145532 (1997)	*Process for making precipitated cellulose,* Akzona, US	Weyerhaeuser, US, (41%)
P (27)	*Solid fuel from biomass* (1986)	US4532873 (1984)	*Suspension firing of hog fuel, other biomass or peat,* Weyerhaeuser, US	Weyerhaeuser, US, (27%)

There were also 568 broker patents, which are patents not exclusively associated with any single cluster (see Table 5).

Table 5 – Broker Patents

Z (568)	*Broker patents* (1997)	US8022257 (2009)	*Methods for producing polyols using crude glycerin*, University of Ohio, US	ConcocoPhillips, US (18%)

Network Patent Analysis: Ownership

The patent landscape and network patent analysis highlights a diversity of ownership in respect of patents and biofuels (Table 6). There is no single dominant company, or even leading group of companies. The leading owner, Roy McAlister and McAlister Technologies of the United States, held 119 patents. The Belgian company Solvay held 70 patents, and the University of California held 64 patents.

Table 6 – Leading owners of biofuels

Owner	**Number of patents in 11,129 biofuel patent search**
McAlister Technologies/Roy McAlister (US)	119
Solvay (Belgium)	70
University of California (US)	64
University of Tsinghua (China)	58
Bekon Energy Technologies (Germany)	57
Sunho Biodiesel (Taiwan)	55
UTS Umwelt (Germany)	55
Chevron (US)	44
UBE Industries (Japan)	42
UPM Kymmene (Finland)	42

There is a mixture of private and public ownership. In terms of private companies, there is a mixture of energy companies, agricultural companies and biotechnology companies making filings in respect of biofuels patents. There is also evidence that fossil fuel companies such as Chevron have been moving into the field of alternative fuels, such as biofuels. The United States Government and United States universities are well-represented in the patent filings. This is to be expected given the investment by United States governments in respect of biofuels.

Network Patent Analysis: Priority Countries and Filing Countries

In terms of the patent landscape, the national affiliations of the patent applications are striking. There is still a great diversity in terms of priority countries and filing countries for biofuels patents (see Tables 7 and 8). The United States, China, members of the European Union, Japan and South Korea figure prominently in the statistics.

Table 7. Biofuel Patents: Priority Country

Age band	**2003-2012**	
Row Labels	**Count**	**Position**
United States	4179	1
China	2209	2
Germany	1693	3
Japan	1021	4
World Intellectual Property Office	828	5
Korea (South)	523	6
European Patent Office	476	7
France	398	8
Great Britain	254	9

Brazil	218	10

Table 8. Biofuel Patents: Filing country

Age band	**2003-2012**	
Row Labels	Count	Position
United States	3038	1
China	2337	2
World Intellectual Property Office	2191	3
Germany	966	4
European Patent Office	927	5
Japan	878	6
Korea	528	7
Canada	283	8
India	244	9
Brazil	225	10

There has been much competition and rivalry between the United States and China in respect of clean technologies. In his State of the Union address in 2013, President Barack Obama commented: "As long as countries like China keep going all in on clean energy, so must we" (Obama 2013b). The field of biofuels is worth considering in this respect. The study undertaken identifies the leading priority countries for identified biofuel patents from 2003 to 2011. The United States leads until 2009 – when it is overtaken by China, and relegated to second position. China has consistently risen in terms of its patent filings – from third in 2006 to second in 2007 and first in 2009. Germany slips in its position from second in 2006 to third place for the following years.

This trend is perhaps reflective of larger developments in respect of patent filings. In 2012, the World Intellectual Property Organization reported that China led the way generally in patent applications in 2011 (World Intellectual Property Organization 2012; Saez 2012). The World Intellectual Property Organization found that China had 526,412 patent applications, followed by the United States with 503,582 applications, and 342,610 for Japan.

Litigation Over Patent Law and Biofuels

While there may be a diversity of patent ownership in respect of biofuels, the field has not necessarily been a harmonious and peaceful area. There has been significant patent litigation in respect of biofuels, despite some predictions to the contrary by commentators such as John Barton (Barton 2007). Eric Lane has commented: "Though we are seeing new innovations nearly every day in second-and third-generation biofuels such as cellulosic ethanol and algae-based biodiesel, it is the first-generation biofuel technology that is scalable and widely commercialized" (Lane 2011, 112). He commented: "Accordingly, companies that have developed and implemented technology for processing first-generation biofuels are starting to enforce their patents" (Lane 2011, 112). There have been a number of prominent disputes in respect of patent law and biofuels. Such disputes have raised questions of validity, patent infringement and patent remedies.

Litigation Between Novozymes and Danisco

The Danish company, Novozymes, is the holder of a large patent portfolio – including in the area of biofuels: "Biofuels are currently the only realistic option proven to successfully accomplish large-scale CO^2 emission reductions while creating jobs, boosting economic growth, and improving energy security" (Novozymes 2013). Novozymes is the patent holder of United States Patent No. 7,713,723**,** which is entitled *Alpha amylase mutants with altered properties* (Thisted *et al.* 2009). The patent application reads: "The variants of the invention are suitable for starch conversion, ethanol production, laundry wash, dish wash, hard surface cleaning, textile desizing, and/or sweetener production."

In 2010, the company sued Danisco**,** along with Genencor International Wisconsin, for patent infringement of United States Patent No. 7,713,723 (*Novozymes A/S v Danisco A/S* 2010a). Formed in 1989 from an industrial merger, Danisco is a Danish company which focuses upon food production, industrial enzymes, and other bioproducts. Danisco was acquired by E.I. DuPont de Nemours & Co ("Danisco") in 2011. In response to Novozymes' infringement complaint, Danisco questioned the validity of the patent – particularly in terms of whether it provided sufficient written description of the claims (*Novozymes A/S v Danisco A/S* 2010b). Danisco also denied that there had been any patent infringement. The company also raised equitable defences under the doctrines of prosecution laches and prosecution history estoppel.

Novozymes v Danisco: The 2011 Ruling on Patent Infringement

In 2011, District court judge Barbara Crabb noted that the parties were competitors in the production and sale of enzymes called alpha-amylases used in making ethanol and other products (*Novozymes A/S v Danisco A/S* 2011a). Focusing upon the question of written description, Crabb J. was unconvinced by Danisco's attack on the validity of the patent: "Although I still have doubts that the specification in the '723 patent provides an adequate written description for the claims, I conclude that defendants have not met their burden to prove by clear and convincing evidence that the '723 patent is invalid as a matter of law" (*Id.* at p. 2).

The judge came to the reluctant conclusion: “It is not without hesitation that I am denying defendants' motion” (*Id.* at p. 11). She worried: “Plaintiffs do not contradict defendants' observation that, if plaintiffs' position is accepted, it means that plaintiffs disclosed 8.589 x 10^{42} possible inventions in their specifications” (*Id.*). She concluded nonetheless that “a reasonable jury could conclude that the written description is adequate under facts in similar cases” (*Id.* at p. 13). The judge wondered whether the problem was really a question of enablement, rather than one of written description.

At the next stage of the proceedings, the judge considered questions of patent infringement, and allegations of inequitable conduct relating to inventorship and prosecution laches. The judge held that “[t]here is no dispute that the accused products meet the remaining limitations of the asserted claims” (*Novozymes A/S v Danisco A/S* 2011b at p. 30). The judge ruled: “Accordingly, I conclude that plaintiffs are entitled to summary judgment on the issue of infringement with respect to all of the accused products with the exception of the "whole broth" products, which do not meet the ‘isolated variant’ limitation” (*Id.*).

Novozymes v Danisco: Patent Remedies

On 26 October 2011, the jury in the United States District Court for the Western District of Wisconsin awarded damages to Novozymes for patent infringement (*Novozymes A/S v Danisco A/S* 2011c). The jury held that Novozymes had lost $8,151,000 USD on its sales of Liquozyme products as a result of Danisco’s infringement of the patent. Furthermore, the jury ruled that Novozymes lost $8,508,500 USD on its sales of glucoamylase as a result of Danisco’s infringement of the patent. Moreover, the jury held that $1,560,000 USD would constitute a reasonable royalty to Novozymes for other lost sales resulting from Danisco’s infringement of

United States Patent No. 7,713,723. The jury also found that Novozymes had proven by clear and convincing evidence that Danisco's infringement of the patent was willful. However, the jury did not find that Novozymes had proven infringement of Danisco's whole broth products. So, in total, the jury awarded Novozymes $18.3 million USD in the Danisco trial over enzymes (Chopping, 2011; and Decker and Sulugiuc, 2011). The decision highlighted a longstanding debate of whether it is appropriate for juries to play such a significant role in patent disputes in the United States (Rimmer 2002; Miller 2004; Duffy and Lemley 2012) and raised questions about the appropriateness and proportionality of remedies in patent matters.

Novozymes v Danisco: 2012 Ruling on Patent Validity

On 4 May 2012, Barbara Crabb of the United States District Court for the Western District of Wisconsin ruled against Novozymes in respect of the validity of the patent (*Novozymes A/S v Danisco A/S* 2012). She commented that "the parties in this case have debated tenaciously many issues of infringement, invalidity and damages, but the focal point has always been the adequacy of the written description for the '723 patent" (*Id.* at p. 2). Crabb J. reflected: "Since the beginning of the case, I have questioned the validity of the patent in this respect . . . Having reviewed the evidence at trial, the developing case law on this issue and the parties' arguments in their post-verdict motions, I am persuaded that defendants have proven by clear and convincing evidence that the claims of the '723 patent are invalid as a matter of law" (*Id.* at pp. 2–3). Accordingly, Crabb J. vacated the judgment and instructed the clerk of court to enter judgment in the favour of the defendants, Danisco.

Novozymes v Danisco: United States Court of Appeals for the Federal Circuit

Novozymes appealed against the decision to the United States Court of Appeals for the Federal Circuit (Novozymes 2012). Novozymes' general counsel Mikkel Viltoft observed: "We disagree with the decision and will file an appeal to the United States Court of Appeals for the Federal Circuit . . . Novozymes will continue to protect and defend its intellectual property rights" (*Id.*). Oral argument was heard in the dispute in *Novozymes A/S. v DuPont Nutrition Biosciences* on 5 February 2013 (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013). The judges were the experienced combination of Rader CJ, Schall and Bryson JJ.

For the majority, Schall J held that the patent claims were invalid because of the failure to meet the written description requirement. In its analysis, the judge held "that no reasonable jury could find that the claims of the '23 patent meet the written description requirement of § 112, ¶ 1, and that the district court therefore correctly entered judgment as a matter of law invalidating those claims (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013: 1346)." The judge held: "In our view, this case is very analogous to *University of Rochester,* where the patent specification failed to disclose any compounds that could be used in the claimed methods, which required administering a drug having a certain selective activity (inhibiting PGHS–2 activity in a human host)." (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013: 1350). The judge concluded: "In sum, we agree with the district court that no reasonable jury could conclude that the 2000 application provides adequate written description to support the later-filed claims of the '23 patent" (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013: 1351).

Rader CJ dissented: 'In conclusion, the jury received expert testimony, heard from skilled protein engineers, reviewed visual aids and publication excerpts, and examined the patent document as guided by those skilled in the art, over an eight day trial' (*Novozymes A/S. v*

DuPont Nutrition Biosciences 2013: 1352). The judge argued: ‘The jury was given a special verdict form asking whether DuPont had proven by clear and convincing evidence that the claims at issue were invalid for lack of written description’ (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013: 1352). His Honour maintained ‘The jury answered in favor of Novozymes, and substantial evidence supports this determination’. Rader CJ concluded: ‘Therefore, I would reverse the grant of judgment as a matter of law and reinstate the jury's verdict’ (*Novozymes A/S. v DuPont Nutrition Biosciences* 2013: 1352).

DuPont Biofuel Solutions (2013) was delighted by the victory over Novozymes. Soonhee Jang, vice president, IP Strategy and Chief IP Counsel, DuPont Industrial Biosciences, said that “the Court of Appeals recognized our rights in the marketplace as a true innovator providing customers with choices.”

A rehearing en banc by the United States Court of Appeals for the Federal Circuit was denied in October 2013.

Other Litigation

There is other biofuels-related patent litigation involving Danisco and Novozymes across a number of jurisdictions.

There have been other actions on foot in the United States. In August 2012, Danisco sought a declaration in the Northern District of Iowa and the Northern District of California that the company’s Rapid-Starch alpha-amalyse products did not infringe a Novozyme patent, and that the patent is invalid, in any case (*Danisco US Inc.* v *Novozymes A/S*). The court dismissed the case in 2013, holding that there was no justiciable controversy between the parties because Novozymes had not engaged in any affirmative acts to enforce its patent rights against Danisco (Lane 2013).

In the United States, Novozymes also sued Illinois enzyme distributor, CTE Global, for patent infringement. The parties settled the lawsuit in 2012, and the court entered a consent judgment and a permanent injunction ending the lawsuit (Lane 2012b).

Such infringement proceedings are not limited to the United States. In the European Union, there has been complex patent litigation between Novozymes and Danisco in relation to patents on animal feed (Bausch and Eitle 2012). There has also been significant patent litigation between Novozymes A/S and Danisco A/S over inventions relating to foodstuffs in the Full Court of the Federal Court of Australia in 2013 (*Novozymes A/S. v Danisco A/S*. 2013). There has been conflict in the Australian Patent Office in 2013 between Novozymes A/S and Genencor (*Novozymes A/S* v *Genencor International, Inc.*). Novozymes A/S has also opposed patent applications by North Carolina State University and Bioresource International in the Australian Patent Office (*Novozymes A/S* v *North Carolina State University and Bioresource International, Inc.*).

There have been other significant skirmishes in respect of patent law and biofuels. There has been a significant patent war between the advanced biofuels company Gevo and the BP-DuPoint joint venture, Butamax Advanced Biofuels (*Butamax Advanced Biofuels LLC* and *E.I. Dupont de Nemours and Co. v Gevo Inc.* 2012; see also Lane 2012b). There have been at least 17 patents at issue in this conflict. The biofuels patent war continued in 2013 (Lane, 2014).

In the 2012 case of *Neste Oil, OYJ v Dynamic Fuel LLC*., Neste Oil has complained in the United States District Court for the District of Delaware of direct and induced patent infringement of a United States patent relating to a "process for the manufacture of diesel range hydrocarbons" (*Neste Oil, OYJ v Dynamic Fuel, LLC*). In 2013, the court stayed the biodiesel lawsuits, pending the re-examination of the asserted patents (Lane, 2014). There have also been a number of disputes in respect of trade secrets.[ii]

In 2013, Novozymes filed a lawsuit in the United States District Court for the Eastern District of Missouri, accusing Boli Bioproducts, a Missouri company, of infringing U.S. Patent No. 6,255,084 (*Novozymes A/S v Boli Bioproducts USA LLC*; Lane, 2014).

In the future, there may well be further conflict over patents in respect of first generation biofuels. Such litigation may lead to consolidation of market ownership and dominance in respect of biofuels. It can be anticipated that there will be litigation in respect of the second and third generations of biofuels, as technologies in those sectors mature and grow in influence.

In addition to patent law, a number of other species of intellectual property can be deployed to address biofuels. Trade secrets, plant breeders' rights (Rimmer 2012a), and trade-marks can also be invoked to provide intellectual property protection in relation to biofuels. The question of eco-labelling deserves further consideration. The Roundtable on Sustainable Biomaterials has been focused on the use of trade marks to certify the environmental impact of biofuels. Such labelling could help differentiate between sustainable biofuels, and those which have an adverse impact upon land and water, food security, biodiversity, or climate change.

The Policy Debate Over Intellectual Property and Biofuels

In his book, *A Practical Guide to Working with TRIPS*, Antony Taubman identifies a number of positions to patent law reform in the field of clean technologies and climate change (Taubman 2011).

Taubman observed that "amidst a dynamic debate over TRIPS and climate change, three general sets of proposals can be identified" (Taubman 2011, 191). One position is to "keep the status quo, but implement it more effectively, such as through improved flow of information about patented technologies and licensing opportunities" (Taubman 2011, 191). A second position is to "adopt initiatives akin to the access to medicines process, establish specific measures to remove barriers to using TRIPS flexibilities, on the model of TRIPS 31bis" (Taubman 2011, 191). A third position is to "implement more fundamental changes to rules on patents, such as revocation or refusal of patents on technologies needed for climate change adaptation or mitigation, and specific carve-outs for least developed countries and other countries vulnerable to climate change impacts" (Taubman 2011, 191).

Taubman comments that "these proposals reflect divergent philosophies and working assumptions about the interplay between the IP system and efforts to promote innovation and diffusion of green technology that have emerged in contemporary debate and international negotiations" (Taubman 2011, 192).

There has been much debate about policy settings in respect of intellectual property and clean technologies at the climate change summits — such as the *Copenhagen Accord* 2009, the *Cancun Agreements* 2010, the *Durban Decisions* 2011, the *Doha Climate Gateway* 2012, the *Warsaw Climate Change Conference* 2013 and the *Lima Call for Climate Action* 2014 — as well as in international institutions, such as the World Intellectual Property Organization and the World Trade Organization (Rimmer 2011a; Rimmer 2011b; Rimmer 2012b). There has been prolonged discussion about what flexibilities are available under patent law to provide access to clean technologies. In particular, there has been a focus upon doctrinal options — such as patentable subject matter; patent criteria; technology transfer; patent pools; compulsory licensing; and requirements for disclosure, informed consent, and benefit-sharing. The issue has prominent in the lead-up to the Paris Climate Talks in 2015. Ahmed Abdul Latif (2015), Carlos Correa (2015) and Frederick Abbott (2015) have debated the possible law reform options in respect of intellectual property and clean technologies. In the context of the field of biofuels, there has been much policy debate about the appropriate settings for rights and exceptions in patent law, policy, and practice for clean technologies.

Patentable Subject Matter

It has been long established that micro-organisms (*Diamond v Chakrabarty*), plants (*J.E.M. Ag Supply v Pioneer Hi Bred International*), and even animals (*Ex parte Allen*) are patentable subject matter under United States patent law, and in many other jurisdictions. Nonetheless, there has been much uncertainty about the boundaries and the limits of patentable subject matter particularly when grappling with emerging technologies — especially in light of the litigation in the Supreme Court of the United States in *Bilski v Kappos, Mayo Collaborative Services v Prometheus Laboratories, Association for Molecular Pathology v Myriad Genetics*, and *Alice Corp. v CLS Bank International*. In his study of synthetic biology, Graham Dutfield observed that analogies are often drawn with existing technologies — such as mechanical inventions — when assessing the patentability of emerging technologies (Dutfield 2012).

A number of technology developers and national governments have promoted biofuels, arguing that they will be a boon to economic development, energy, the environment, and climate change. Some commentators have been enthusiastic about the use of patents in respect of biofuels. Adam Wolek, an intellectual property attorney, argues that patents can help address concerns about the market for biofuels: "Patents are particularly crucial for the biofuels industry because large-scale production facilities require standardized procedures and technologies to produce large amounts of uniform fuel" (Wolek 2011, 238). He elaborated that developers of new biofuels needed proper incentives: "The right to exclude competitors from using a patented technology for twenty years should draw substantial investment and ameliorate many investment concerns, as the potential gains of patenting a technology that becomes an industry standard may outweigh the risk" (Wolek 2011, 256). Wolek concluded that patents are critical for companies wanting to engage in "empire-building" in the area of biofuels (Wolek 2011, 256–57).

In the United Kingdom, the Nuffield Council on Bioethics considered the question of the regulation of biofuels. The Council stressed that "moral values relevant to current and new biofuels include: human rights, solidarity, sustainability, stewardship and justice" (Nuffield Council on Bioethics 2011, 64). The council recommended that the future development of biofuels should take into account six principles for ethical policy-making – including (1) human rights, (2) environmental sustainability, (3) climate change, (4) fair trade, (5) equitable cost-sharing and benefit-sharing, and (6) research development (Nuffield Council on Bioethics 2011, xxv). The Council contended: "Policies for, and regulation of, biofuels have led to or exacerbated ethical problems in the past, so it is important to have a set of ethical principles against which the policies can be evaluated" (Nuffield Council on Bioethics 2011, Guide to the

Report, 5). Such an approach would emphasize the need to take into account considerations of ethics, justice, and public policy in determinations about patent criteria.

There are a number of enterprising biotechnology companies applying a range of genetic and genomic techniques to harvest fuel from algae (Waltz 2009). There has been great interest in the implications of synthetic biology for intellectual property, energy, the protection of the environment and the climate change (Ahmann and Dorgan 2007).

The ETC Group — based in Canada — has been negative about the adoption of new technologies, such as biofuels and synthetic biology (ETC Group 2010). They have argued that such technologies will have adverse impacts in areas such as energy independence, food security, biodiversity, and climate change. The ETC Group alleged: "Under the pretext of addressing environmental degradation, climate change and the energy and food crises, industry is portending a 'New Bioeconomy' and the replacement of fossil carbon with living matter, now labeled 'biomass'" (ETC Group 2010). The organization was concerned that biofuels threatened food security, particularly in developing countries: "The most productive and accessible biomass is in the global South — exactly where, by 2050, there may be another 2 billion mouths to feed on lands that (thanks to climate chaos) may yield 20-50% less" (ETC Group 2010). The ETC Group has been particularly skeptical about the latest generation of biofuels based upon biotechnology: "Although this would seem to be the worst time possible to put new pressures on living systems, governments are being told that 'Synthetic Biology' — a technology just being invented — will make and transform all the biomass we will ever need to replace all the fossil fuels we currently use" (ETC Group 2010). The ETC Group has called for a moratorium in respect of such technologies and for the exclusion of such subject matter from the scope of patent protection.

There has been much vigorous debate over the patentability of synthetic biology – particularly in light of previous controversies over gene patents (Rai and Boyle 2007; Rai and Kumar 2007; Dutfield 2012).

Technology Transfer and Climate Change

The debate over intellectual property and technology transfer is a long standing one, cutting across the fields of public health, biodiversity, energy, and climate health. Ahmed Abdul Latif and Pedro Roffe from the International Centre for Trade and Sustainable Development have provided an overview of the fifty years of international debate over the topic (Latif and Roffe 2011). Latif and Roffe commented: "While multilateral processes cannot provide all the answers, meaningful international action for promoting technology transfer within a general technology acquisition framework is taking shape, as reflected in the recent establishment of a Technology Mechanism under the *United Nations Framework Convention on Climate Change* 1992 (UNFCCC)" (Latif and Roffe 2011).

Over several years, the international climate talks have established a new Technology Mechanism — known as the UNFCCC Climate Technology Centre and Network (Zahar, Peel, and Godden 2013, 278–282). The proposal was first mooted by the United Kingdom Carbon Trust and India during international climate discussions. The *Copenhagen Accord* 2009, the *Cancun Agreements* 2010, the *Durban Decisions* 2011 and the *Doha Climate Gateway* 2012 established an international framework for the Technology Mechanism. The *Warsaw Climate Change Conference* 2013 established modalities and procedures for the Climate Technology

Centre and Network and its Advisory Board. By the time of the *Lima Climate Talks* 2014, the Climate Technology Centre and Network was operational.

At the Doha Climate Summit in 2012, the United Nations Environment Programme was selected to administer the UNFCCC Climate Technology Centre and Network (United Nations Environment Programme 2012b). The bid involved a consortium of research centres from around the world. The other key participants in the bid include the United Nations Industrial Development Organisation ("UNIDO") — co-manager of the Core Centre; the Asian Institute of Technology based in Thailand; the Bariloche Foundation from Argentina; the Council for Scientific and Industrial Research from South Africa; the Energy and Research Institute from India; the Environment and Development Action in the Third World from Senegal; the Tropical Agricultural Research and Higher Education Center from Costa Rica; the World Agroforestry Centre from Kenya; the Deutsche Gesellschaft für Internationale Zusammenarbeit from Germany; the Energy Research Centre of the Netherlands; the National Renewable Energy Laboratory from the United States; and the UNEP Risø Centre from Denmark (United Nations Environment Programme 2012a). This model will facilitate research, development, and diffusion in respect of biofuels.

One of the participants in the network is the National Renewable Energy Laboratory ("NREL"). The NREL has an impressive record of research and development in respect of biofuels, emphasized as follows: "Through biomass research, NREL is developing technologies to convert biomass—plant matter such as trees, grasses, agricultural residue, algae, and other biological material—to fuels" (NREL 2013a). The NREL stressed: "These biofuels will reduce our nation's dependence on foreign oil, improve our air quality, and support rural economies" (NREL 2013a). The NREL has filed and registered a number of patents in respect of biofuels. The NREL seeks to promote the dissemination of its technologies to the private sector: “Through technology partnerships, NREL seeks to reduce private sector risk and enable investment in the adoption of renewable energy and energy efficiency technologies” (NREL 2013b). The NREL commented: “The transfer of these technologies to the marketplace helps displace oil, reduce carbon emissions, and increase U.S. industry competitiveness” (NREL 2013b).

Naomi Oreskes, the co-author of *Merchants of Doubt* (Oreskes and Conway 2010) has contended that Barack Obama should make use of the national laboratory system in the United States to address climate change (Oreskes 2013). She laments: “Curiosity-driven science has not yet provided the solutions to global warming, and universities are not well situated to address a single, overarching problem” (Oreskes 2013). While she notes that the United States President does not have authority over the nation’s universities, he does have authority over the national laboratory system. Oreskes insists that “President Obama can move independently of Congress to address this critical issue: He can mobilize scientists through the U.S. national laboratory system … The labs have been mobilized before; the time has come to mobilize them again” (Oreskes 2013).

At his second inauguration speech in January 2013, President Barack Obama emphasized: “We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations” (Obama 2013a). While acknowledging that “[t]he path towards sustainable energy sources will be long and sometimes difficult”, Obama insisted: “America cannot resist this transition, we must lead it” (Obama 2013a). He also stressed that the United States would defend its intellectual property rights in respect of clean technologies: “We cannot cede to other nations the technology that will power new jobs and new industries, we must claim its promise” (Obama, 2013a).

The World Intellectual Property Organization has also established WIPO GREEN to facilitate information-sharing and technology transfer in respect of clean technologies. This will provide a useful international platform for the diffusion of clean technologies.

Patent Pools

There has been much discussion about the use of patent pools, technology clearing houses, and open source strategies to facilitate access to clean technologies (Rimmer 2011a, 312–342 and 396–7).

Jeremy de Beer has observed: “So-called patent thickets—multiple upstream patents where overlapping rights may impede the development or commercialization of technology—are an issue of some concern for which cross-licensing and patent pooling have been suggested as a possible solution” (de Beer 2011, 11).

Calestous Juma and Bob Bell, Jr. have explored the possibility of patent pools in respect of biofuels (Juma and Bell 2009, 77). The pair have been skeptical as to whether patent pools would fully resolve issues in respect of technology transfer: “If patent pools are a possibility in the area of biofuels, they are probably unlikely to change the underlying structural barriers to technology transfer” (Juma and Bell 2009, 77). Juma and Bell commented that “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 anti-competitive cartel)" (Juma and Bell 2009, 77). The pair has been circumspect about the mechanism: "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" (Juma and Bell 2009, 77).

The Nuffield Council on Bioethics summarised its concerns about patent law and biofuels thus: "For biofuels in many cases, financial return will only be possible after the investment of very large sums of money, and intellectual property will play a key role in attempts to secure such a return" (Nuffield Council on Bioethics 2011, 62–63). Nonetheless, the Council commented: "Just reward also means finding a balance between rewarding parties for their innovation and investment while trying to encourage access to knowledge and materials" (Nuffield Council on Bioethics 2011, 62–63). The Group suggested: "Another approach is to influence the way in which intellectual property is exploited – which is done principally through the granting of licences" (Nuffield Council on Bioethics 2011, xxx). The Nuffield Council on Bioethics observed: "The widespread use of non-exclusive licences which utilise the principles and best practices outlined in a recent OECD report should be encouraged in the area of biofuels" (Nuffield Council on Bioethics 2011, xxx).

Considering the patent clusters in respect of biofuels, there could be scope for patent pools and cross-licensing to facilitate access to key, influential patents.

Compulsory Licensing

There has been much international debate about the use of compulsory licensing in respect of clean technologies – including biofuels (Rimmer 2011a; Rimmer 2011b; Rimmer 2012b). Developed nations, such as the United States, Canada, and members of the European Union have been hostile to the provision of compulsory licensing in respect of clean technologies. Members of the BASIC and BRICS group — including Brazil, China, India, and South Africa — have pushed for access to clean technologies, but at the same time have made significant patent applications in certain fields. Developing countries — members of the Group of 77 — have argued that there is a need for the use of flexibilities; in particular, compulsory licensing may provide increased access to clean technologies.

Calestous Juma and Bob Bell, Jr. have evaluated the use of compulsory licensing in respect of biofuels (Juma and Bell 2009, 76). The pair commented: "When there are no close substitutes for a biofuels technological product or process, compulsory licensing may be an option" (Juma and Bell 2009, 76). Juma and Bell noted further that compulsory licensing can be deployed to deal with a number of public policy objectives — such as addressing anti-competitive conduct. However, the pair were doubtful about the utility of this mechanism, concluding that "compulsory licensing may be a blunt instrument that is unlikely to promote technological innovation" (Juma and Bell 2009, 77).

On the subject of compulsory licensing, the Nuffield Council on Bioethics recognised: "Many consider compulsory licence provisions as a form of safety valve within intellectual property law, simply designed to moderate the excessive demands of licensors" (Nuffield Council on Bioethics 2011, 103). However, the Council was hostile to the mechanism: "The compulsory license system is too complex and confrontational to be used except in extreme circumstances to gain access to technology" (Nuffield Council on Bioethics 2011, 103). In the Council's view, voluntary forms of patent licensing would be less confrontational and threatening.

By contrast, Professor Carlos Correa is somewhat more enthusiastic about the use of compulsory licensing in the area of agriculture — particularly for public policy purposes such as food security, climate change, and energy independence (Correa 2012). He commented that "[a]s an alternative to an uncompensated exception equivalent to the breeders' exception, patent laws could provide for a remunerative exception based on a compulsory license: a breeder who might be prevented from legally commercializing a new plant variety because it contains one or more third parties' patented components, may be entitled to obtain a compulsory license on the relevant patent/s" (Correa 2012, 15). Correa recommends that "national patent laws should provide for compulsory licenses in cases where the exploitation of a protected plant variety would infringe a patent" (Correa 2012, 15).

In Australia, the Productivity Commission has considered substantive law reform in respect of patent law and compulsory licensing (Productivity Commission 2013), but has only been willing to contemplate limited reforms in respect of compulsory licensing — via a competition test, or a public interest test. The Productivity Commission has suggested that Crown Use could be used to address domestic national emergencies and circumstances of extreme urgency. The Productivity Commission has not addressed the need for compulsory licensing for humanitarian purposes to deal with issues such as food security. In that realm, the Productivity Commission asserted that compulsory licensing was unlikely to be an effective means to address concerns about global food security (Productivity Commission 2013).

Arguably, though, countries need to develop modern and flexible compulsory licensing regimes to deal with a range of public policy concerns under patent law — including matters such as energy security, food and agriculture, biodiversity, and climate change. The case of biofuels patents highlights the need for the patent regime to be able to address a wide range of public policy concerns.

Access to Genetic Resources, Informed Consent, Benefit-Sharing, and Disclosure

The principles of access to genetic resources, disclosure, informed consent, and benefit-sharing have been applied to a wide variety of contexts – including genetic resources, food and agriculture, traditional knowledge and medicine (Lawson 2012).

There has been a push to apply the principles of disclosure, informed consent, and benefit-sharing to the topic of patent law and biofuels. The Roundtable on Sustainable Biomaterials has emphasized that "Free, Prior and Informed Consent shall form the basis for the process to be followed during all stakeholder consultation, which shall be gender sensitive and result in consensus-driven negotiated agreements" (RSB Services Foundation 2011).

On the topic of access to genetic resources, the Nuffield Council on Bioethics emphasized: "The intellectual property regime can play a role in ensuring that the costs and benefits associated with biofuels are distributed in an equitable way" (Nuffield Council on Bioethics 2011, xxxi–xxxii). The Council suggests that such a goal could be achieved by "taking one of the key objectives of the *Convention on Biological Diversity* 1992 – i.e. the fair and equitable sharing of the benefits arising from the utilisation of genetic resources – and integrating it into the intellectual property regime" (Nuffield Council on Bioethics 2011, xxxii). The Nuffield

Council on Bioethics promoted the *Nagoya Protocol* 2010 for this purpose: "If successful, the *Nagoya Protocol* would allow developing countries, in particular, to exploit their genetic resources and reduce possible occurrences of misappropriation of those resources" (Nuffield Council on Bioethics 2011, xxxii).

The Council had a number of substantive recommendations in respect of access to genetic resources (which is striking, given its limited recommendations on the topics of patent law and plant breeders' rights). It recommended "that a 'disclosure of origin' requirement be introduced into UK patent law to improve transparency about genetic resource use in order to facilitate access and benefit sharing" and that "consideration be given to the introduction of a mandatory 'disclosure of origin of genetic resources' requirement in intellectual property law with appropriate sanctions, either outside or within patent law, for non- or incorrect disclosure" (Nuffield Council on Bioethics 2011, 114). The Council emphasized that such a measure would "help facilitate countries providing genetic resources to monitor compliance with regulations and contracts regarding access to and sharing of benefits from genetic resources, and to bring national policy in line with the *Bonn Guidelines*" (Nuffield Council on Bioethics 2011, 114).

Such a disclosure requirement would enable a better consideration of questions on bioethics in respect of biofuel patents.

Conclusion

The topic of intellectual property and biofuels highlights tensions in respect of the larger public policy debate about energy independence, food security, and climate change.

The patent landscape and network patent analysis reveal that the field of biofuels has a high concentration of patents. There are significant patent thickets in relation to biodiesel production and bioproducts, biogas, and cellulosic biofuels and by-products. The first generation of biofuels has the largest number of patents, and most influential biofuels networks. The second generation and the third generation of biofuels are still only emerging in terms of influential patent networks. It could be anticipated that there will be greater patent filings in these areas in the future — particularly given the limitations of the first-generation of biofuels.

In terms of policy responses, there are a number of pressing issues in relation to patent law and biofuels. There has been much controversy over patent law and biotechnology in respect of limits of patentable subject matter (Saez 2013). In this context, there has been debate over the patentability of biofuels — particularly in respect of later generations of biofuels. There has also been a growing conflict over patents in respect of first-generation biofuels. It can furthermore be anticipated that there will be future conflict over patents relating to second- and third-generation biofuels. The topic of technology transfer remains a significant one in respect of clean technologies, such as biofuels. The UNFCCC Climate Technology Centre and Network will hopefully promote research, development, and diffusion in respect of biofuels. WIPO GREEN will also be an important marketplace to trade and share clean technologies. Given the crowded nature of the patent landscape, there could be scope for patent pools to facilitate access to key technologies in respect of biofuels. There is a need to modernise compulsory licensing regimes to provide access to clean technologies. Furthermore, the topic of biofuels raises important issues about access to genetic resources. There is a need to ensure that patent applications in respect of biofuels comply with requirements in respect of disclosure, informed consent, and benefit-sharing. This will be an important area of debate in the Paris climate talks in 2015.

There needs to be further international collaboration and co-ordination in respect of the topic of intellectual property law and biofuels — especially given the mutual responsibility for the area between *United Nations Framework Convention on Climate Change* 1992, the United Nations Environment Programme, the *Convention on Biological Diversity* 1992, the International Energy Agency, the World Intellectual Property Organization, and the World Trade Organization (Rhodes 2010).

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[i] The keywords for the first generation of biofuels included: ‘Starch’, ‘Sugar’, ‘animal fats’, ‘vegetable oil’, ‘edible oil’, ‘soy’, ‘soybean’, ‘rapeseed’, ‘jatropha’, ‘mahua’, ‘mustard’, ‘flax’, ‘sunflower’, ‘palm oil’, ‘hemp’, ‘pennycress’, ‘pongamia’, ‘pinnata’, ‘triglyceride’, ‘biodiesel’, ‘diesel’, ‘biogas’, ‘alcohol’, ‘bioalcohol’, ‘ethanol’, ‘butanol’, ‘propanol’, ‘bioethanol’, ‘biobutanol’, ‘biopropanol’ and ‘syngas’. The keywords for the second generation of biofuels included ‘wood’, ‘agricultur’, ‘cellulos’, ‘fibr’, ‘Waste’, ‘Sewage’, and ‘sludge’. The keywords for the third generation of biofuels included ‘algae’, ‘microalgae’, ‘seaweed’, and ‘algal’.

[ii] There has been significant trade secrets litigation in respect of biofuels: see the United States cases of *BlueEarth Biofuels v Hawaiian Electric Company* and *SunOpta, Inc. v Abengoa Bioenergy New Technologies, Inc.*; and the Canadian case of *Abener Energia, S.A. v Sunopta Inc.*.