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Master of Science
Mention Microbiology, Plant Biology and Biotechnologies

An overview of the technological development on biofuels
– biodiesel and ethanol – of BRIC (Brazil, Russia, India
and China), through the analysis of patent filings in the
area

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Curitiba, September 2011

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Programa de Pós-Graduação em Processos Biotecnológicos

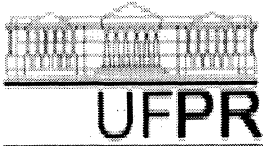
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RELATÓRIO DE DEFESA DE DISSERTAÇÃO DE MESTRADO

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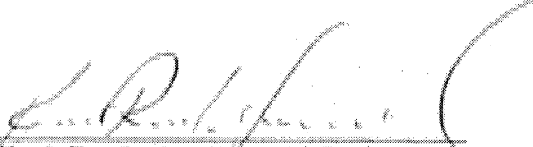
Aos sete dias do mês de novembro de 2011, na sala de video conferência do Programa de Pós-Graduação em Processos Biotecnológicos, do Centro Politécnico da Universidade Federal do Paraná, Jardim das Américas, foi instalada pelo Prof Dr Carlos Ricardo Soccol, Coordenador do Programa *Master Biodev*, Brasil, a banca examinadora para a Quinquagésima Oitava Defesa de Dissertação de Mestrado, área de concentração: Agroindústria e Biocombustíveis. Estiveram presentes no Ato, além do Coordenador do Programa *Master Biodev*, professores, alunos e visitantes.


A Banca Examinadora, atendendo determinação do Colegiado do Curso de Pós-Graduação em Processos Biotecnológicos, ficou constituída pelos Professores Doutores José Rodriguez León (UP), Luiz Gustavo Lacerda (UP), Jean-Luc Tholozan (Université de la Méditerranée-França), Jean Lorquin (Université de la Méditerranée-França) e Carlos Ricardo Soccol (UFPR – orientador da dissertação).

Às 12h00, a banca iniciou os trabalhos, convidando o candidato **Eduardo Scopel Ferreira da Costa** a fazer a apresentação da Dissertação intitulada: **"An overview of the technological development on biofuels – biodiesel and ethanol – of BRIC (Brazil, Russia, India and China), through the analysis of patent filings in the area"**. Encerrada a apresentação, iniciou-se a fase de arguição pelos membros participantes.


Tendo em vista a dissertação e a arguição, a banca composta pelos professores doutores José Rodriguez León, Luiz Gustavo Lacerda, Jean-Luc Tholozan, Jean Lorquin e Carlos Ricardo Soccol declarou o candidato Aprovado (de acordo com a determinação dos Artigos 32/33/34/35 da Resolução 13/96 de 23.07.96).

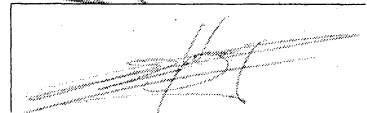
Curitiba, 07 de novembro de 2011.


Prof. Dr. Carlos Ricardo Soccol


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Prof. Dr. Luiz Gustavo Lacerda


Prof. Dr. Jean Lorquin


Dr. Jean Lorquin

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ABSTRACT

It is well known that fossil fuels are the basis of the global energy market. The amount of these non-renewable fuels is diminishing rapidly, and the world must find alternative sources of fuels, and ways to make them feasible, in order to boost global energy matrix in the next decades. Besides, the unbridled use of these fuels is harming the environment and causing several problems, such as global warming, elevation of sea levels and changes in entire ecosystems. Therefore, renewable fuels come in handy to solve those problems. Biofuels, such as biodiesel and ethanol, are fuels derived somehow from biomass. Biodiesel is produced through the transesterification of vegetable oils (products of grain processing) and ethanol through the fermentation of sugars, such as sucrose, by microorganisms. Brazil, China, India and Russia are expected to be amongst the 6 most industrialized countries in the world by 2050. As big consumers of fossil fuels, they must be ahead of the production of biofuels, so they do not need to depend on importing fossil fuels to continue growing. To measure the technological development of those countries, patent information was used. Patents filed by the 4 countries in both ethanol and biodiesel related technologies were searched in the Derwent Innovation Index database, and analyzed individually, so that it was possible to define the state of development of each country. China dominates filings in both technologies, with 76% of filings in biodiesel and 74% in ethanol. Brazil comes in second place in biodiesel related technologies with 15% and Russia stays is the second best for ethanol related inventions, with 16%, even though Brazil has the biggest capacity of biodiesel and ethanol production. This scenario is explained by the major investments China has been making in Research & Development of new technologies and the lack of culture from Brazilian companies, regarding protecting its inventions.

Keywords: Biofuel. Biodiesel. Bioethanol. Patents. BRIC. Innovation. Sustainable Technologies.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANP – Agência Nacional do Petróleo (Oil National Agency – Brazil)

AU – Australia (for patents)

BE – Belgium (for patents)

BR – Brazil (for patents)

BRIC – Brazil, Russia, India and China

CN – China (for patents)

CO₂ – Carbon Dioxide

DE – Germany (for patents)

DII – Derwent Innovation Index

DK – Denmark (for patents)

EU – European Union

FR – France (for patents)

G6 – Six most industrialized countries in the world

GMO – Genetically Modified Organisms

GNP – Gross National Product

IE – Ireland (for patents)

IEA – International Energy Agency

IEDI – Instituto de Estudos para o Desenvolvimento Industrial (Institute for Industrial Development Studies – Brazil)

IN – India (for patents)

IPC – International Patent Classification

JP – Japan (for patents)

MU – Brazilian abbreviation for patents of Utility Models

NL – Netherlands (for patents)

OECD – Organization for Economic Co-operation and Development

PCT – Patent Cooperation Treaty

PI – Brazilian abbreviation for Privilege of Invention

PN – Patent Number

PTO – Patent and Trademark Office

REN21 – Renewable Energy Policy Network for the 21st Century

RU – Russia (for patents)

SU – Soviet Union (for patents)

TRIPS – Agreement on Trade Related Intellectual Property Rights

TS – Title and Abstract

UK – United Kingdom (for patents)

UNCTAD – United Nation Conference on Trade And Development

US – United States of America (for patents)

USA – United States of America

USDA – United States Department of Agriculture

WIPO – World Intellectual Property Organization

WTO – World Trade Organization

1. INTRODUCTION

1.1. Objectives

The present study aims to compare the technological efforts made on the production of biofuels, mainly biodiesel and ethanol, by the countries that integrate the BRIC group (Brazil, Russia, India and China).

The chosen indicator to establish the technological development of these countries is the number of patents filed on related areas to the numerous technological routes, specifically the ones using biotechnology, that refer to biofuel's production. The present study limits to the scientific-technological areas related to everything that involves the process of production bioethanol and biodiesel. Therefore, the patents will be filtered by the keywords on their abstracts and titles, the countries where the priority has been requested first (Brazil, Russia, India and China) and the countries where the patent has been filed.

From this study, it will be possible to identify, by the analysis of the patent applications made by inquiry in research institutes and companies from those countries, on their national patent offices (Brazil, China, India and Russia):

- The evolution of the technological development of each country in the area, with the passing years;
- The mains applicants on each country;
- The fields and technological routes that are studied most by each country;
- Who maintains the lead on the referred technologies.

1.1 Justifications

The growing demand for renewable fuels brings up the need to study the efforts that have been made on the development of new technologies. The emerging countries have been increasing their fuel consumption and the worry about the limited amount of fossil fuels brings up the need to rethink energy use. For this reason, the present study was limited to the BRIC group (Brazil, Russia, India and China). Besides, they are on a similar scientific-technological maturity, have a bunch of social problems, but have considerably strong industries, big consumer market, vast natural resources and large territories.

Hence, the present study is justified, and aims to show an overview of technologies concerning biodiesel and ethanol that has been subject of patent, and that have been developed in the countries that compose the BRIC group.

2. BIBLIOGRAPHIC REVIEW

It is well known that fossil fuels, mainly oil based, form the basis of the global energy matrix, especially for transportation uses and heat generation. However, with the amount of available oil decreasing quickly, the volatility of prices, the political instability at the producing region environmental problems caused by its unsustainable usage, the demand for alternatives fuels has grown, in order to diversify this matrix. In this context, several kinds of alternative fuels have emerged, among which, biofuels stand out. Biofuels are those fuels derived, in some way, from biomass.

In 2006, biofuels represented about 1,8% of the fuel used for transportation in the world, mainly due to its use in European countries and developing countries, such as Brazil. Ethanol had its production tripled from 2000 to 2007 reaching 52 billion liters, while biodiesel production expanded from 1 billion to about 11 billion liters, on the same period. This growth was motivated by the increase of the ethanol amending in gasoline fuel and the share of biodiesel in the diesel fuel. USA (ethanol from corn), Brazil (ethanol from sugar cane) and the European Union (biodiesel from rapeseed) lead the production of transport biofuels. China is also increasing its production of biofuels constantly (DEMIRBAS, 2009; UNEP, 2009).

In 2010, investment in renewable energy reached US\$ 211 billion, as increase of 32% when comparing with 2009. Developing country investments in biofuel projects exceeded those of developed countries. Almost 3% of global road transport fuels in 2010 were liquid biofuels. Regarding ethanol, Brazil and USA together represented 88% of the global production, being the USA the world's leading ethanol exporter, overcoming Brazil (REN21, 2011; UNEP, 2011).

So, it is expected that those investments may turn into inventions that may reach the market anytime.

2.1. Patents as Source of Information

Patents are a relevant source of information about all sorts of technologies. On its content, is included important information about inventive step processes, location of emerging technologies, inventive networks, emerging technologies, among others. When combined with other data, they provide basis for a broad analysis of various dimensions of innovations, as the role of intellectual property of economical performance, entrepreneurship and on search for connections in the science and technology development. As many others, these indicators have advantages and disadvantages, and reflect several stages of the innovation process (OECD, 2009; TRIPS, 1994).

From 2002 and 2008, almost 3,000 biofuel related patents were published, with a considerable growth in the last two years of the referred period. In 2007, the number of biofuel patents (1,045) was more than the combined total of solar power (555) and wind power (282) patents published in that year. Assuming that biofuel, solar power and wind power are the leading renewable energy technologies, then, in 2007, biofuel patents, more specifically biodiesel, clearly dominate renewable energy (in terms of sheer numbers). It is expected that legislation directed to climate change will continue influencing biofuel patents. In 2022 at least 16 billion gallons of USA transportation fuel will have to be cellulosic biofuel. Also, 21 billion gallons of USA transportation fuel will have to be derived from sources other than traditional ethanol biofuel (JAMIS and JOSHI, 2008).

Analyzing a patent document, either product or process patent, it must be taken into consideration the 4 mains requirements to the granting of protection of an invention: novelty, inventiveness, industrial application and sufficient descriptiveness (TRIPS, 1994).

Thinking about the novelty and inventiveness, it is evident that most patent documents will contain the newest information regarding a specific technology. It is definitive state of the art material. When they do not fulfill those requirements, they are not granted. The industrial application requirement leads us to the conclusion that most patents has relevant information to be used in industries, regardless if they are granted, because, either way, that information will remain in public domain, aiding someone to solve a technical problem the invention was supposed to solve.

With respect to sufficient descriptiveness, we reach the amount of information. A patent document must have sufficient and complete information, in order that a person skilled in the art is able to carry out the invention properly. It is in this concept that we rely to identify the importance of patent documents as source of technological information (TRIPS, 1994).

2.2. Biofuels

2.2.1. Biodiesel

The chemical reaction of a vegetable oil with an alcohol (methanol or ethanol, for instance) will result in an ester (methyl or ethyl, depending on the alcohol used), that is called biodiesel. Since ethanol already is widely produced in Brazil and USA, ethyl ester would be the most interesting option, but commercially it is easier to find methyl ester. The use of biodiesel is limited to blending with diesel oil, up to now, what already helps reducing air pollutant emissions. Using biodiesel helps to restrain the increase of the greenhouse effect, and may reach strong results when used in a large global scale. Biodiesel is not aggressive to the environment and it is a renewable source of energy. It does not carry the same drawbacks that fossil fuels do, such as high market prices and

negative impact on the environment (UNEP, 2009; ROVERE, PEREIRA and SIMÕES, 2011).

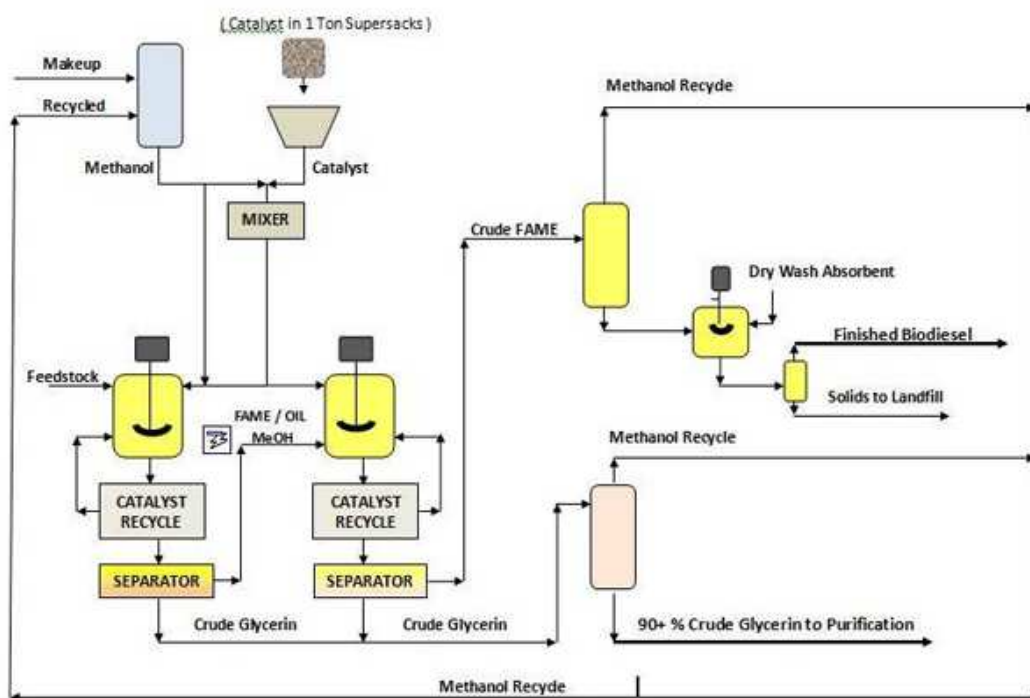


Illustration 1 – A diagram of a biodiesel production process.
Font: Ozarks New Energy (2011)

Biodiesel has a lot of advantages, such as the capacity to reduce the carbon emissions, adds more job opportunities, reduces the need of use and import fossil fuels, and increases vegetable oil supplies, which will reduce its costs. It is one of the most environmentally friendly, from the fuels available in the market, carrying the potential to reduce up to 80% the CO₂ life cycle (SAMBODO, 2009; MWKHFLEFA, SIGAA and SAIDURB, 2011).

Biodiesel current global production is of about 11 billion liters and is expected to grow up to 24 billion liters, until 2017, since a lot of countries will increase the minimum amount of blending on diesel fuels (IEA, 2007; EBTP, 2011 http://www.biofuelstp.eu/global_overview.html#prod).

2.2.2. Ethanol

The potential of ethanol as alternative fuel has brought to itself worldwide attention. Among the advantages of using ethanol blended with gasoline or alone, are lower quantities of emissions of carbon mono oxide, nitrogen oxides and hydrocarbon after combustion. Even the blended one reduces those emissions, since ethanol acts as oxidizing agent (TAKAHASHI et al, 2000; BADGER, 2002; MIELENZ, 2001).

The process for production ethanol from sugar cane starts with the pretreatment of the sugar cane. This process consists on the removal of organic material and shredding the cane into smaller pieces. After this process, the feedstock is fed and milled to extract juice and separate it from the cane bagasse, which is a fiber residue of the process. A great part of the bagasse os composed of cellulosic material, which can be used to produce second generation ethanol. It is also used as feedstock for boilers, to produce low-cost energy, which supply electricity and steam for the process. The milling process aims, mainly, to extract sucrose from the cane. The cane juice is, then, filtered, chemically treated and pasteurized. During the filtration process, vinasse, another sub-product of the process, is produced. The next step is evaporation of the juice, in order to increase its concentration of sugar. Following this step, we reach the crystallization of the syrup, by boiling or cooling, what leads to a mixture of clear crystals with molasses, with high sugar concentrations. Molasses are removed by centrifugation, after which is pretreated with pasteurization and addition of lime. This process will sterilize the molasse, leaving it ready to be fermented. Sugars are then fermented into ethanol by yeasts, during the fermentation step, that can vary from 4 to 12 hours. The resulting wine is centrifuged, to recover the yeast. Then, the alcohol in the fermented wine is distillated, using different boiling points, to separate it from other

materials. The obtained product is hydrated ethanol (SMEETS et al, 2006; KUMAR et al, 2009).

2.3. BRIC (Brazil, Russia, India and China)

The idea of BRIC was first formulated by Jim O'Neil, the chief economist of Goldman Sachs, in 2001. In 2006, the concept gave birth to a group, incorporated in the external policies of Brazil, Russia, India and China. The economical power of BRIC is considerable. For instance, between 2003 and 2007, the 4 countries represented 65% of the expansion of the worldwide GNP, which already overcomes USA and EU. In 2003 the BRIC represented about 9% of the world Gross National Product (GNP), and, in 2009, 14%. Up to 2006, the BRIC were not gathered in a mechanism that allowed their linkage, what changed after the Chancellor' Meeting of the 4 countries. This was the first step in order to Brazil, Russia, India and China started working together (BRAZIL, 2011 <http://www.itamaraty.gov.br/temas/mecanismos-inter-regionais/agrupamento-brics>).

For the next 50 years, if things go right, the BRICs economies could be larger than the G6, in US dollar terms. In 2050, Brazil, Russia, India and China will be part of the G6, making company to USA and Japan, the only remaining members of the current scenario. (GOLDMAN SACHS GROUP, 2003)

The current scenario predicts that China is going to be the leader in manufactured goods, India in services, and Brazil and Russia are going to be very important suppliers of the raw materials for the other two importing countries. One of the effects already felt by the market is the fact that the BRIC nations have overtaken USA in global energy industry. The suppliers from this group have taken more than

30% of the energy supply market. PetroChina, Gazprom, Petrobras and India's Oil & Natural Gas Corp are some examples of companies that are shifting the market. An important concern regarding the rise of Brazil, Russia, India and China is that as those countries grow, they need more and more oil for energy supply. In a scenario where the world supply seems to have peaked, we could see prices going up in a near future. China and India are using lots of their coal reserves, which emit even more CO₂ than oil consumption. This scenario can bring catastrophic rises in sea level and abrupt changes in global climate, as said by many climatologists. The focus on developing alternative energy sources is necessary. China is already investing in lots of them, such as wind, biofuels and hydroelectric, in order to increase its renewable energy capacity to 10% in 2020 (<http://www.power-technology.com/features/feature1417>, 2011; BEEDIE, 2007).

2.3.1. Brazil's Situation

Over the next 50 years, Brazil's GNP growth rate averages 3.6%. The size of Brazil's economy is predicted to overtake Italy by 2025, France by 2031 and UK and Germany by 2036 (GOLDMAN SACHS GROUP, 2003).

In 2008, Brazilian government invested in Research and Development, including taxes exemption and direct grants, about 1.1% of its GDP, what means more than R\$ 5 billion (PACHECO, 2010; WORLD BANK, 2011).

Brazil is commercializing ethanol for over 75 years. The history starts in 1934 with the application of ethanol as additive to gasoline. In 1975, the Brazilian Military Government launched the "Pro-Álcool" Program, which intended to reduce dependence on oil imports, after the oil shocks of the early 1970's. This Program lasted until 1989, when the Military Government ended, and it was the largest fossil fuel substitution

program in the world. After the program ended, it left Brazil with an outstanding infrastructure on handling ethanol and a distribution network that ethanol all over the country. Furthermore, it left Brazil with the largest and mostly developed sugarcane industry in the world. Ethanol industry was boosted again with the emergence of the flex cars in 2003, which could be fueled with both ethanol and gasoline. Also, there are several governmental initiatives to promote both ethanol and biodiesel production, such as tax incentives and credit lines for building new plants (BARROS, 2010).

Brazil's production of ethanol is over 28 billions of liters, with an average annual growth rate of almost 10%. The main feedstock used by Brazil to produce ethanol is sugar cane. Brazil's production nominal capacity of biodiesel is almost 6 billion liters, and the real production reached 2.3 billion liters in 2010. Soybean oil is the most used raw material to produce biodiesel, with almost 80% of the total produced (ANP, 2011).

2.3.2. China's Situation

China's GDP growth rate is expected to fall to 5% in 2020. By 2045, growth is expected to slow to down to around 3.5%. Even so, high investment rates, a large labor force and steady convergence would mean that China will become the world's largest economy by 2041 (GOLDMAN SACHS GROUP, 2003).

China spent, in 2004, 1.4% of its GDP in Research and Development, what meant more than US\$ 30 billion of investments. They were planning to reach over US\$ 115 billion in 2019 (ESCALATING R & D, 2006; WORLD BANK, 2011).

China produced in 2006 over one million tons of biofuels, staying behind Brazil and USA, only. Although ethanol production is not large – about 2 billion liters in 2010,

mainly from corn (80%), wheat and rice (20%) – biodiesel production reached over 3 billion liters. The primary feedstock for ethanol production in China is wheat and corn. The main feedstock for biodiesel production is used kitchen oil, residues from vegetable oil crushers and jatropha oil (WEYWEHAEUSER et al, 2007; SCOTT and JUNYANG, 2011).

2.3.3. India's Situation

India's growth rate is expected to remain above 5% during the next 50 years, in unlike its BRIC companions. India's GDP overcome Japan's one by 2032. It is also expected that the population of India will continue to grow throughout the next 50 years, what leads to the conclusion that it has the potential to raise its US dollar income per capita in 2050 to 35 times current levels. Still, India's income per capita will be significantly low (GOLDMAN SACHS GROUP, 2003).

India invests about 0.8% of its GDP in research and development, but is planning to increase this expenditure to about 2% (WORLD BANK, 2011; <http://www.deccanherald.com/content/45452/india-raise-scientific-rampd-spend.html>).

Biodiesel in India will, most likely, be produced using jatropha oil, as feedstock. Production of biodiesel in India is not yet commercially significant and up to now it was not demonstrated as economically viable biofuels. The lack of sufficient jatropha seeds to produce biodiesel is likely to frustrate the government's plan to blend 20% of biodiesel with conventional diesel up to 2012. Although, there are not many information regarding production of biodiesel in India, since the commercial production is not yet organized, some estimates say that it ranges anywhere between 100 and 200 million

liters each year, but with no commercial feasibility (ARADEY, 2011; GONSALVES, 2006).

Ethanol in India is mainly produced by the fermentation of sugar cane molasses, since their strategy remains on using non-food resources to produce biofuels. Also, the production of advanced ethanol is in its nascent phase, what is a consequence of its research & development program. The recent production capacity is over 4 billion liters per year, and it looks sufficient to supply the national demand until 2017. Government's goal presently is to blend 5% of ethanol in petrol. The consumer market for ethanol in India is mainly for non-fuel usage, but the imports for fuel ethanol has been growing recently (<http://www.deccanherald.com/content/45452/india-raise-scientific-rampd-spend.html>; ARADEY, 2011).

Research and development activities are focusing on the development of new technologies for production of advanced biofuels from wood biomass, agricultural and forest waste, municipal solid waste conversion, microalgae and photosynthetic organisms (ARADEY, 2011).

2.3.4. Russia's Situation

Russia's growth projections are interfered by its population, which is recently shrinking. However, Russia is expect to achieve some great results on the next decades and by 2050, the country's GDP per capita is expected to be the highest in the BRIC group, and comparable to the G6. Russia's economy overtakes Italy in 2018, France in 2024, UK in 2027 and Germany in 2028 (GOLDMAN SACHS GROUP, 2003).

Russia expends 1.04% of its GDP in research and development (WORLD BANK, 2011).

As Russia is one of the world's largest producers and exporters of fossil fuels biofuels don't receive special attention by the government. However, commitments under the Kyoto Protocol and interest in exporting biofuels could turn Russia to biofuels industry development (SMITH and MURAN, 2009).

Russia does not produce ethanol for fuel application. However, there are many distilleries capable of producing ethanol for other industries, with a total capacity of 1 billion liters. Yet, there are 2 fuel ethanol plants under construction, and another dozen planned. Russia could use any of its grains production, particularly wheat, barley, and corn, since it is a great exporter of these items. However, increasing grain prices may difficult bioethanol production in Russia. Alternatively, Russia could use other sources such as sugar beet molasses. Besides, Russia has large sources of cellulosic biomass from its large wood-processing industry. Russian government has not yet decided the most efficient type of biofuels to be produced there (SMITH and MURAN, 2009).

The same thing happens to biodiesel. There is no current relevant production in Russia, but a number of companies are interested in building biodiesel plants, with rapeseed as the main feedstock. Biodiesel produced in Russia are also intended for export markets in the EU (ROTHKOPH, 2007).

3. METHODOLOGY

3.1. Search for patents

To retrieve biodiesel and ethanol related patents filed in countries of the BRIC group, a patent search was performed, using the following method:

- a) Selection of the databases used;
- b) Construction of the search strategy for each technology;
- c) Narrow the results found on b), in order to reduce contaminations;
- d) Find how many patents were filed in Brazil, Russia, India and China, and who (name of the applicant and country of origin) filed then;
- e) Make an evolution curve of the filings of those patents, from 1963 to 2011;
- f) List the patent applicants, and its country of origin, in each selected country;
- g) Classify each patent found in specific areas related to biodiesel and ethanol technologies.

For both biodiesel and ethanol searches, the database used was the same, the Derwent Innovation Index (DII).

3.1.1. Search for Biodiesel Patents

In order to find only patents related to biodiesel technologies, a keyword search on the Derwent database was performed. The strategy used to do it was to search every patent that has on its abstract at least one of the following terms: biodiesel, fame, “alkyl ester” and “fatty acid methyl ester”, using the Boolean operator OR between the terms,

and the Boolean operator AND inside the composite terms, and the wildcard * after each word. So, the strategy used in the advanced search section of Derwent Innovation Index was

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*))

where TS means that we are searching for the terms after the equal sign in the Title or the Abstract of the patents. The time span for this search was from 01/01/1963 to 09/11/2011.

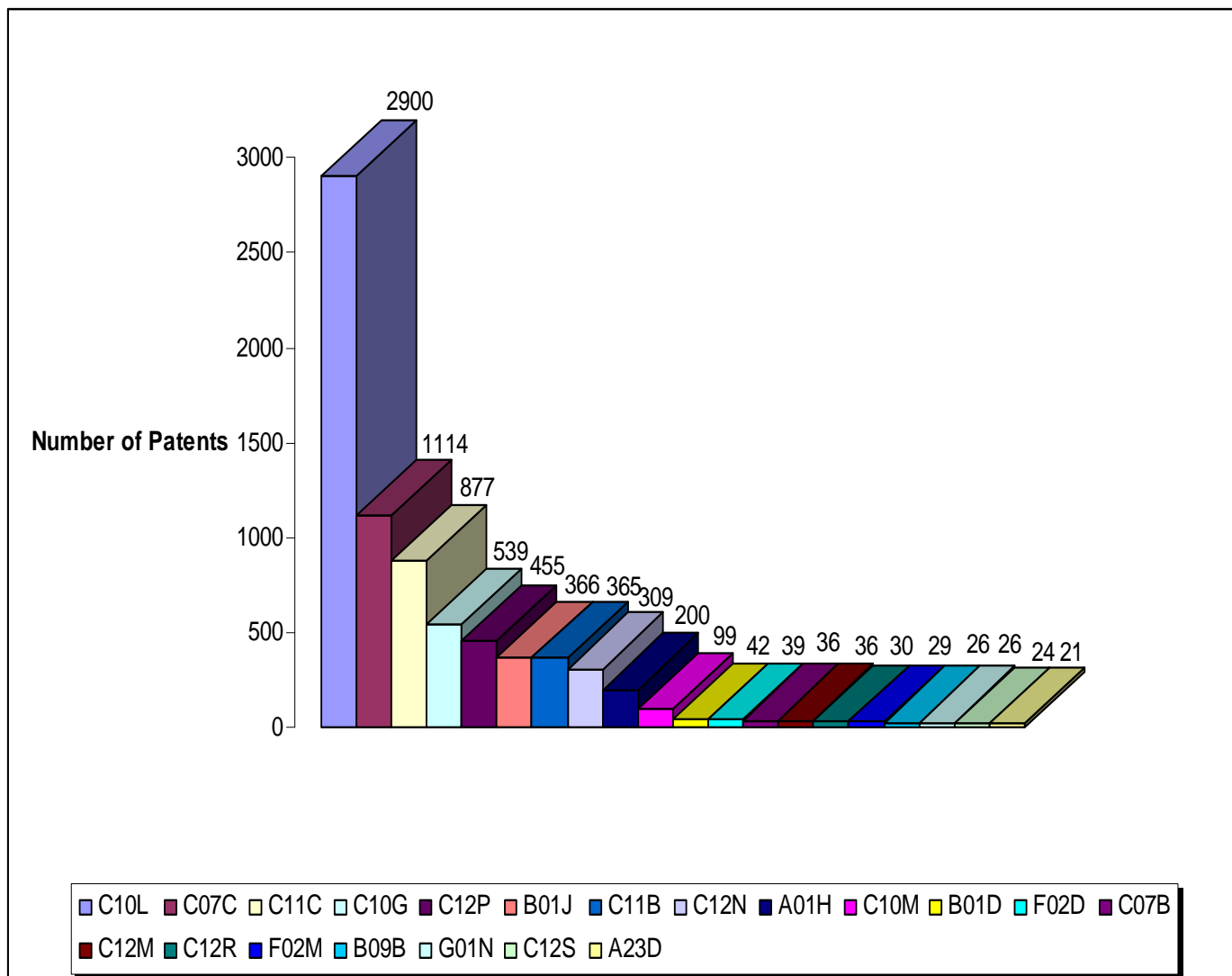
Doing that, the DII database retrieved 3688 patents from several areas, as listed in the table 1:

Derwent Subject Area	Number of Patents
Engineering	2906
Chemistry	2788
Energy & fuels	1989
Instruments & instrumentation	1059
Polymer science *	680
Biotechnology & applied microbiology	558
Transportation	280
Agriculture	271
Pharmacology & pharmacy *	235
Food science & technology	223
Computer science *	199
Construction & building technology *	122
Imaging science & photographic technology *	101
Materials science *	94
Communication *	91
Water resources	82
Metallurgy & metallurgical engineering *	59
General & internal medicine *	56
Sport sciences *	51
Optics *	39
Mining & mineral processing *	24
Nuclear science & technology *	1
Public, environmental & occupational health *	1

Table 1 - Subject areas of the biodiesel patents retrieved from the Derwent Patent database, using keyword advanced search, as only filter. * Marked areas are unrelated do any biodiesel technology.

As can be noticed from the table 1, there are several subject areas unrelated to any biodiesel technology. This happens because the search results are contaminated. In order to improve this search, the patents belonging to undesired subject areas were excluded. The undesired areas, for this study purposes, were Pharmacology & Pharmacy, Computer Science, Construction & Building Technology, Imaging Science & Photographic Technology, Materials Science, Communication, Metallurgy & Metallurgical Engineering, General & Internal Medicine, Sport Sciences, Optics, Mining & Mineral Processing, Nuclear Science & Technology. Excluding then from the search, the number of patents retrieved went down to 2748.

Each one of these patents has at least one IPC code associated. Aiming to improve the search and to observe which areas are more developed, according to these criteria, those codes are shown in the graphic 1, below.



Graphic 1 – Main IPC subclasses from the biodiesel patents retrieved from DII, using the strategy explained above.

Each IPC subclasses represents a technology field, as exposed on the table 2.

IPC	Technology Field
A01H	New plants or processes for obtaining them; Plant reproduction by tissue culture techniques
A23D	Edible oils or fats, e.g. margarines, shortenings, cooking oils
B01D	Separation
B01J	Chemical or physical processes, e.g. catalysis, colloid chemistry; Their relevant apparatus
B09B	Disposal of solid waste
C07B	General methods of organic chemistry; Apparatus therefore

C07C	Acyclic or carbocyclic compounds
C10G	Cracking hydrocarbon oils; Production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerization; Recovery of hydrocarbon oils from oil-shale, oil-sand, or gases; refining mixtures mainly consisting of hydrocarbons; reforming of NAPHTHA; Mineral waste
C10L	Fuels not otherwise provided for; Natural gas; Synthetic natural gas obtained by processes not covered by subclasses C10G or C10K; Liquefied petroleum gas; Use of additives to fuels of fires; Fire-lighters
C10M	Lubricating compositions; Use of chemical substances either alone or as lubricating ingredients in a lubricating composition
C11B	Producing, e.g. by pressing raw materials or by extraction from waste materials, refining or preserving fats, fatty substances, e.g. lanolin, fatty oils or waxes; Essential oils; Perfumes
C11C	Fatty acids from fats, oils or waxes; Candles; Fats, oils or fatty acids by chemical modification of fats, oils, or fatty acids obtained therefrom
C12M	Apparatus for enzymology or microbiology
C12N	Micro-organisms or enzymes; Compositions thereof; Propagating, preserving, or maintaining micro-organisms; Mutation or genetic engineering; Culture media
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
C12R	Indexing scheme associated with subclasses C12C-C12Q or C12S, relating to micro-organisms
C12S	Processes using enzymes or micro-organisms to liberate, separate or purify a pre-existing compound or composition; processes using enzymes or micro-organisms to treat textiles or to clean solid surfaces of materials
F02D	Controlling combustion engines
F02M	Supplying combustion engines in general with combustible mixtures or constituents thereof
G01N	Investigating or analyzing materials by determining their chemical or physical properties

Table 2 - Biodiesel patent's IPC subclasses, and it's technology focus.

After that, the same strategy was used to Brazil, China, India and Russia, individually. For that, the search was narrowed to find only the patents that had on its number the codes BR, PI, BRPI, MU, BRMU (Brazilian patents), CN (Chinese patents), IN (Indian patents), RU and SU (Russian and Soviet patents). Therefore, 4 search strategies were developed, as described below

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(BR* or PI* or BRPI* or MU* or BRMU*)

to find patents filed in Brazil;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(CN*)

to find patents filed in China;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(IN*)

to find patents filed in India;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(RU* or SU*)

to find patents filed in Russia or Soviet Union.

Thereafter, each patent retrieved this way had its title, abstract and bibliographic information (Patent Number, Inventors, Applicants, IPC, Priority Number and Cited Patents) saved to a local database. Sorting those patents by applicant, it was possible to define, not only who the applicants in each country were, but also their countries of origin. This was an important step to define the position of each country on biodiesel related technologies on Brazil, China, India and Russia.

The next step was to find the evolution of BRIC over the last 5 decades. In order to do it, the same strategy described before was used in 10 different time spans (1963 – 1970; 1971 – 1975; 1976 – 1980; 1981 – 1985; 1986 – 1990; 1991 – 1995; 1996 – 2000; 2001 – 2005; 2006 – 2010; 2011). Since the DII only has patents from after 1963, that was the inferior limit of the timeframe.

Finally, each patent's title and abstract were read and afterwards classified in one of the technological characteristics, listed in the table 3.

Inventions using Enzymatic process
Inventions using Microalgae
Inventions using Bacteria
Inventions using Fungi
Inventions using Yeast
Inventions using GMO (Genetically Modified Organisms)

Table 3 – Technological characteristics in which the biodiesel patents retrieved from the search were classified.

It still must have to be considered that one patent can be classified on more than one category. For instance, an invention can use genetically modified yeast to accumulate oil and a recombinant lipase to perform the catalysis of this oil, what would put the invention in 3 categories (Enzymatic process, Yeast and GMO).

With all these data in hands, it was possible to perform several comparisons between the technological development of BRIC's countries, such as:

- Evolution of patent filings through the years;
- Distribution of patent filings inside the BRIC;
- Position of the BRIC group in the world;

- Position of the BRIC group as residents and non-residents applicants;
- Role of national and international companies on the BRIC's technological development;
- Participation of non-residents on patent filings;
- See how much those countries use biotechnology, to produce biodiesel.

3.1.2. Ethanol Patents Filter

In order to find only patents related to ethanol technologies – function, production or application as fuel, only - a keyword search on the Derwent Innovation Index was performed. The strategy used thereunto was to search every patent that has on its abstract at least one of the following terms: ethanol, “ethyl alcohol”, bioethanol AND one of the terms fuel, energy, biofuels, renew, combust, cinder, motor, using the Boolean operator OR between the terms, and the Boolean operator AND inside the composite terms, and the wildcard * after each word. So, the strategy used in the advanced search section of Derwent Innovation Index, to retrieve ethanol related patents was

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*))

where TS means that we are searching for the terms after the equal sign in the Title or the Abstract of the patents. The time span for this search was from 01/01/1963 to 09/11/2011.

Doing that, the DII database retrieved 20395 patents from several areas, as listed in the table 4:

Derwent Subject Area	Number of Patents
Chemistry	19187
Engineering	12955
Polymer Science *	9960
Energy & Fuels	7355
Instruments & Instrumentation	6859
Pharmacology & Pharmacy *	3016
Imaging Science & Photographic Technology *	2922
Transportation	2632
Biotechnology & Applied Microbiology	2441
Materials Science *	1810
Food Science & Technology	960
Metallurgy & Metallurgical Engineering *	888
Agriculture	817
Computer Science *	795
General & Internal Medicine *	453
Water Resources	411
Optics *	220
Communication *	211
Nuclear Science & Technology	84
Construction & Building Technology *	67
Mining & Mineral Processing *	47
Public, Environmental & Occupational Health *	27
Sport Sciences *	12

Table 4 - Subject areas of the ethanol related patents retrieved from the Derwent Patent database, using keyword advanced search, as only filter. * Marked areas are unrelated do any ethanol technology.

As can be noticed from table 4, there are several subject areas unrelated to any ethanol fuel technology. This happens because the search results are yet contaminated.

In order to improve this search, every patent belonging to an undesired subject area is excluded. The undesired areas, for this study purposes, are Polymer Science, Pharmacology & Pharmacy, Imaging Science & Photographic Technology, Materials Science, General & Internal Medicine, Computer Science, Metallurgy & Metallurgical Engineering, Optics, Communication, Construction & Building Technology, Nuclear Science & Technology, Mining & Mineral Processing, Sport Sciences and Public, Environmental & Occupational Health. Excluding then from the search, the number of patents left were 6975.

Each one of these patents has at least one IPC code associated, as shown in the table 4.

IPC	Technology Field
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques
A23K *	Feeding-stuffs specially adapted for animals; methods specially adapted for production thereof
A23L *	Foods, foodstuffs, or non-alcoholic beverages, not covered by subclasses a21d or a23b-a23j; their preparation or treatment, e.g. cooking, modification of nutritive qualities, physical treatment; preservation of foods or foodstuffs, in general
A61K *	Preparations for medical, dental, or toilet purposes
A62D *	Chemical means for extinguishing fires; processes for making harmful chemical substances harmless, or less harmful, by effecting a chemical change; composition of materials for coverings or clothing for protecting against harmful chemical agents; composition of materials for transparent parts of gas-masks, respirators, breathing bags or helmets; composition of chemical materials for use in breathing apparatus
B01D	Separation
B01F	Mixing, e.g. dissolving, emulsifying, dispersing
B01J	Chemical or physical processes, e.g. catalysis, colloid chemistry; their relevant apparatus
B05D *	Processes for applying liquids or other fluent materials to surfaces, in general
B09B	Disposal of solid waste
B82B *	Nano-structures formed by manipulation of individual atoms, molecules, or limited collections of atoms or molecules as discrete units; manufacture or treatment thereof

C01B *	Non-metallic elements; compounds thereof
C01F *	Compounds of the metals beryllium, magnesium, aluminium, calcium, strontium, barium, radium, thorium, or of the rare-earth metals
C01G *	Compounds containing metals not covered by subclasses c01d or c01f
C02F	Treatment of water, waste water, sewage, or sludge
C04B *	Lime; magnesia; slag; cements; compositions thereof, e.g. mortars, concrete or like building materials; artificial stone; ceramics; refractories; treatment of natural stone
C05F *	Organic fertilisers not covered by subclasses c05b, c05c, e.g. fertilisers from waste or refuse
C06B *	Explosive or thermic compositions; manufacture thereof; use of single substances as explosives
C06D *	Means for generating smoke or mist; gas-attack compositions; generation of gas for blasting or propulsion (chemical part)
C07B	General methods of organic chemistry; apparatus therefore
C07C	Acyclic or carbocyclic compounds
C07D *	Heterocyclic compounds
C07F *	Acyclic, carbocyclic, or heterocyclic compounds containing elements other than carbon, hydrogen, halogen, oxygen, nitrogen, sulfur, selenium, or tellurium
C07H *	Sugars; derivatives thereof; nucleosides; nucleotides; nucleic acids
C07K *	Peptides
C08B *	Polysaccharides; derivatives thereof
C09B *	Organic dyes or closely-related compounds for producing dyes; mordants; lakes
C09K	Materials for applications not otherwise provided for; applications of materials not otherwise provided for
C10G	Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation; recovery of hydrocarbon oils from oil-shale, oil-sand, or gases; refining mixtures mainly consisting of hydrocarbons; reforming of naphtha; mineral waxes
C10J *	Production of producer gas, water-gas, synthesis gas from solid carbonaceous material, or mixtures containing these gases; carburetting air or other gases
C10K *	Purifying or modifying the chemical composition of combustible gases containing carbon monoxide
C10L	Fuels not otherwise provided for; natural gas; synthetic natural gas obtained by processes not covered by subclasses c10g or c10k; liquefied petroleum gas; use of additives to fuels or fires; fire-lighters
C10M *	Lubricating compositions; use of chemical substances either alone or as lubricating ingredients in a lubricating composition

C10N *	Indexing scheme associated with subclass C10M
C11B *	Producing, e.g. by pressing raw materials or by extraction from waste materials, refining or preserving fats, fatty substances, e.g. lanolin, fatty oils or waxes; essential oils; perfumes
C11C *	Fatty acids from fats, oils or waxes; candles; fats, oils or fatty acids by chemical modification of fats, oils, or fatty acids obtained therefrom
C11D *	Detergent compositions; use of single substances as detergents; soap or soap-making; resin soaps; recovery of glycerol
C12C *	Brewing of beer
C12F *	Recovery of by-products of fermented solutions; denaturing of, or denatured, alcohol
C12G *	Wine; other alcoholic beverages; preparation thereof
C12H *	Pasteurisation, sterilisation, preservation, purification, clarification, ageing of alcoholic beverages or removal of alcohol therefrom
C12M	Apparatus for enzymology or microbiology
C12N	Micro-organisms or enzymes; compositions thereof; propagating, preserving, or maintaining micro-organisms; mutation or genetic engineering; culture media
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
C12R	Indexing scheme associated with subclasses c12c-c12q or c12s, relating to micro-organisms
C13K	Saccharides, other than sucrose, obtained from natural sources or by hydrolysis of naturally occurring di-, oligo- or polysaccharides
C25B *	Electrolytic or electrophoretic processes for the production of compounds or non- metals; apparatus therefor
C30B *	Single-crystal growth; unidirectional solidification of eutectic material or unidirectional demixing of eutectoid material; refining by zone-melting of material; production of a homogeneous polycrystalline material with defined structure; single crystals or homogeneous polycrystalline material with defined structure; after-treatment of single crystals or a homogeneous polycrystalline material with defined structure; apparatus therefore
F01N *	Gas-flow silencers or exhaust apparatus for machines or engines in general; gas-flow silencers or exhaust apparatus for internal-combustion engines
F02B *	Internal-combustion piston engines; combustion engines in general
F02D	Controlling combustion engines
F02M *	Supplying combustion engines in general with combustible mixtures or constituents thereof
F23D *	Burners
F24C *	Other domestic stoves or ranges; details of domestic stoves or ranges, of general application

G01N	Investigating or analysing materials by determining their chemical or physical properties
H01B *	Cables; conductors; insulators; selection of materials for their conductive, insulating, or dielectric properties
H01L *	Semiconductor devices; electric solid state devices not otherwise provided for
H01M *	Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
H05B *	Electric heating; electric lighting not otherwise provided for

Table 5 – IPC subclasses retrieved on the first keyword advanced search on ethanol production related patents. * Marked IPC are unrelated do any ethanol technology.

There are several IPC subclasses unrelated to ethanol production and its function, usage or application as fuel. To eliminate the contaminants from this search, the unrelated subclasses were also excluded from the results. The subclasses left are shown on the table 5.

IPC	Technology Field
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques
B01D	Separation
B01F	Mixing, e.g. dissolving, emulsifying, dispersing
B01J	Chemical or physical processes, e.g. catalysis, colloid chemistry; their relevant apparatus
B09B	Disposal of solid waste
C02F	Treatment of water, waste water, sewage, or sludge
C07B	General methods of organic chemistry; apparatus therefore
C07C	Acyclic or carbocyclic compounds
C09K	Materials for applications not otherwise provided for; applications of materials not otherwise provided for
C10G	Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation; recovery of hydrocarbon oils from oil-shale, oil-sand, or gases; refining mixtures mainly consisting of hydrocarbons; reforming of naphtha; mineral waxes
C10L	Fuels not otherwise provided for; natural gas; synthetic natural gas obtained by processes not covered by subclasses c10g or c10k; liquefied petroleum gas; use of additives to fuels or fires; fire-lighters
C12M	Apparatus for enzymology or microbiology

C12N	Micro-organisms or enzymes; compositions thereof; propagating, preserving, or maintaining micro-organisms; mutation or genetic engineering; culture media
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
C12Q	Measuring or testing processes involving enzymes or micro-organisms; compositions or test papers therefor; processes of preparing such compositions; condition-responsive control in microbiological or enzymological processes
C12R	Indexing scheme associated with subclasses c12c-c12q or c12s, relating to micro-organisms
C13K	Saccharides, other than sucrose, obtained from natural sources or by hydrolysis of naturally occurring di-, oligo- or polysaccharides
F02D	Controlling combustion engines
G01N	Investigating or analysing materials by determining their chemical or physical properties

Table 6 - IPC subclasses retrieved on the first keyword advanced search on ethanol production related patents, without unrelated ICP subclasses.

Hereafter, the same strategy was used to Brazil, China, India and Russia, individually. For such, the search was narrowed to find only the patents that had on its number the codes BR, PI, BRPI, MU, BRMU (Brazilian patents), CN (Chinese patents), IN (Indian patents), RU and SU (Russian and Soviet patents). Thus, 4 search strategies were developed, as described below

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(BR* or PI* or BRPI* or MU* or BRMU*)

to find patents filed in Brazil;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(CN*)

to find patents filed in China;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(IN*)

to find patents filed in India;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(RU* or SU*)

to find patents filed in Russia or Soviet Union.

Then, each one of the retrieved patents had its title, abstract and bibliographic information (Patent Number, Inventors, Applicants, IPC, Priority Number and Cited Patents) saved to a local database. Sorting those patents by applicant, it was possible to define, not only who the applicants in each country were, but also their countries of origin. This was an important step to define the position of each country on ethanol related technologies on Brazil, China, India and Russia.

The next step was to find the evolution of BRIC over the last 5 decades. So, the same strategy described before was used in 10 different time spans (1963 – 1970; 1971 – 1975; 1976 – 1980; 1981 – 1985; 1986 – 1990; 1991 – 1995; 1996 – 2000; 2001 – 2005; 2006 – 2010; 2011). Since the DII only has patents from after 1963, that was the inferior limit of the timeframe.

Finally, each patent's title and abstract were read and afterwards classified in one of the technological characteristics, listed in the table .

Inventions using Enzymatic process
Inventions using Sugar Cane as primary raw material
Inventions using Corn as primary raw material

Inventions using GMO (Genetically Modified Organisms)
Inventions related to Second or Third Generation Ethanol

Table 7 - Technological characteristics in which the ethanol patents retrieved from the search were classified.

It is important to point that one patent can be classified on more than one category. For instance, an invention can use genetically modified yeast with better yields of ethanol production to ferment glucose from cellulose hydrolyzed in the pre-treatment of the raw materials, which would put the invention on 3 different categories (enzymatic process, GMO and Second Generation Ethanol).

With all these data in hands, it was possible to perform several comparisons between the technological developments of BRIC's countries, such as:

- Evolution of patent filings through the years;
- Distribution of patent filings inside the BRIC;
- Position of the BRIC group in the world;
- Position of the BRIC group as residents and non-residents applicants;
- Role of national and international companies on the BRIC's technological development;
- Participation of non-residents on patent filings;
- See how much those countries use biotechnology, to produce biodiesel.

3.2. Search for Scientific Publications

To do a comparison between the countries of BRIC, in terms of development in both ethanol and biodiesel related technologies, it was used, besides the number of patents each country has been filing, the number of scientific articles they have been publishing.

3.2.1. Biodiesel

Basically, the same strategy used for the patent search was used here. So, the strategy terms used to find Biodiesel scientific publications on the Web Of Science SM database, was the following:

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(BR* or PI* or BRPI* or MU* or BRMU*)

to find patents filed in Brazil;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(CN*)

to find patents filed in China;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(IN*)

to find patents filed in India;

TS=(biodiesel* or fame or (alkyl* and ester*) or (fatty* and acid* and methyl* and ester*)) AND PN=(RU* or SU*)

to find patents filed in Russia or Soviet Union.

This was performed for the same time spans used on the biodiesel patent search.

3.2.2. Ethanol

Basically, the same strategy used for the patent search was used here. So, the strategy terms used to find Ethanol, as fuel, scientific publications on the Web Of Science SM database, was the following:

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(BR* or PI* or BRPI* or MU* or BRMU*)

to find patents filed in Brazil;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(CN*)

to find patents filed in China;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(IN*)

to find patents filed in India;

TS=(ethanol* or (ethyl* and alcohol*) or bioethanol* and (fuel* or energy* or biofuels* or renew* or combust* or cinder* or motor*)) AND PN=(RU* or SU*)

to find patents filed in Russia or Soviet Union.

This was performed for the same time spans used on the ethanol patent search.

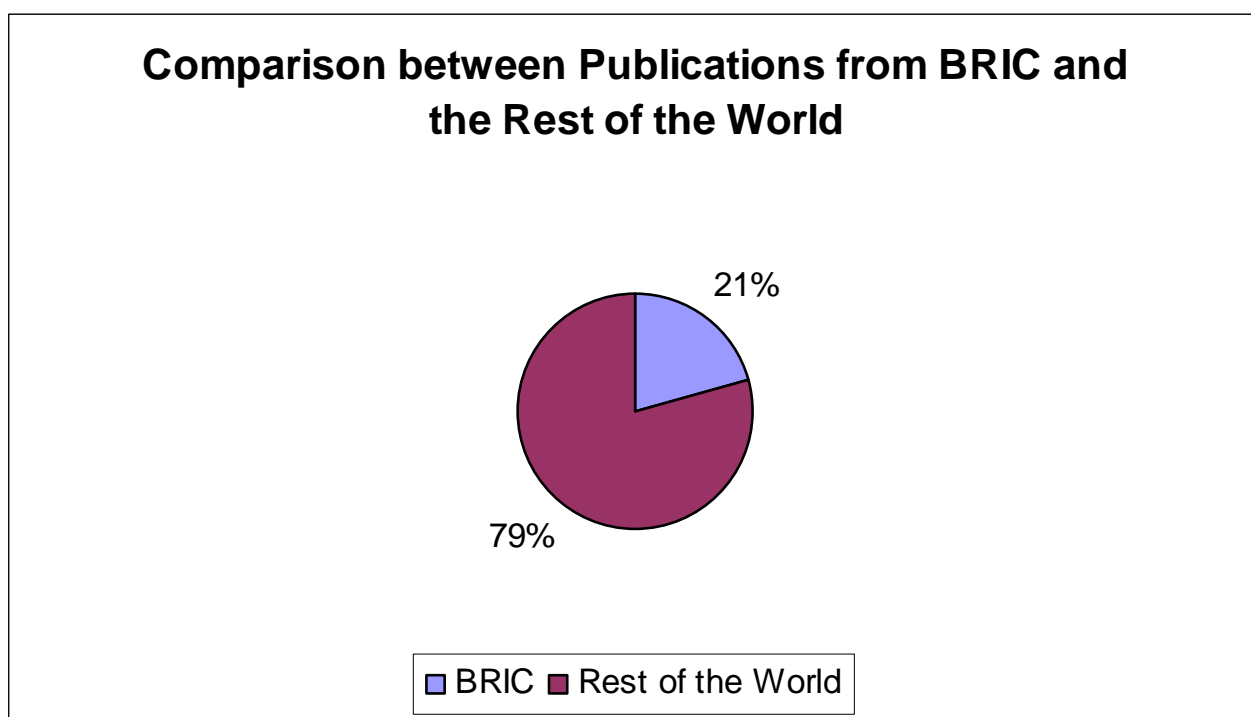
4. RESULTS AND DISCUSSION

4.1. Biodiesel

Initially it is going to be presented the numbers retrieved from the analysis of biodiesel patents and scientific publications, detailing the situation of each country individually and a general overview.

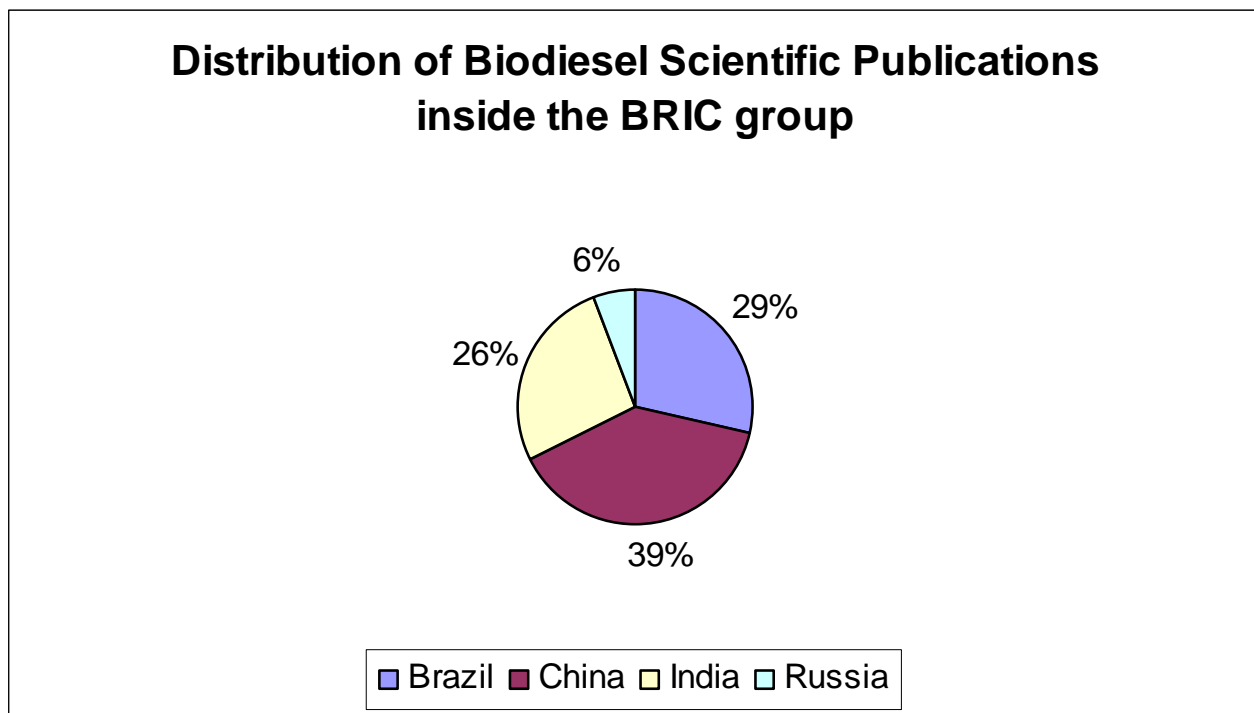
4.1.1. Scientific Publications

The retrieval of scientific publications made using the methodology presented in the chapter 3.2, returned us a total of 13456 objects, of which 769 were Brazilian, 1094 were Chinese, 729 were Indian and 166 were Russian. So, the BRIC group was responsible for more than 20% of all scientific publications on the world, from 1963 to 2011, as shown in the graphic 2.



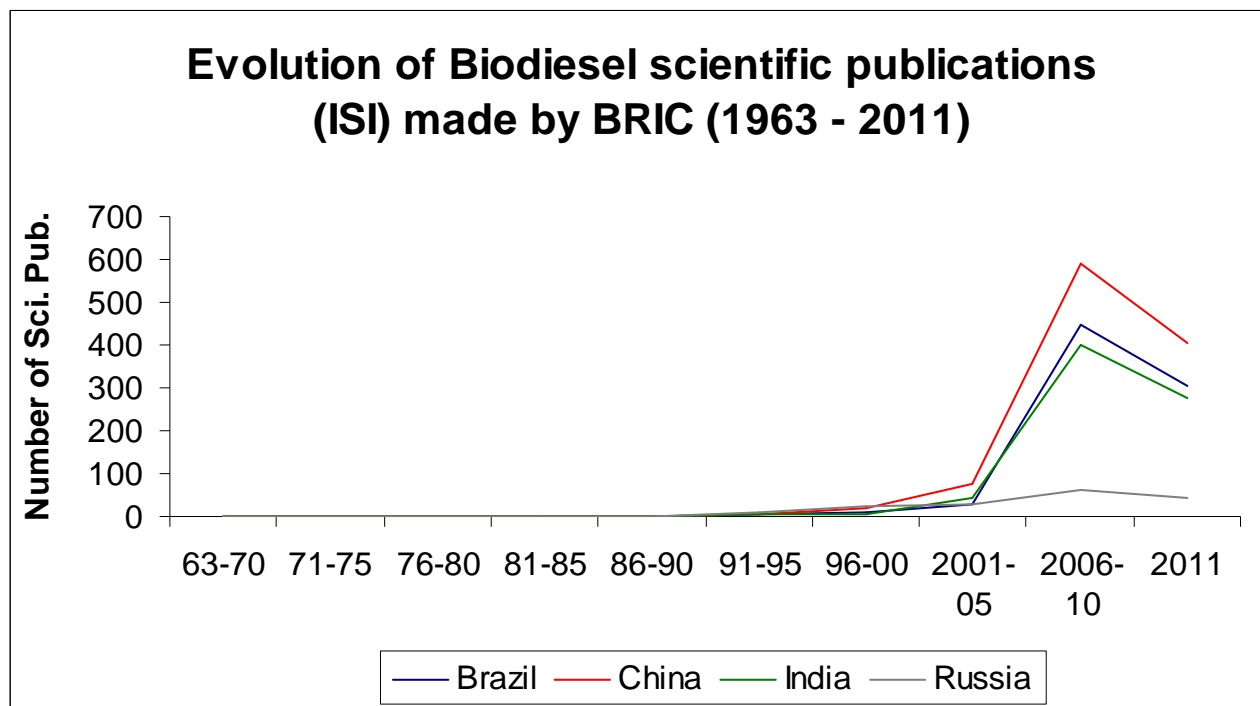
Graphic 2 –Role of the BRIC group in the scientific publications made in the world, from 1963 – 2011. We can see by this graphic that the BRIC group is responsible for more than 20% of the total scientific publications in the world, in regard of biodiesel advances.

From the graphic 3, it can be noticed that, despite the leadership of China, Brazil (29%), China (39%) and India (26%) are balanced on the advances in biodiesel technology, when taking in consideration the number of scientific publications on the area. Russia (6%) still lags behind the other companions of the BRIC group.



Graphic 3 – Role of each BRIC country on publishing articles related to advances in Biodiesel. It is possible to notice from this graphic that, excluding Russia, the remaining countries are balanced on this criteria, even though the leadership of China is considerable.

Graphic 4 presents the evolution of those publications from 1963 – 2011. It is well evident that the scientific publications on the area started to grow in the mid 1990's, when the search for alternative sources of fuel became more important. There is another inflexion point at the beginning of the 21st century, representing that the biodiesel technology became one of the main focus of the nowadays research priorities. Also, the number of scientific publications made in 2011 alone is almost as big as the number from 2006 to 2010.

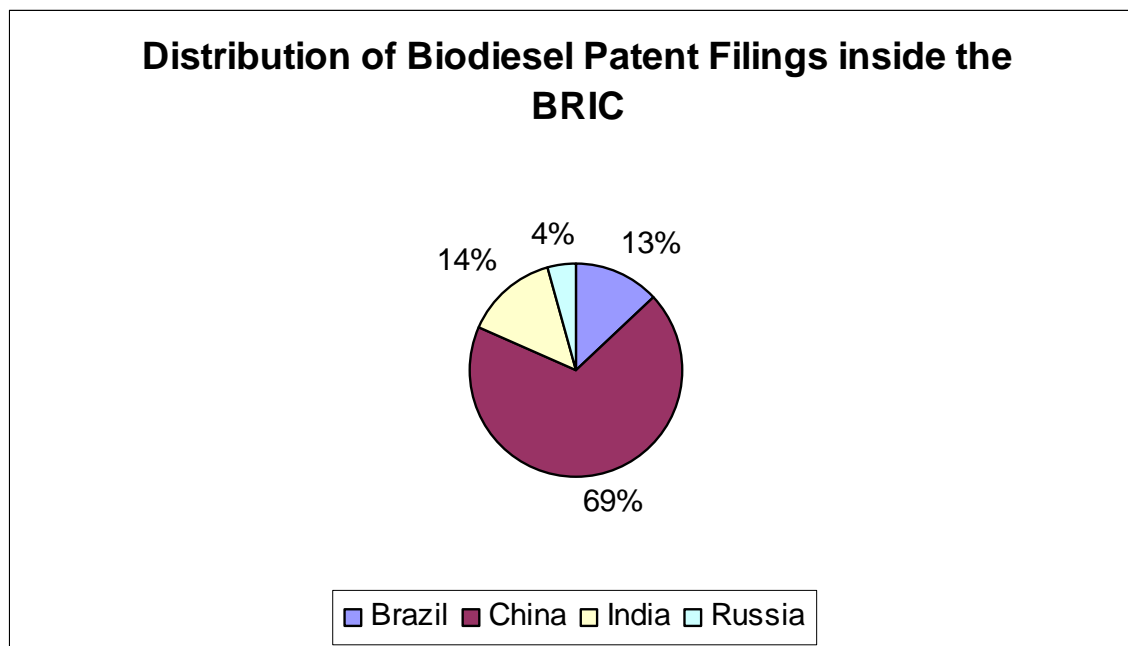


Graphic 4 – The evolution of Biodiesel scientific publications made by BRIC started growing in the mid 1990's, reaching an inflexion point at the beginning of the years 2000, and show a strong tendency on continue growth in 2011. Also, It is possible to see that Brazil, China and India developed together in all those years. Russia started well on the mid 90's and stayed behind on the beginning of the years 2000.

It is also noticeable that Russia started developing together with its companions, but stayed behind from 2000 ahead.

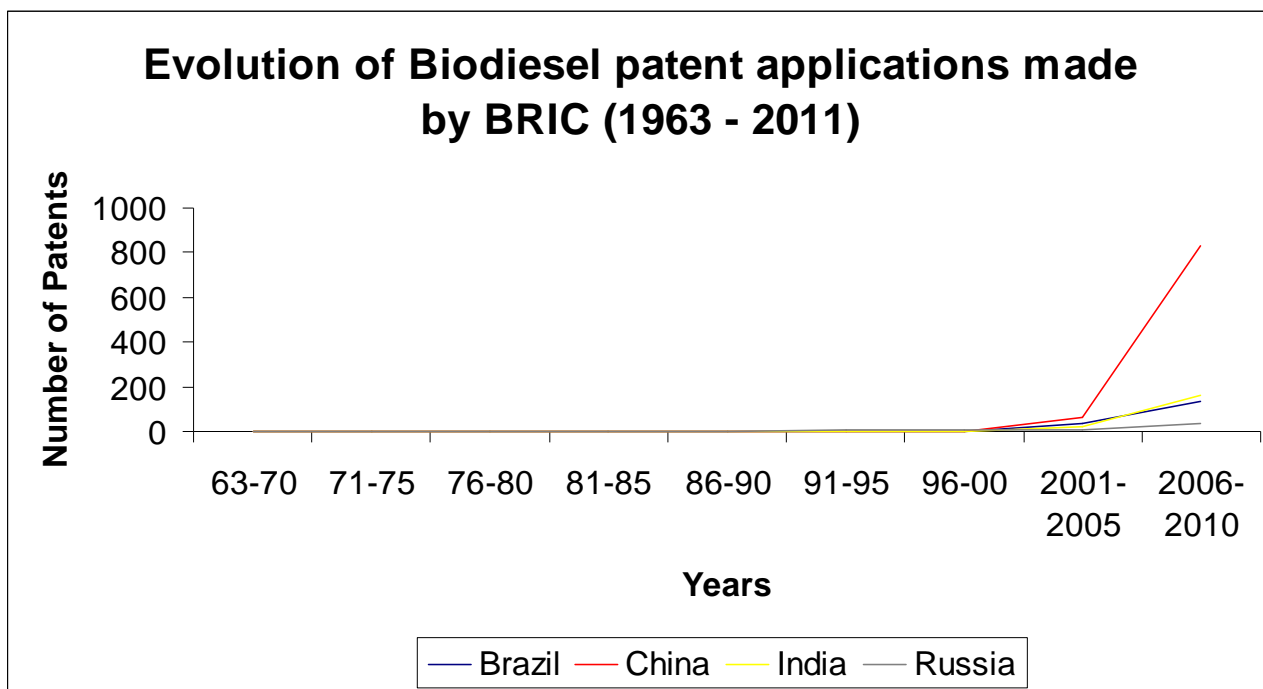
4.1.2. Patents

The search for patents, as described on the chapter 3.1.1, retrieved 2753 patents filed in the world, in which, in Brazil were filed 186, in China 973, in India 196 and in Russia 62. Hence, the BRIC group received 1417 Biodiesel patent filings, from 1963 to 2011. Those filings were not necessarily made by resident applicants, so these numbers still does not represent the advances the cited countries are making in biodiesel technology. In graphic 5, we can see that China remains as the most searched country, inside the BRIC group, for patent filings. It will be possible to see afterwards if this number is coherent with the patent filings made by China and the other 3 countries of BRIC.



Graphic 5 – The distribution of patent filings in the BRIC group show us that China has more patent filings than the other 3 countries combined.

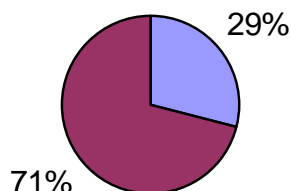
Graphic 6 shows how the number of patents filed in the BRIC group grew since 1963 until nowadays. As it happened with the scientific publications, the number remained steady until the mid 90's and reached an inflexion point at the beginning of the years 2000. However, Brazil and India did not follow China's development the same way they did, regarding scientific publications. When it comes to patents, China grew almost 13 times from 2005 ahead in comparison to the period before, while Brazil, India and Russia showed much lesser growth rates at the same period (Brazil – almost 4 times more; India – about 7 times more; Russia – almost 6 times more).



Graphic 6 – The evolution of biodiesel patent filings made by BRIC is similar to the scientific publication’s evolution, except for the China’s participation. It developed way more than its companions from 2005 ahead, reaching almost 5 times more patents than India, which comes in second place.

It is necessary to point out that those numbers presented before are only for filing of patents on the national Patent and Trademark Offices (PTOs) from Brazil, China, India and Russia. An important data, that is possible to see afterwards, is the proportion between resident and non-resident filings on each of these PTOs. Considering this data, the graphic 7 is able to show a comparison of filing of patents made by the BRIC countries together and the ones made by the rest of the world. The number (29%) is a little higher than the one found for scientific publications.

Comparison of Biodiesel Patents Filed by BRIC Countries and Countries From the Rest of the World

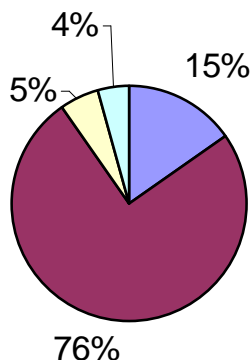


Rest of World BRIC

Graphic 7 – Comparing the patent filings made by the BRIC countries and countries from the rest of the world, we can see that BRIC plays an important role on biodiesel technological development, with almost 30% of all patents filed in the world.

Excluding the non-residents applicants from the results the distribution of patent filings inside the BRIC group changes a lot, as can be seeing in the graphic 8. China increases its leadership, while Brazil overcome India and takes the second place. As can be noticed, India has a similar technological development with Russia, while Brazil stands on a different level between then and China.

Distribution of Biodiesel BRIC patent filings by residents in their countries of origin



■ Brazil ■ China ■ India ■ Russia

Graphic 8 – The distribution of patent filings from BRIC countries, excluding non-resident filings, presents us a new scenario, in which China extends its leadership and Brazil takes over the second place that belong to India, when we consider the non-resident filings.

The next pages it will be discussed the situation of each country individually.

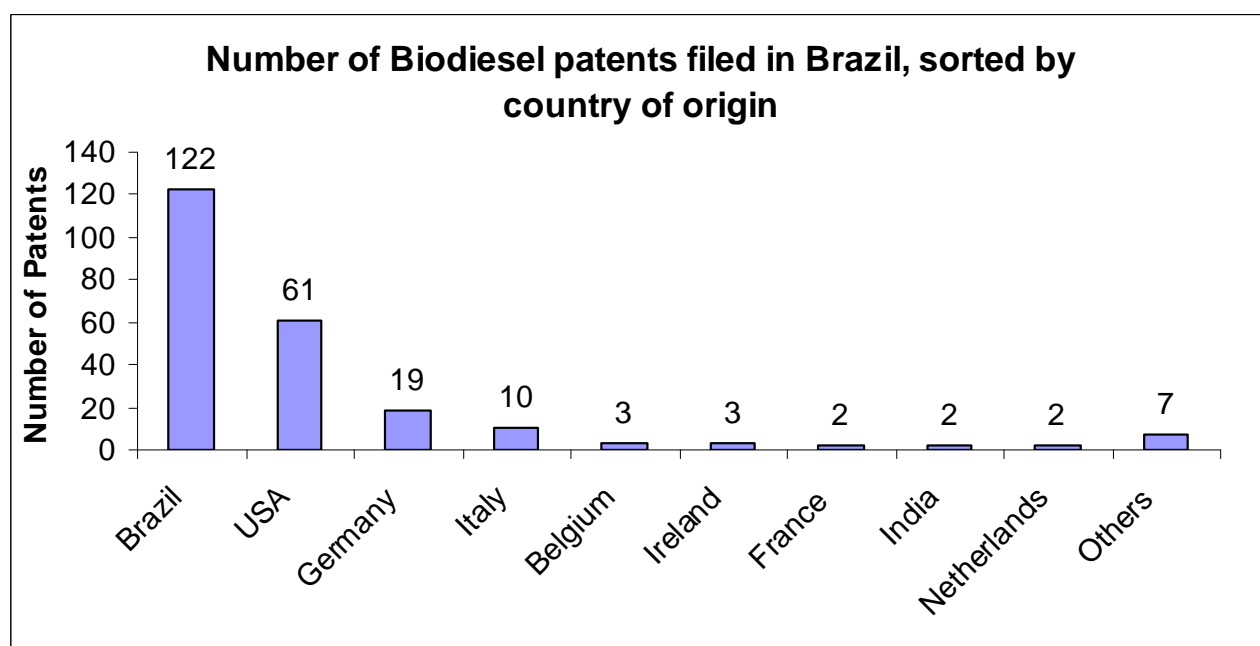
4.1.2.1. Brazil

In order to measure the technological development of Brazil, using patents as reference, it must be considered that a lot of patents filed in the Brazil's PTO are not from Brazil. Therefore, the graphic 9 shows the countries that appears most on patent filings in Brazil's PTO. A total of 11 countries filed at least one biodiesel related patent. Those countries are listed on table 8.

Country of Origin	Number of Patents
Austria	1
Belgium	3
Brazil	122
Cayman Island	1

Denmark	1
France	2
Germany	19
Hungary	1
India	2
Ireland	3
Italy	5
Japan	1
Netherlands	2
Sweden	1
Switzerland	1
USA	61

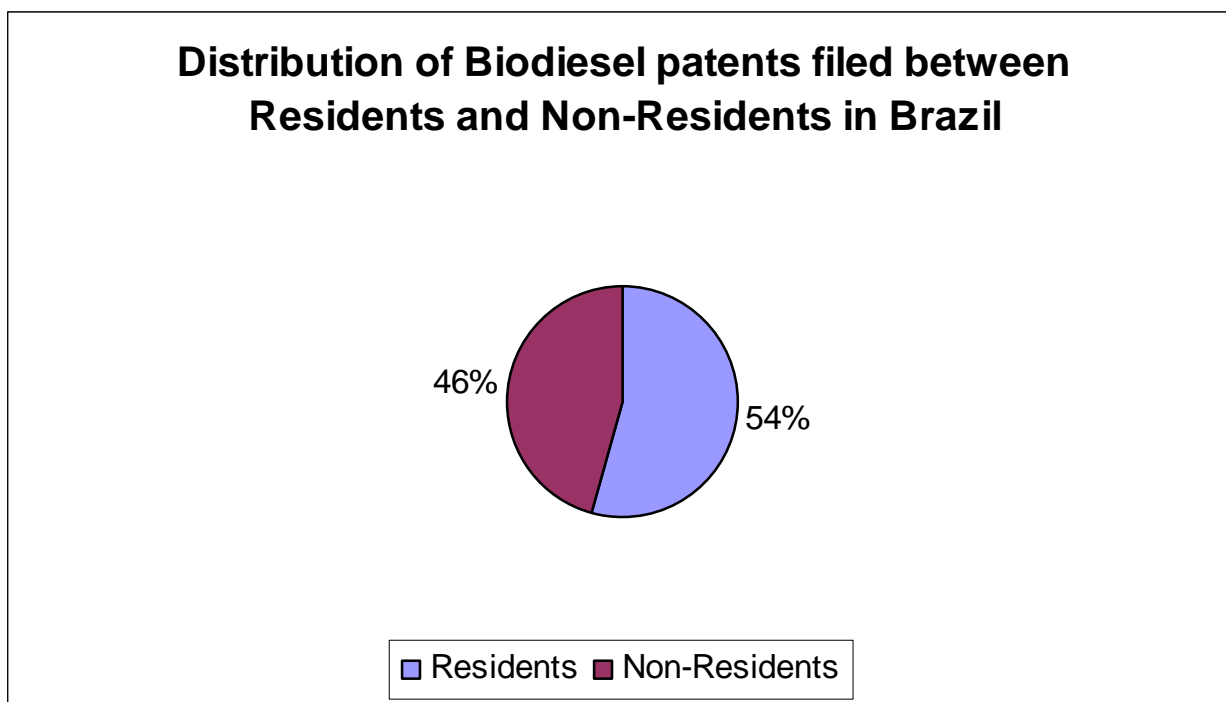
Table 8 – Countries with at least one patent filing in Brazilian PTO. The participation of Brazil and USA here is clearly dominant.



Graphic 9 – By this graphic we can see the leadership of Brazil, and the countries that has at least 2 patent applications in Brazil.

Analyzing the graphic 9 and table 8, it is noticeable that patents filed in Brazil are mostly made by resident applicants. In fact, Brazilian applicants alone filed more

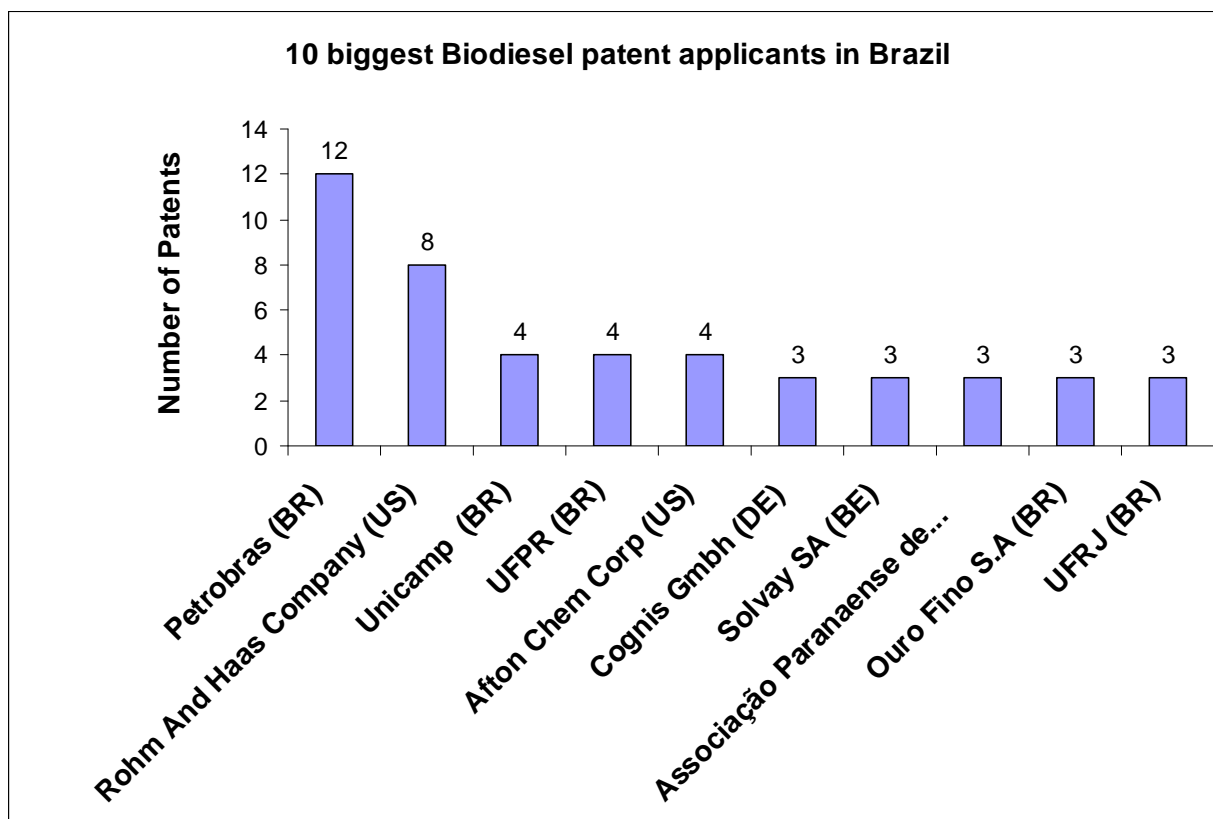
patents than all applicants from other countries. The graphic 10 shows that in percentage numbers.



Graphic 10 – Brazilian resident applicants dominate patent filings in their own country.

That is a clear evidence of, at least an effort of the Brazilian technological development in the area, since Brazil is also considered as one of the biggest markets for biofuels. Thus, it was expected that Brazil would have been chosen as priority for companies that develop new technologies in this area. Despite that fact, Brazil still leads the filings in its own market.

Another important evidence of Brazilian technological development is that from the 10 biggest applicants, 6 are from Brazil, including the leader PETROBRAS. Unites States of America has 2 representatives, a Germany and a Belgium company completes the list, as shown on the graphic 11.

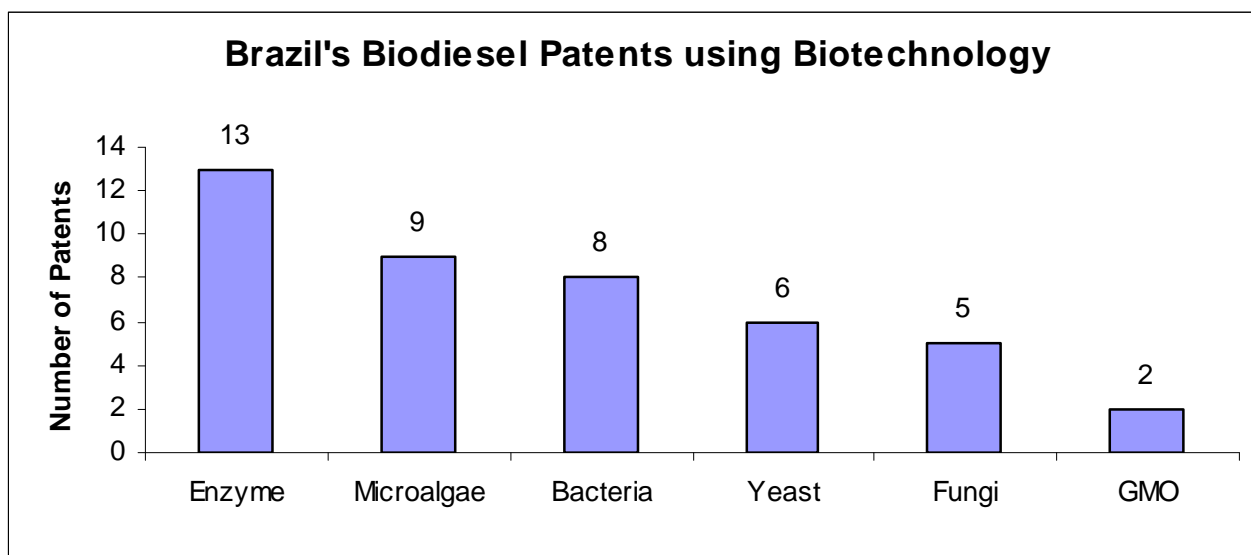


Graphic 11 - From the 10 biggest patent applicants in Brazil, only 4 are non-Brazilians. PETROBRAS is leader with a fair advantage from Rohm and Haas, from USA. Another important fact we can see on this graphic is that 4 Brazilian applicants are Universities and only two are companies, in which one is private and one is public.

It is interesting to notice that only one Brazilian private company appears on the list shown on graphic 11, Ouro Fino SA. While Petrobras is a Brazilian state oil company, Unicamp, UFPR and UFRJ are public universities and Associação Paranaense de Cultura is the legal representative of the Catholic University of Paraná, a Brazilian private university. This shows that even though Brazil develops new technologies related to biodiesel, it is not fully prepared to fuel the market with its products, since universities only aim to transfer technologies to the productive sector, not being able to produce and sell any sort of products.

Regarding the use of biotechnology in the development of biodiesel related technologies, the graphic 12 shows that Brazil is focusing in two different areas:

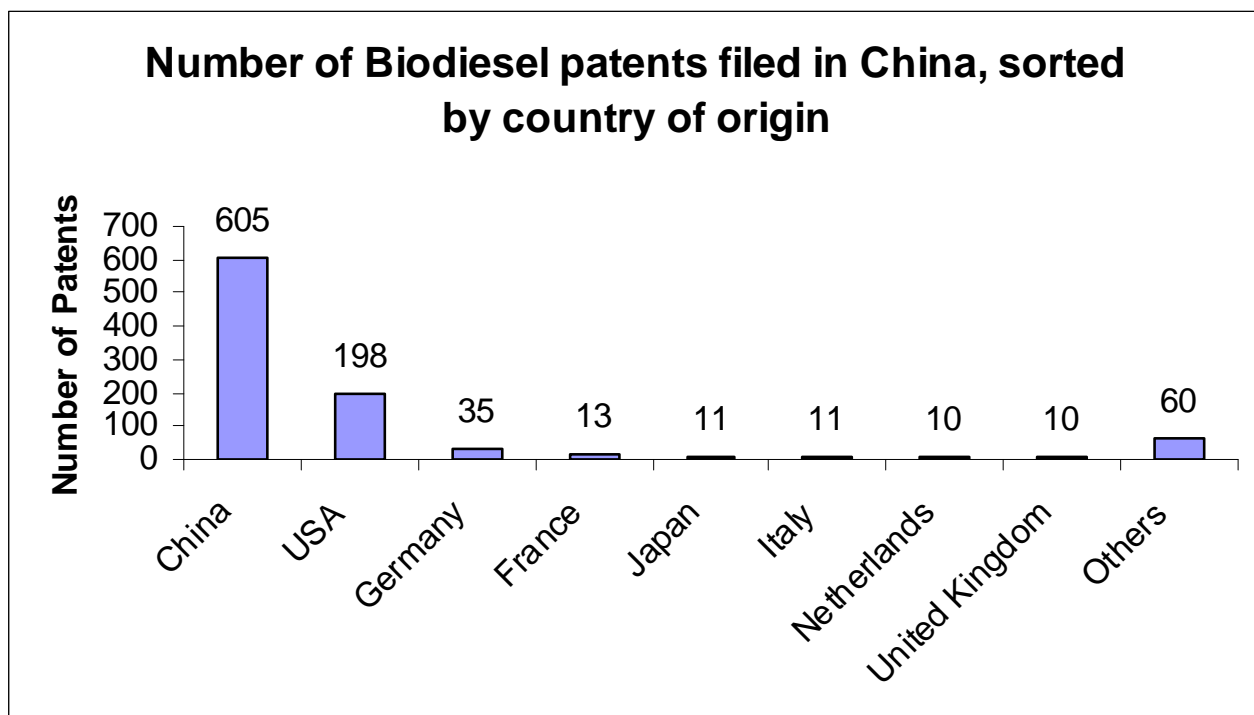
enzymatic catalysis of the transesterification and microalgae fermentation, to produce oils. It is also possible to see that Brazil does not develop much technology regarding Genetically Modified Organisms, to produce Biodiesel.



Graphic 12 – Brazil is highly interested in using biotechnology to perform enzymatic catalysis of oils, as we can see on this graphic. Also, the use of microalgae fermentation to produce oils in a more sustainable way is of utter interest for Brazil. However, the use of GMOs is not a priority for Brazil up to this moment.

4.1.2.2. China

As Brazil, China is considered as a great market for biodiesel, since it is one of the biggest economies in the world, nowadays. So, it is important to take a look at the non-residents patent applicants numbers, before draw any conclusion about China's development. Graphic 13 shows the countries that appears most on patent filings in Chinese PTO.



Graphic 13 – By this graphic it is easy to see how China leads biodiesel patent filings in its own country. USA comes in second place, but with less than one third of its main rival. Brazil, India and Russia does not appear on the top 10 applicants.

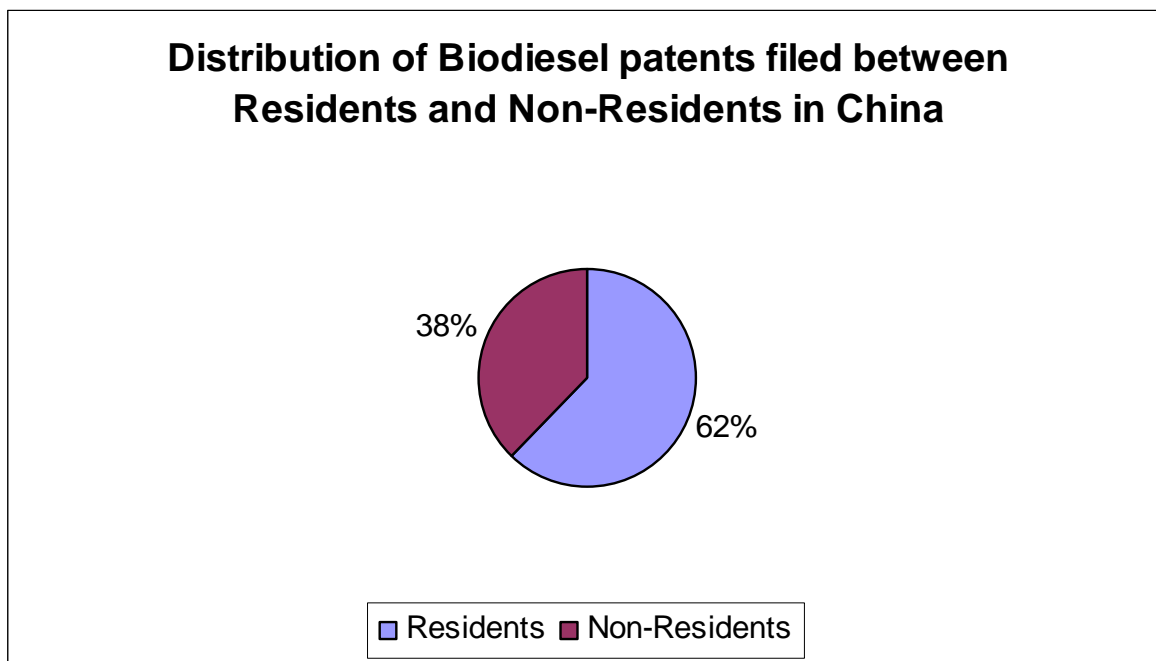
A total of 26 countries filed at least one biodiesel related patent. Those countries are listed on table 9.

Country of Origin	Number of Patents
Australia	8
Austria	2
Belgium	7
Brazil	5
Canada	9
China	605
Denmark	9
Finland	5
France	13
Germany	35

Hungary	2
India	1
Ireland	7
Israel	9
Italy	11
Japan	11
Malaysia	3
Netherlands	10
New Zealand	1
Poland	3
South Korea	1
Spain	1
Sweden	2
Switzerland	5
United Kingdom	10
USA	198

Table 9 – Every country that has at least one patent application in China’s PTO. China and USA are responsible for more than 80% of the total filings.

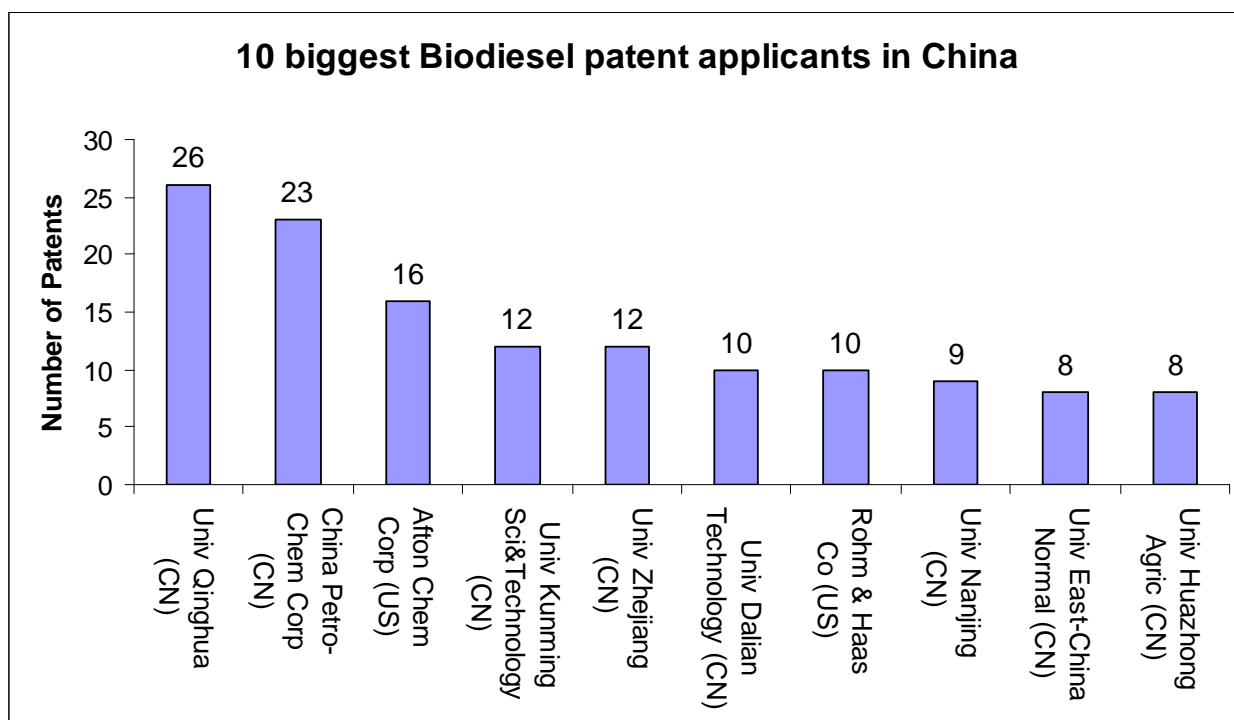
Analyzing the graphic 13 and table 9, it is possible to see that most of the patents in China are filed by resident applicants. In fact, Chinese applicants alone filed almost twice more patents than all applicants from other countries together. Graphic 14 shows that in percentage numbers.



Graphic 14 –Chinese resident applicants dominate patent filings in their own country.

With this numbers it is quite clear that China is not only a big market for biodiesel, but also an important supplier of new technologies in the area. The fact that they have more than 3 times more patent applications than USA in their own PTO shows their sovereignty in protecting biodiesel technologies nationally.

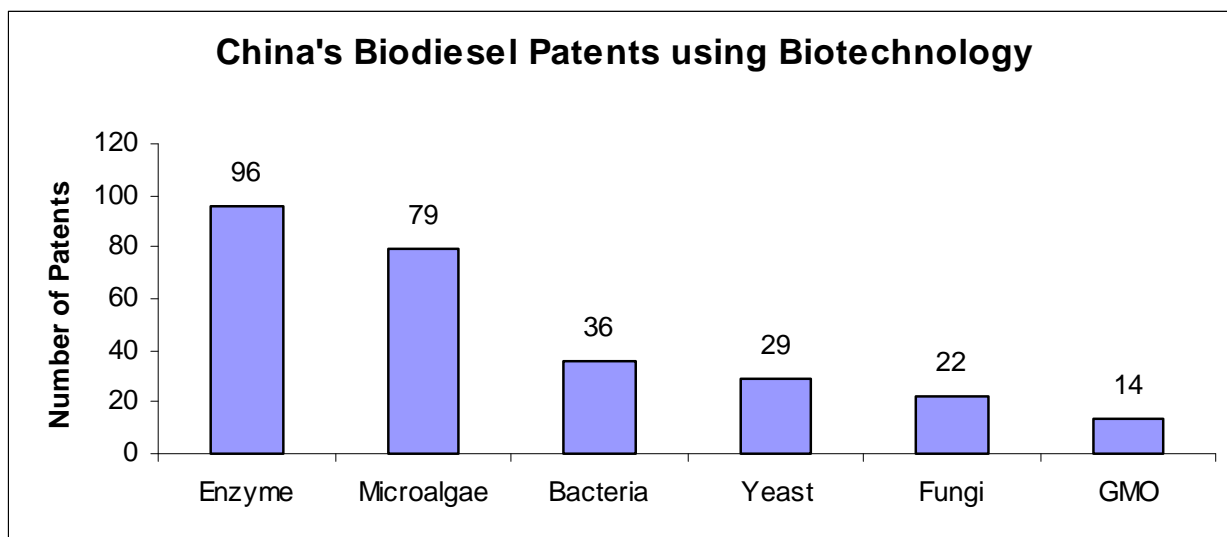
Another important evidence of Chinese technological development is that from the 10 biggest applicants, 8 are Chinese. Unites States of America has 2 representatives only, as shown on the graphic 15.



Graphic 15 - 8 Chinese companies are among the 10 biggest applicants in China. However 7 of them are universities. USA is represented by two multinational companies, that appear also in the Brazilian scenario.

As Brazil, China has more universities developing biodiesel technologies. From the 8 Chinese companies shown by the graphic 15, only one is not a university. So, China still has to make these technologies to the industry, transforming its enormous potential into capacity of production.

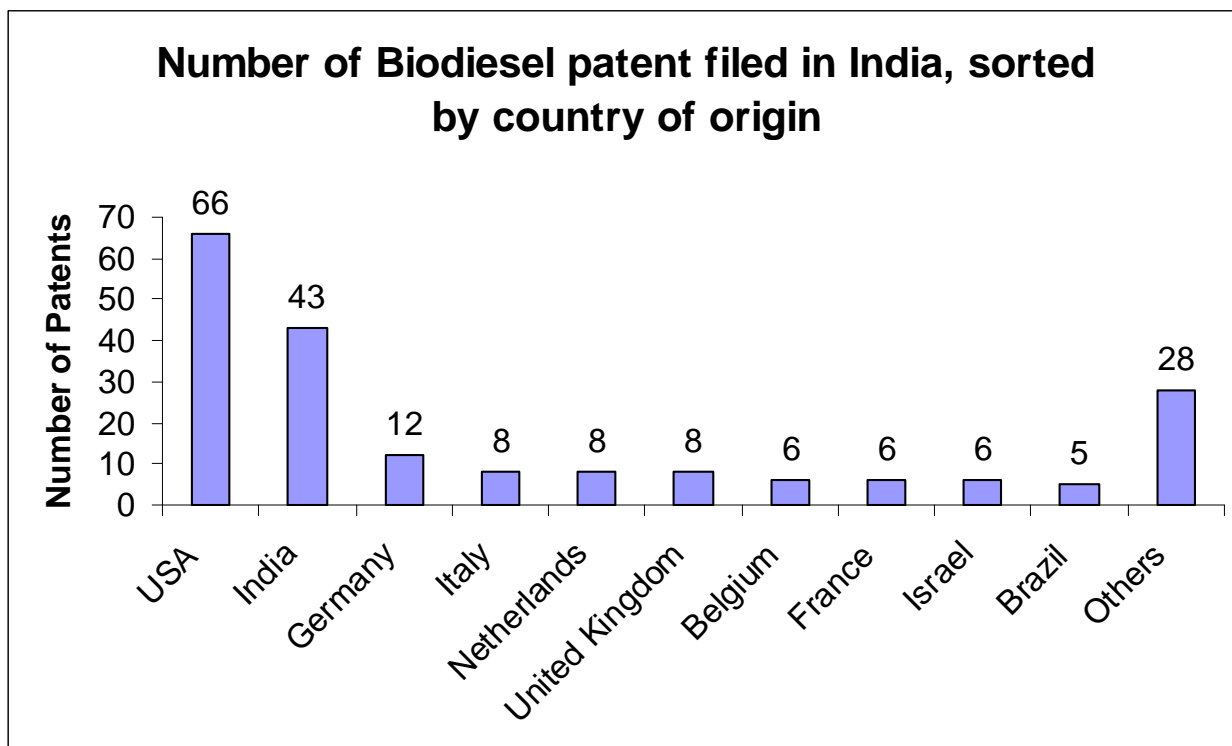
Regarding to the use of biotechnology in the development of biodiesel related technologies, graphic 16 shows that China has a similar focus than Brazil. It is obvious that China has more impressive absolute numbers, but relatively to its total numbers, the development is quite similar.



Graphic 16 – China is highly interested in using biotechnology to perform enzymatic catalysis of oils, as we can see on this graphic. Also, the use of microalgae fermentation to produce oils in a more sustainable way is of utter interest for China.

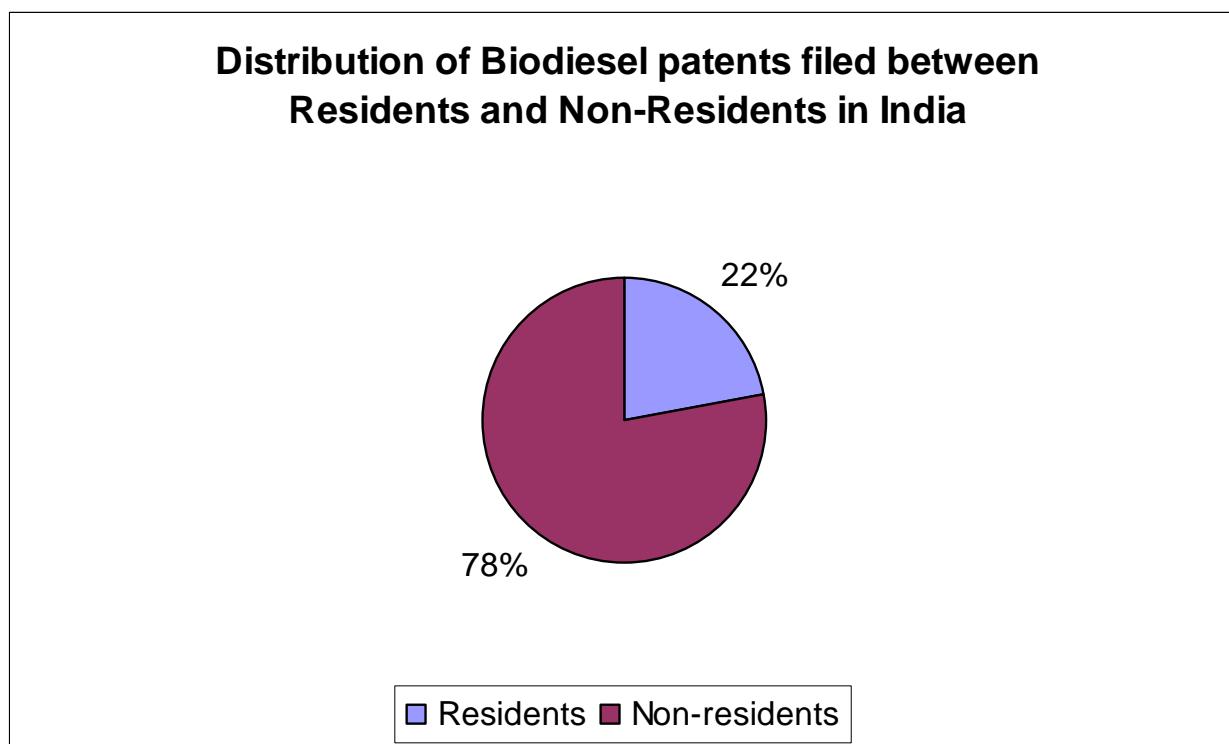
4.1.2.3. India

Differently from Brazil and China, India does not lead patent filings in its own country. USA has the leadership in that country and several other countries have at least one filing there. Graphic 17 shows this data properly.



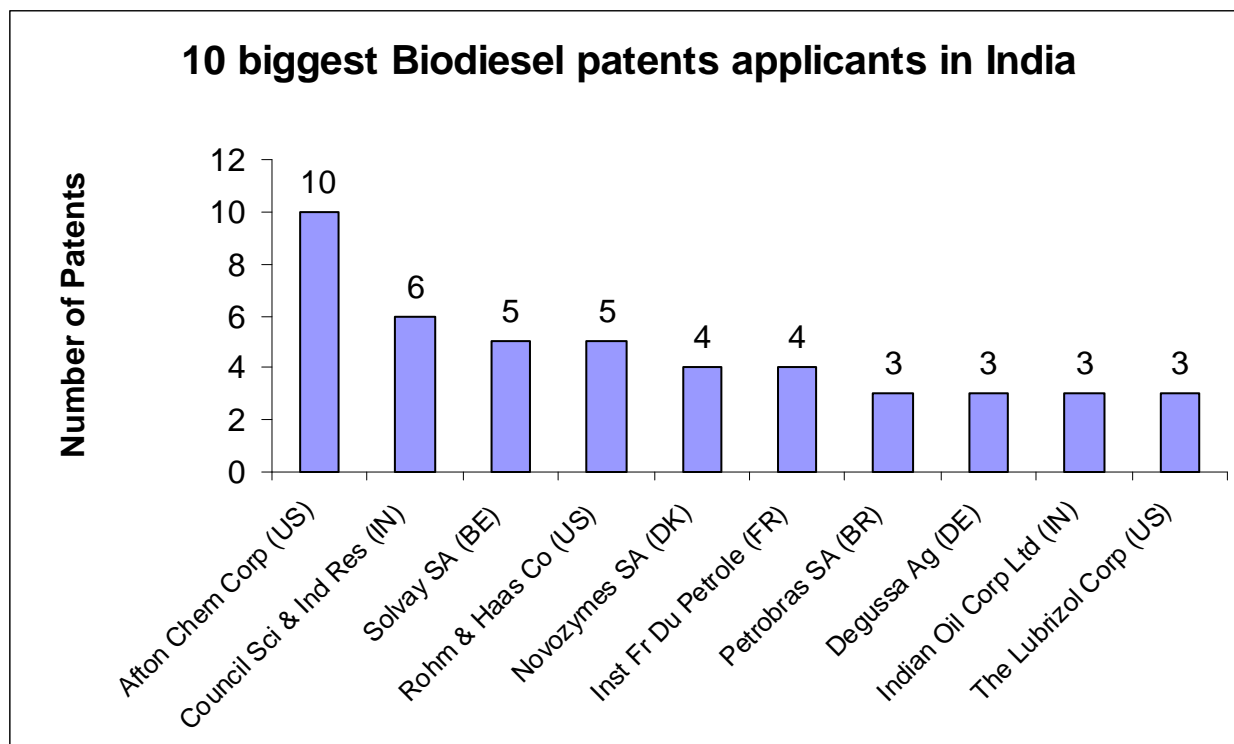
Graphic 17 – USA is the country that filed more biodiesel patents in India, up to now. India comes in second place, reaching the worst result among the BRIC countries, in regarding the proportion between residents and non-residents filings.

This numbers define India as a potential market for biodiesel, since a lot of international companies seek protection for their technologies there. Still, India shows modest numbers in their own country, demonstrating that they are not taking biodiesel as a priority, currently. To confirm this thesis, graphic 18 shows a comparison amongst the number of patents filed in India by residents and non-residents. As seen, non-residents filed almost 4 times more patents than residents in India



Graphic 18 – The comparison of biodiesel patent filings from residents and non-residents in India, highlights that it assumes the role of a consumer market, only.

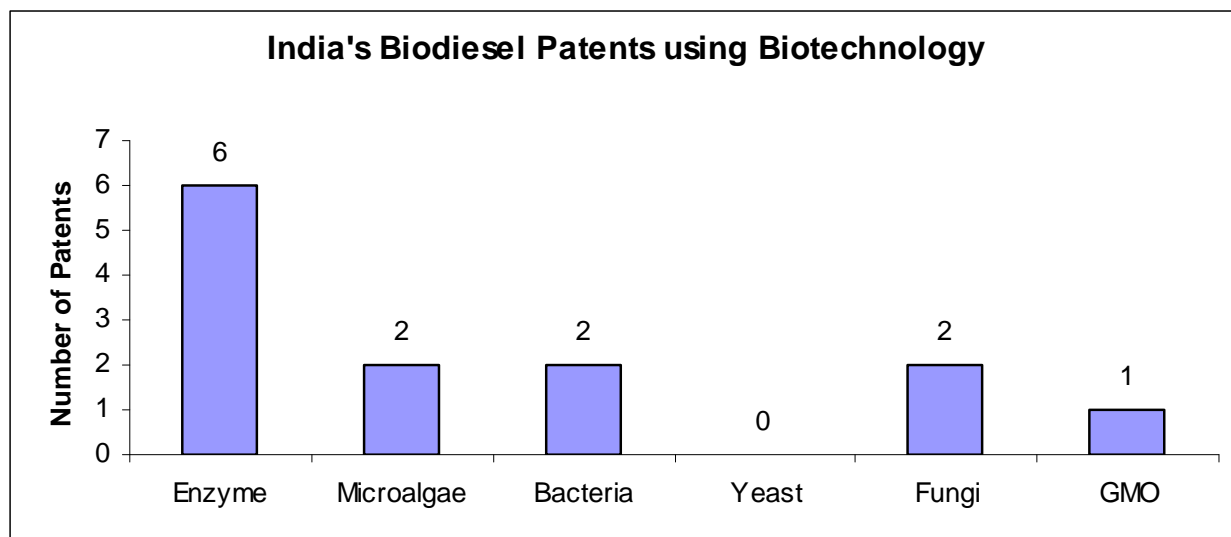
As expected, only 2 of the biggest 10 applicants are Indian. This country shows the more diverse origin of applicants, among BRIC's members. From the top 10 applicants, 2 are residents, 3 are from USA, 1 is Belgium, 1 is from Denmark, 1 is French, 1 is Brazilian and 1 is German.



Graphic 19 – Main companies that seek protection for their inventions on biodiesel, in India. The resident country only have 2 companies on the top 10 applicants, what evince their less than average development in the area.

It is interesting to point out that Brazil appears for the first time as a significant non-resident applicant inside BRIC, as well as PETROBRAS, the Brazilian State Oil Company.

As Brazil and China, India is prioritizing enzymatic catalysis of oils, to produce biodiesel, concerning the use of biotechnological tools in the area. The country does not have any expressive numbers in using biotechnology for producing biodiesel, what was expected, considering their overall numbers, as demonstrated in graphic 20.



Graphic 20 – Biotechnology use in Indian biodiesel patents is reduced, due to its lack of priority in protecting biodiesel related inventions.

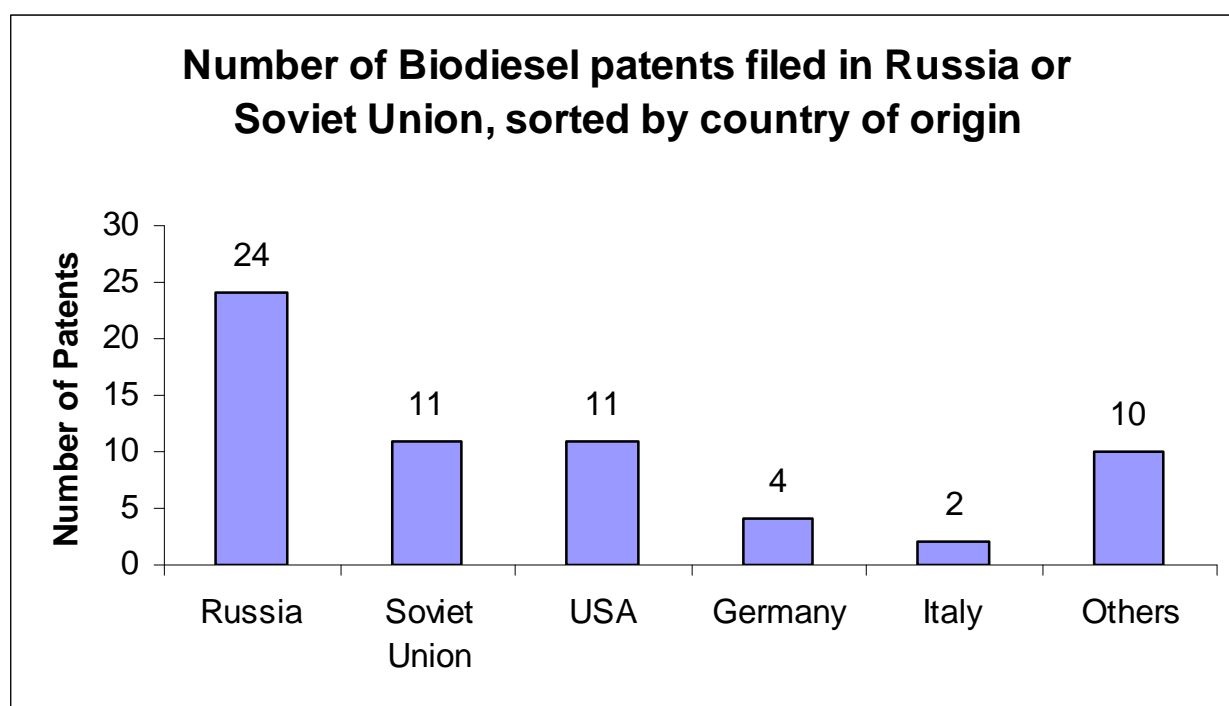
4.1.2.4. Russia

To analyze Russia's number, it is fundamental to remember that the country was, until 1989, a socialist republic, called Soviet Union, which gathered several other countries. Besides, the Russian Federation is not member from the World Trade Organization or signatory of the TRIPS agreement. Thus, the exceptions and limitations for granting patents do not, necessarily, follow the same rule as Brazil, China and India, for instance.

Nevertheless, as signatory of the Paris Union Convention, they must grant national treatment to foreign applications and follow the same basic requirements of novelty, inventive step and industrial application, when analyzing inventions. Regarding to national inventions, the applicant must submit it to the State before filing the patent. If the Russian government asserts that the invention must keep as a state secret, the applicant can not file the patent. So, it is possible to define Russia's potential as a market by the number of patent filings from foreigners, but it is not that effective to construe their technological development, due to these limitations. Also, it was expected

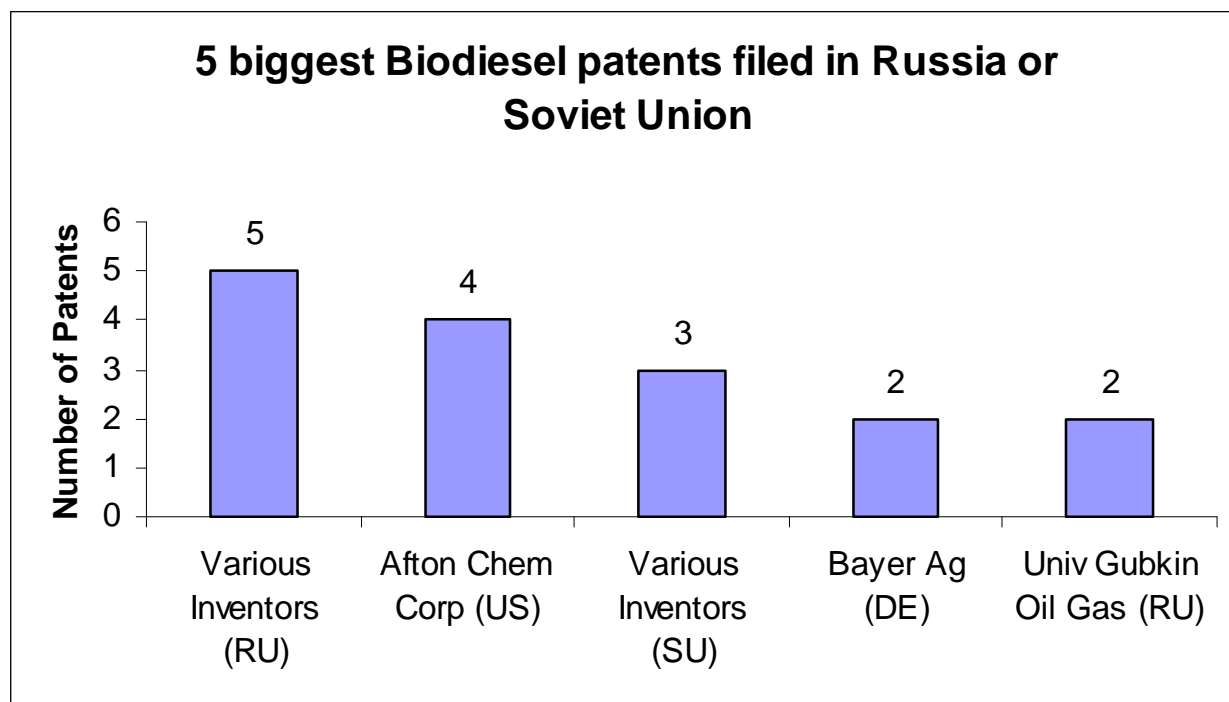
that Russia would have more modest numbers, due to its well known capacity of fossil fuels production. So, biofuels do not receive particular interest from the government.

From the graphic 21, it is possible to see that Russia and former Soviet Union leads patent fillings in biodiesel. The lack of protection from other countries leads us to one possible conclusion: Russia is not considered an important consumer market for biodiesel.



Graphic 21 – The lack of protection of inventions related to biodiesel in Russia, leads to the conclusion that the country is not considered as priority market for biodiesel.

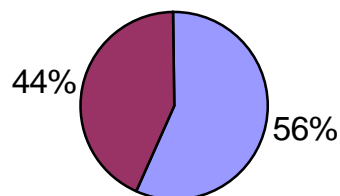
The same thing happens with the main applicants in Russia. According to the graphic 22, only 3 companies have more than 2 patent fillings in Russia or Soviet Union, being 2 of them foreigners. Individual inventors play an important role on filling patents in Russia or Soviet Union.



Graphic 22 – From the 5 biggest applicants of patents in Russian Federation or Soviet Union, only 3 are companies, being 2 foreigners. This is another fact that corroborates Russia’s position as a non-attractive market for biodiesel.

Considering the low number of national patent filings due to State’s policy, the distribution of resident and non-resident applicants in Russia is similar to the one found in Brazil. However, these numbers do not lead to the same conclusions as before, since Russia is not being considered as a potential market for biodiesel new technologies.

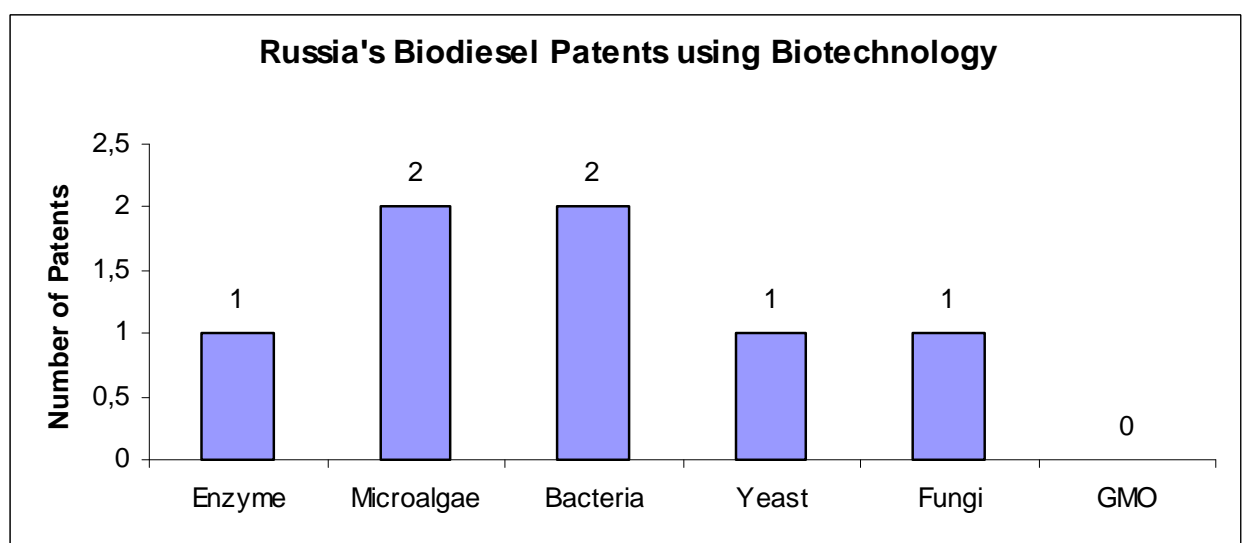
Distribution of Biodiesel patents filed between Residents and Non-Residents in Russia or Soviet Union



■ Residents ■ Non-Residents

Graphic 23 – Even though residents play a bigger role in patent filings in Russia, we can not imply that the country is well developed, due to its low absolute numbers.

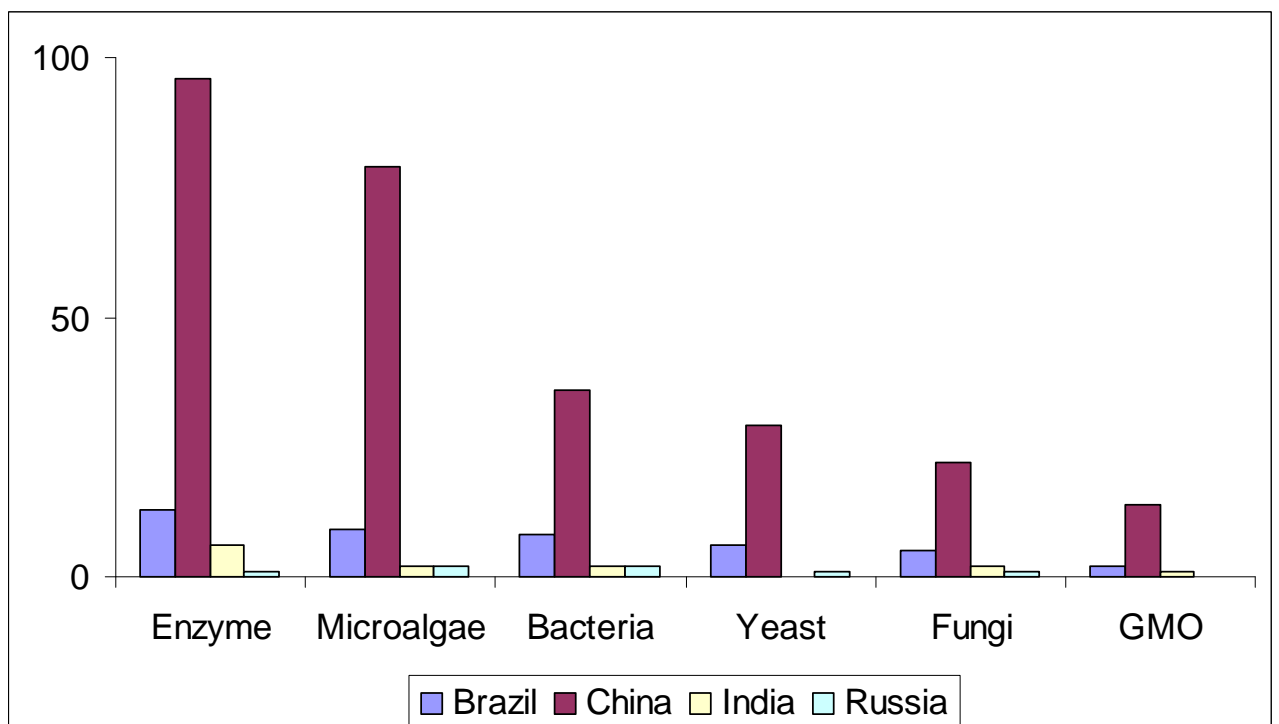
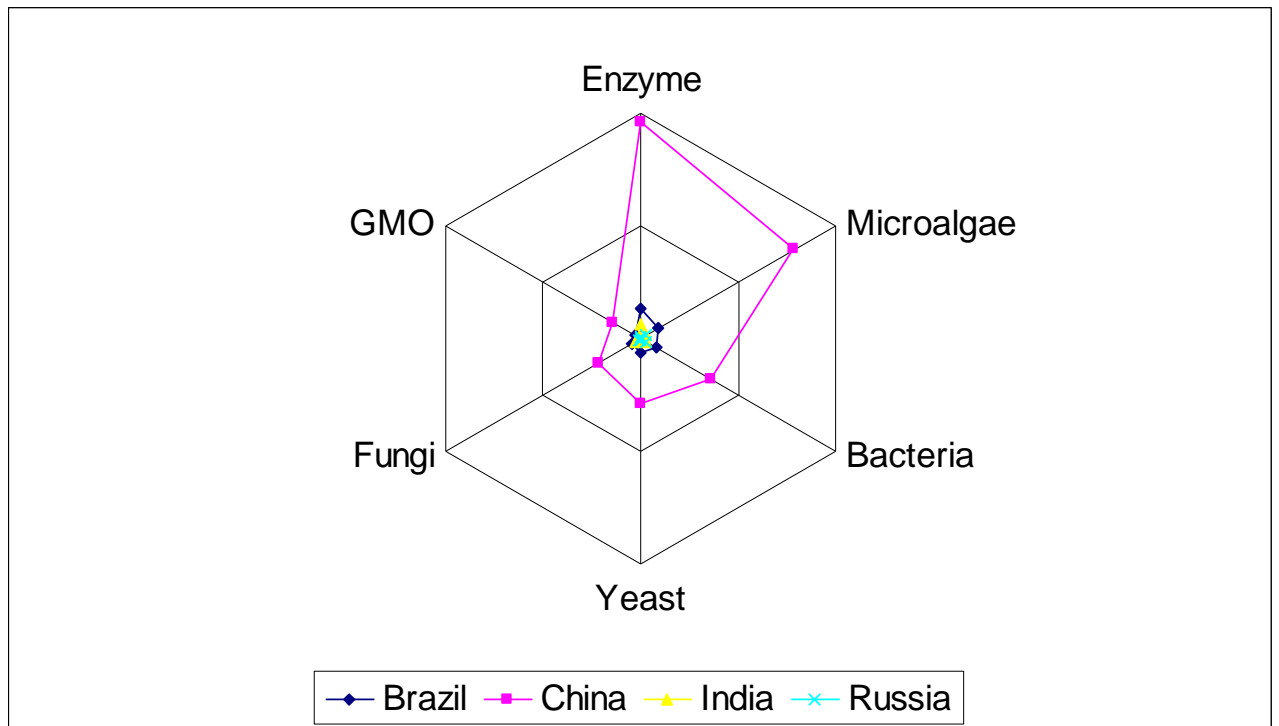
Russia does not have expressive numbers in biotechnology application for biodiesel production, what was expected, considering their overall numbers, as demonstrated in graphic 24.



Graphic 24 – Biotechnology use in Russian protected inventions. The numbers are not significant.

4.1.2.5. Biotechnology overview

In the radar graphic 25, it is very clear that China is dominating every Field of biotechnology usage to produce biodiesel. This is mainly because of its absolute numbers

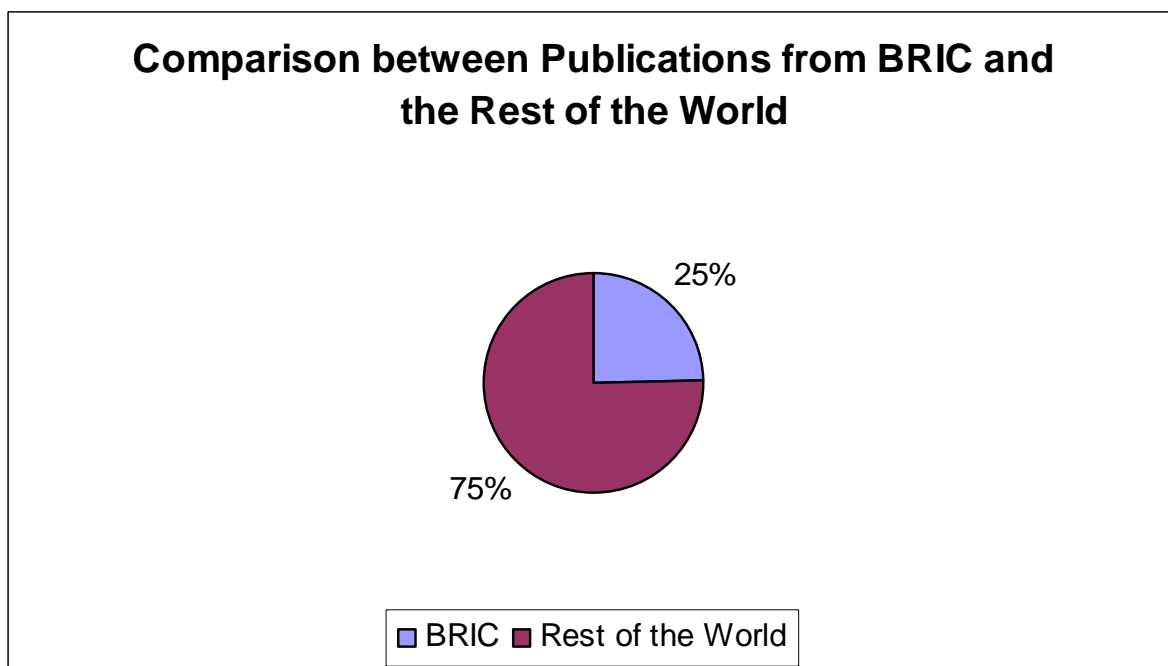


4.2. Ethanol

On the next pages, the numbers retrieved from the analysis of ethanol patents and scientific publications are going to be shown, detailing the specific situation of Brazil, China, India and Russia, individually. At last, a general overview of the biotechnology use to improve ethanol development is going to be presented.

4.2.1. Scientific Publications

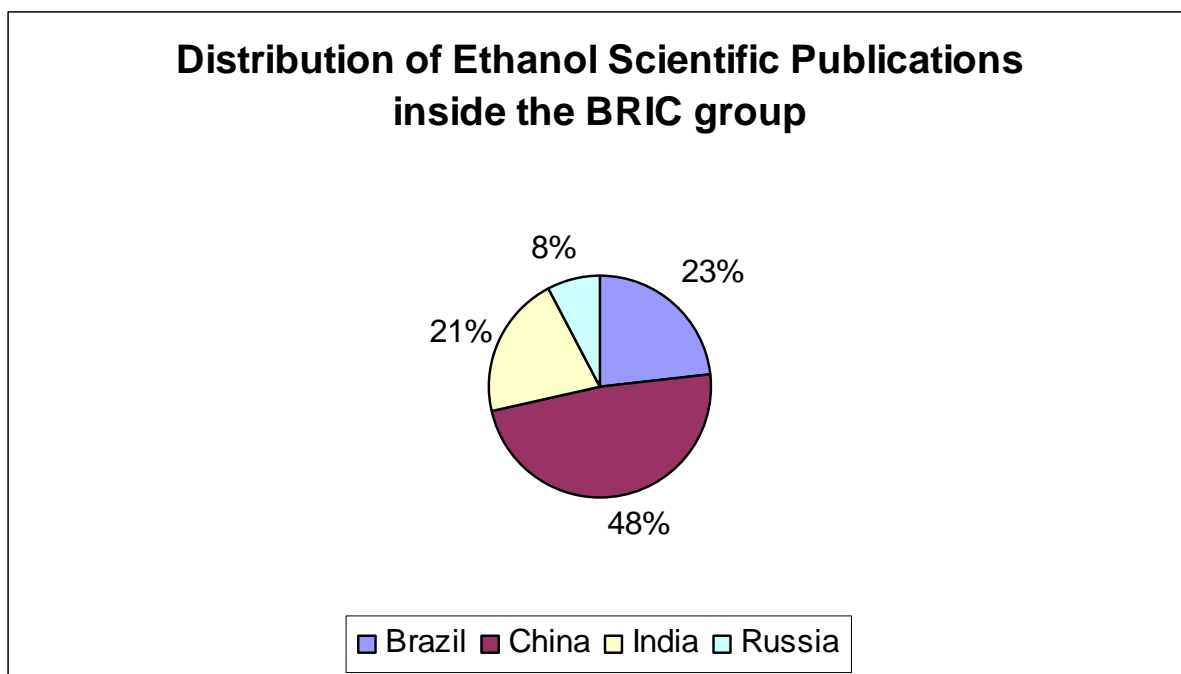
The retrieval of scientific publications made using the methodology presented in the chapter 3.2, returned a total of 17016 publications, of which 971 are Brazilian, 2021 are Chinese, 868 are Indian and 328 are Russian. The BRIC group is responsible for almost one quarter of every scientific publication in the world, from 1963 to 2011, as shown in the graphic 25.



Graphic 25 –Parallel between scientific publications made by BRIC and other countries. BRIC is responsible for almost one quarter of every scientific publication on ethanol, in the world.

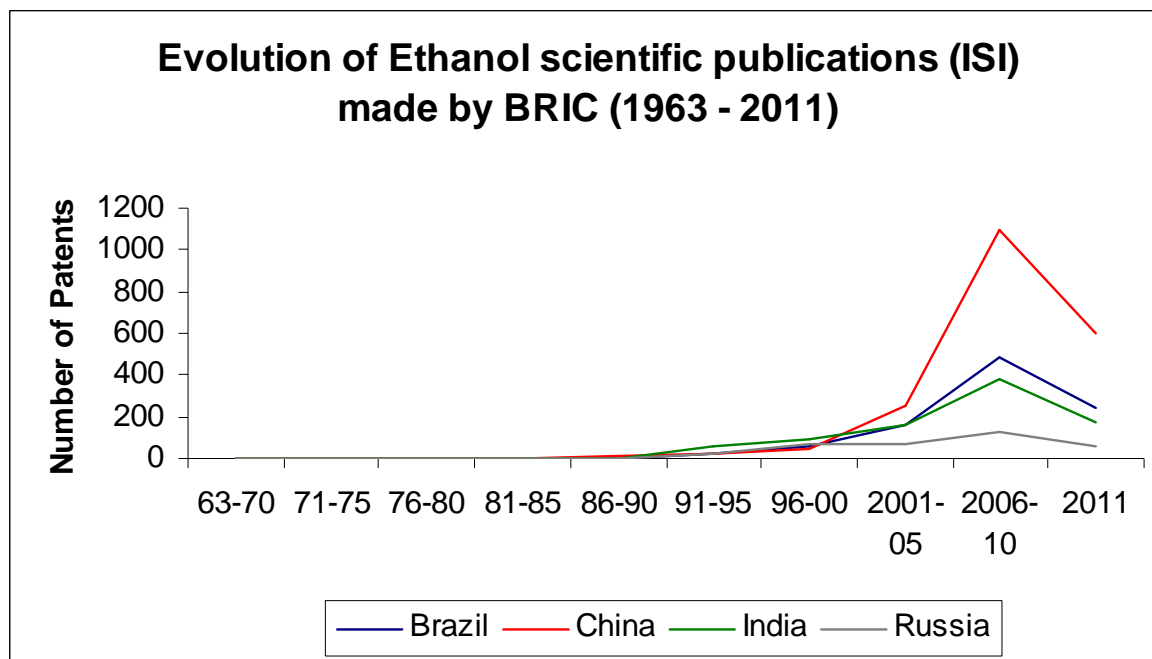
It is noticeable that Brazil (23%) and India (21%) are balanced on the advances in ethanol, when taking into account scientific publications in the area. China (48%) has

almost more than the other 3 countries together, what shows a solid leadership on the area. Russia (8%) does not measure to any of its 3 companions, as expected. Those data are well marked on the graphic 26, below.



Graphic 26 – Contribution of each BRIC country on publishing articles, related to advances in ethanol. China has a solid leadership on this item.

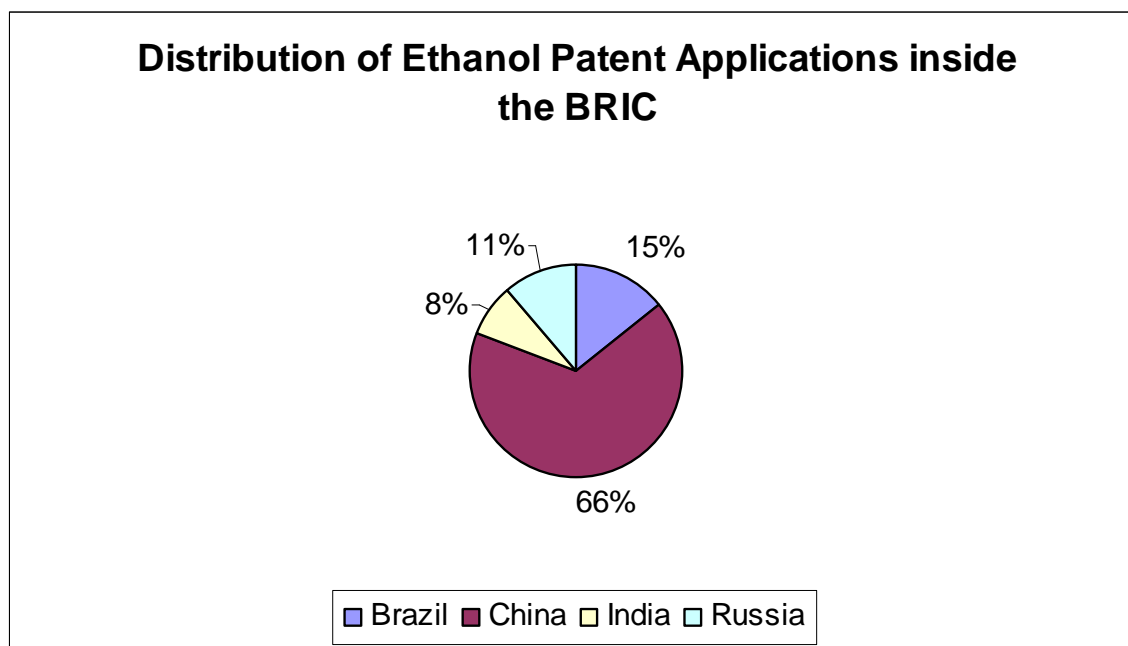
Graphic 27 shows how those publications grew from 1963 – 2011. The first publications on the area appeared on the middle of the 1980's. Publications from the 4 countries grew together until the end of the 1990's, when Russia stayed steady until nowadays. On the beginning of the years 2000, China reached an inflexion point and grew more than Brazil and India, which grew almost the same thing up to now.



Graphic 27 – The evolution of ethanol related scientific publications by BRIC, from 1963 to 2011. Brazil and India grew similarly, while China reached a bump in the beginning of the last decade, and Russia became stable in the last 10 years.

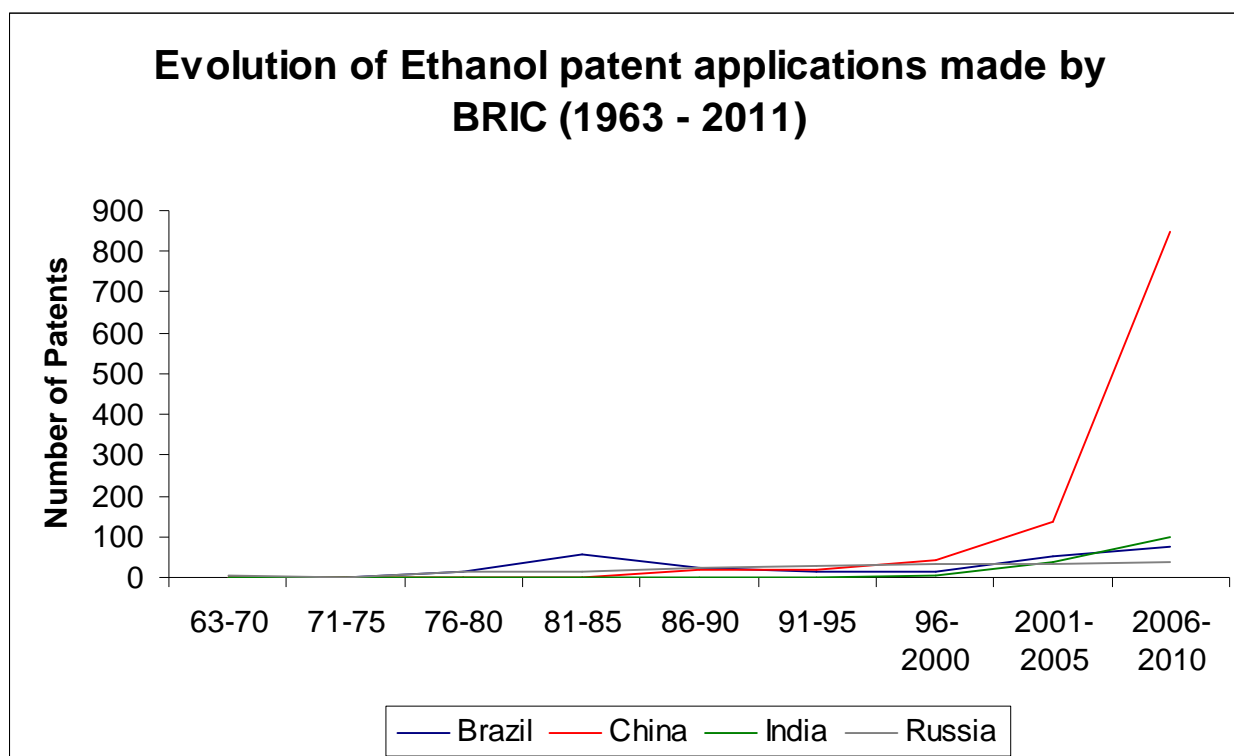
4.2.2. Patents

The search for patents, as described on the chapter 3.1.1, retrieved 4647 patents filed in the world, in which, in Brazil were filed 255, in China 1161, in India 144 and in Russia 193. Hence, the BRIC group received 1753 ethanol inventions seeking protection by patent, from the year 1963 to 2011. Those filings were not entirely made by national applicants, so these numbers still does not represent the advances these countries are making in ethanol related technologies. In graphic 28, it can be seeing that China is the country, inside the BRIC group, that received most patent filings. Now it is possible to see afterwards if this number is coherent with the patent filings made by China and the other 3 countries of BRIC.



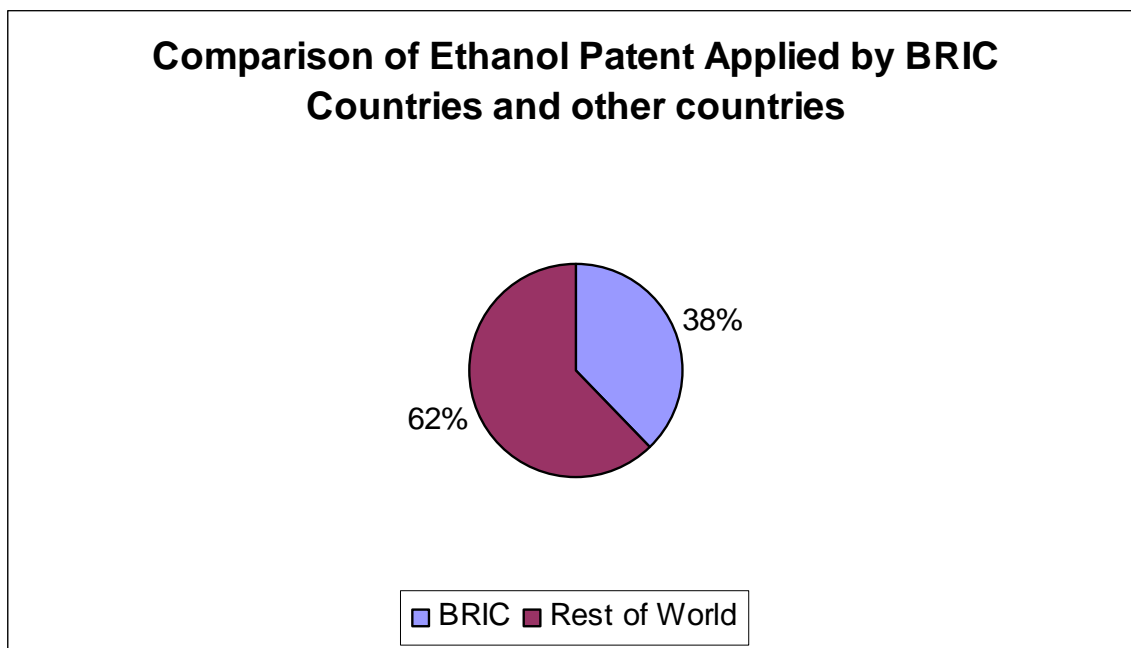
Graphic 28 – Distribution of ethanol patents in the BRIC group show that China has more filings than the other 3 countries combined.

Graphic 29 shows the evolution of patents filings in Brazil, China, India and Russia since 1963. The numbers of patents grew differently than the number of scientific publications. Brazil shows the biggest growth from 1976 to 1986, due to its program called “Pro-Álcool”, developed during the military government, and disabled in the end of the 1980’s. China, India and Russia started receiving patent filings regarding ethanol related technologies, after 1995, when the flex car was invented. Brazil started to grow again in the same period. However, China developed more than Brazil, India and Russia since the end of the 1990’s.



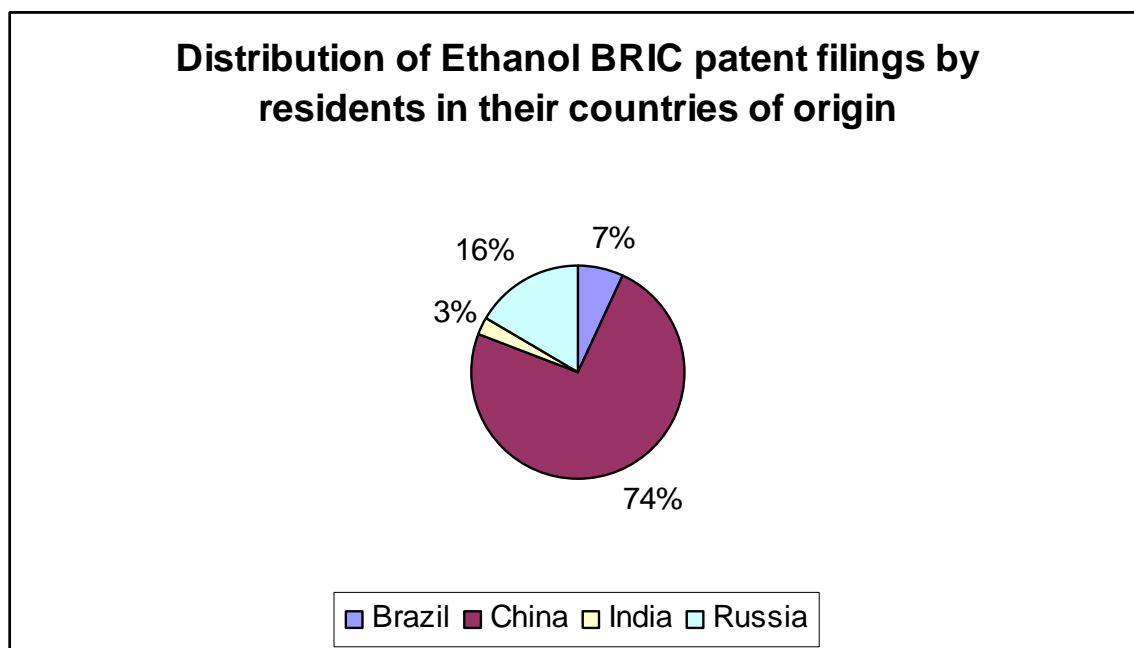
Graphic 29 – Evolution of ethanol patent filings by BRIC. Brazil had a considerable growth from 1975 to 1986. After that, all 4 countries only showed any growth in the mid 1990's. China took the leadership in the late 1990's.

It is necessary to point out that those numbers presented before are only for filing of patents on the national Patent and Trademark Offices (PTOs) from Brazil, China, India and Russia. An important data that can be seeing afterwards, is the proportion between resident and non-resident filings on each of these PTOs. Considering this data, the graphic 30 is able to show a comparison of patents filings made by the BRIC countries together and the ones made by the rest of the world. The number (38%) is higher than the one found for scientific publications. This was expected, since from the top 3 producers of ethanol in the world 2 are part of BRIC (Brazil – 2nd and China – 3rd).



Graphic 30 – Comparing the patent filings made by the BRIC countries and countries from the rest of the world, we can see that BRIC plays an important role on ethanol technological development, with almost 40% of all patents filed in the world.

Excluding the non-residents applicants from the results the distribution of patent filings inside the BRIC group changes a lot, as can be seeing in the graphic 31. China increases its leadership, while Russia overcomes Brazil and takes the second place. As can be noticed, India has a similar technological development with Brazil, while Russia stands on a different level between then and China.



Graphic 31 – The distribution of patent filings from BRIC countries, excluding non-resident filings, presents us a new scenario, in which China extends its leadership and Russia takes over the second place that belong to Brazil, when we consider the non-resident filings.

Now it is possible to take a look at the situation of each country individually.

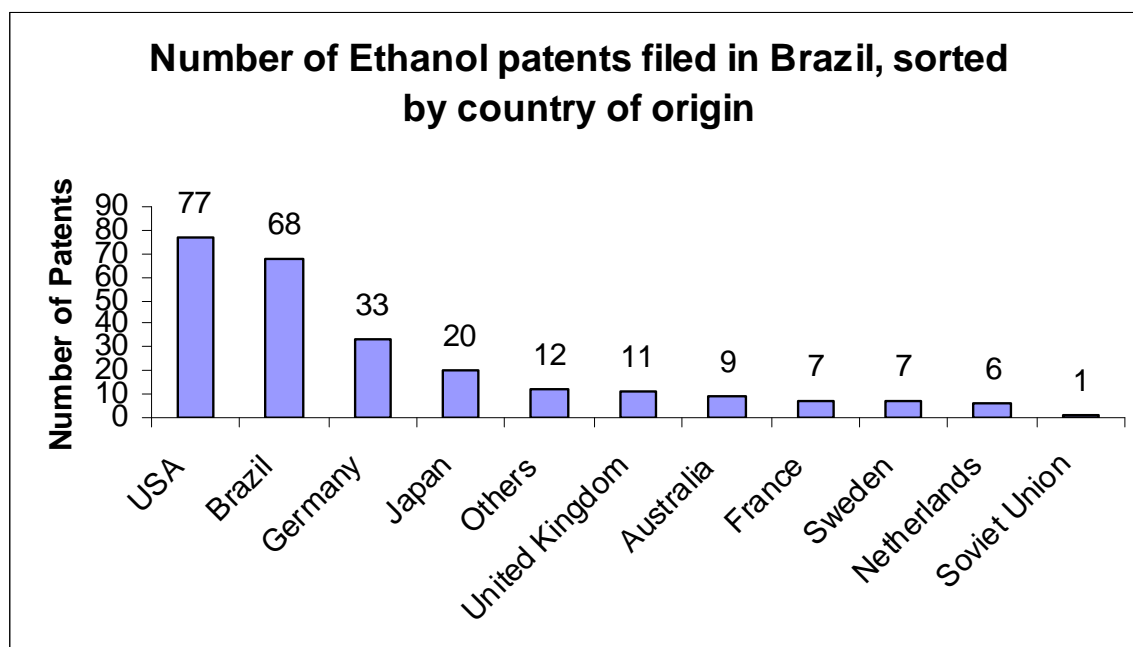
4.2.2.1. Brazil

In order to measure the technological development of Brazil, using patents as reference, it must be considered that a lot of patents filed in the Brazilian's PTO are not from Brazil. Therefore, the graphic 32 shows the countries that appears most on patent filings in Brazilian's PTO. A total of 19 countries filed at least one ethanol related patent. Those countries are listed on table 10.

Country of Origin	Number of Patents
Australia	9
Austria	1
Brazil	68
Canada	2
China	2

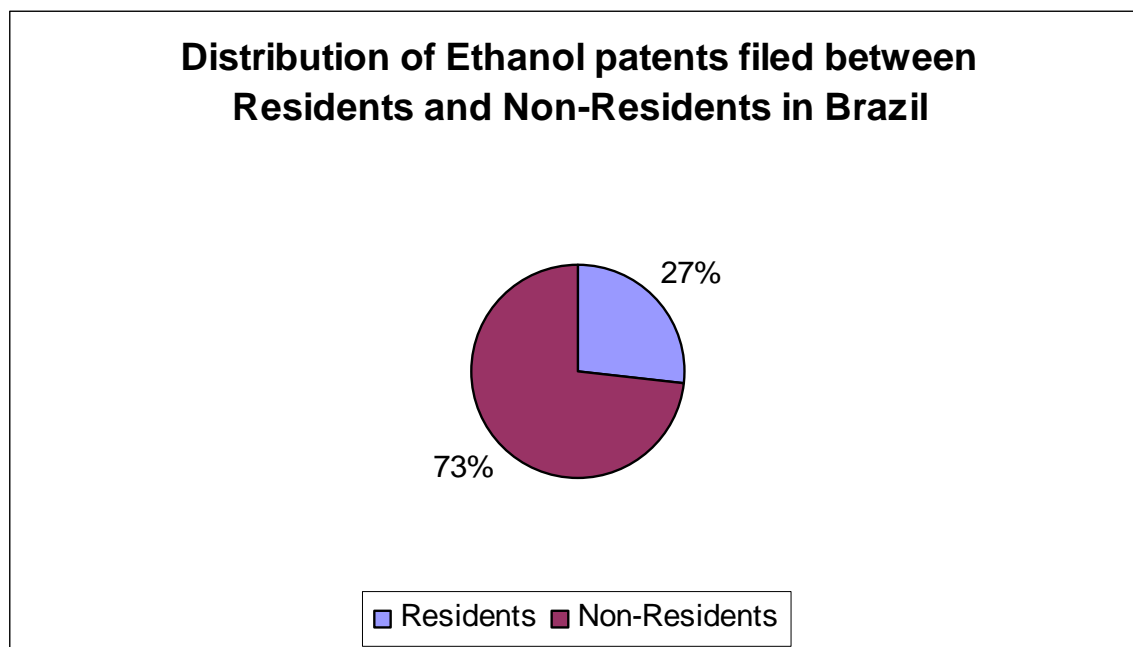
Congo	1
Denmark	1
France	7
Germany	33
India	1
Ireland	5
Italy	2
Japan	20
Netherlands	6
South Korea	1
Soviet Union	1
Sweden	7
United Kingdom	11
USA	77

Table 10 - Countries with at least one patent filing in Brazilian PTO. Brazil and USA are the leaders of filings, but Germany and Japan deserves to be mentioned as important applicants.



Graphic 32 – By this graphic we can see the leadership of USA, the biggest producer of ethanol in the world, and the remaining countries that has at least 2 patent applications in Brazil.

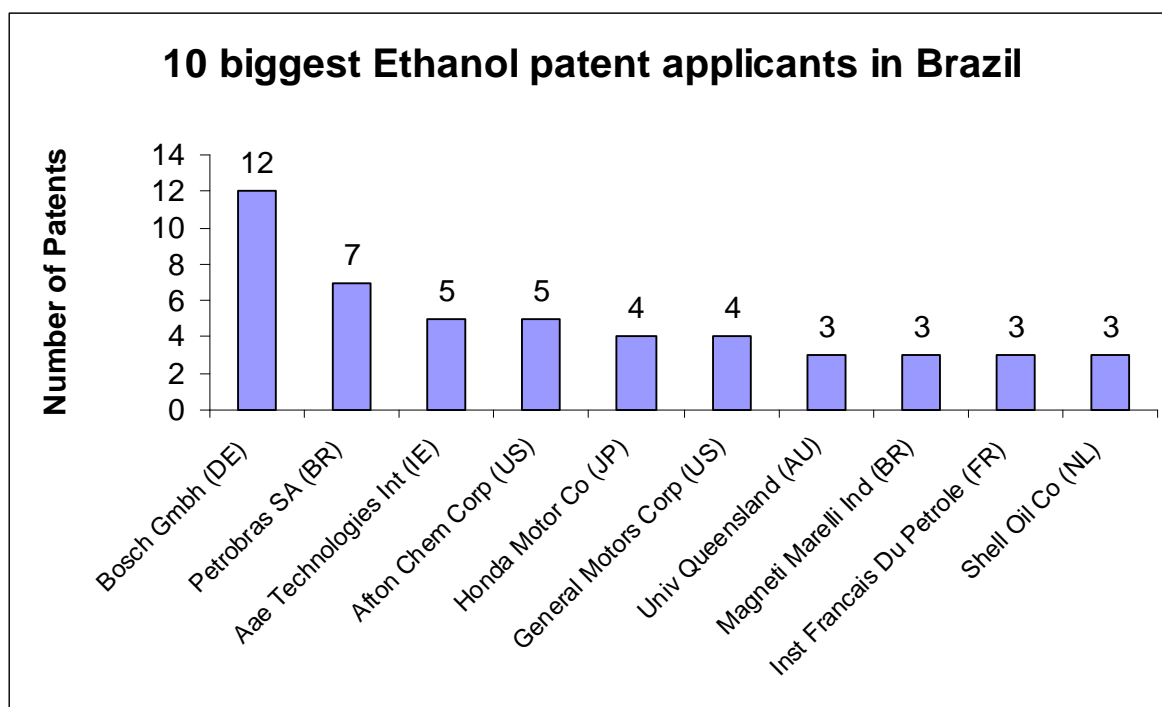
Analyzing the graphic 32 and table 9, it is noticeable that patents filed in Brazil are mostly made by non-resident applicants. Graphic 10 show us that in percentage numbers.



Graphic 33 – Non-resident applicants dominate patent filings in Brazil.

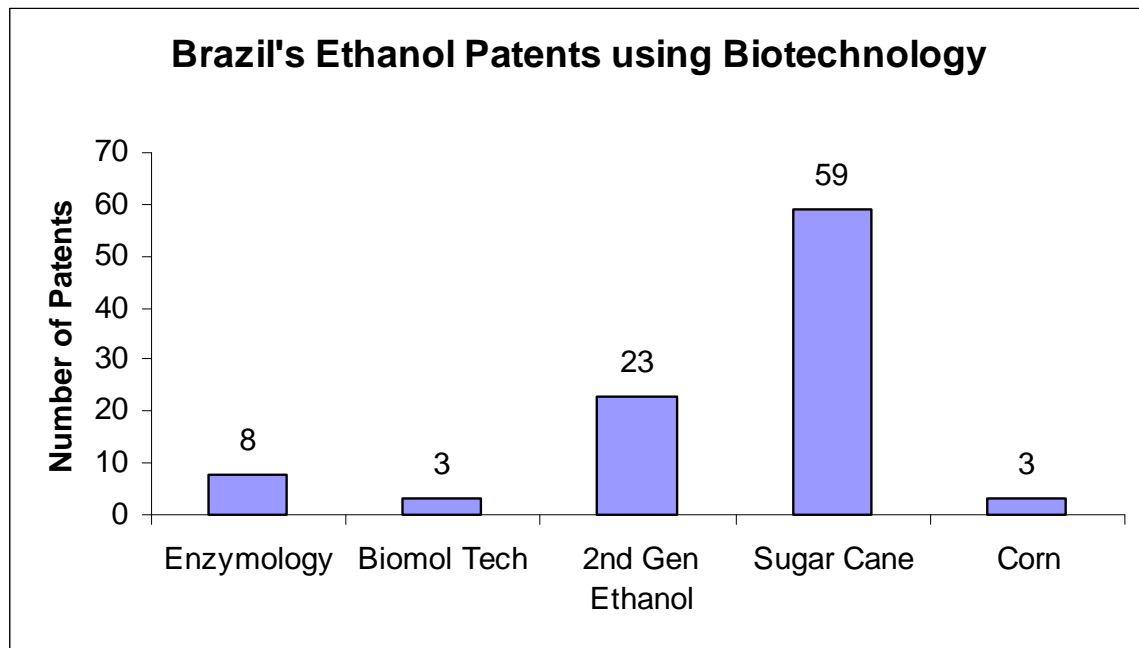
The participation of the USA is explicable, since the country is the biggest producer of ethanol in the world, and Brazil is one of the biggest consumer markets of this product. But it was expected better numbers from Brazilian companies.

Another important evidence of Brazil's importance as a market, but not as a developer of new technologies, is that from the 10 biggest applicants, only 2 are Brazilians, including the sub-leader PETROBRAS.



Graphic 34 - From the 10 biggest patent applicants in Brazil, only 2 are Brazilians.

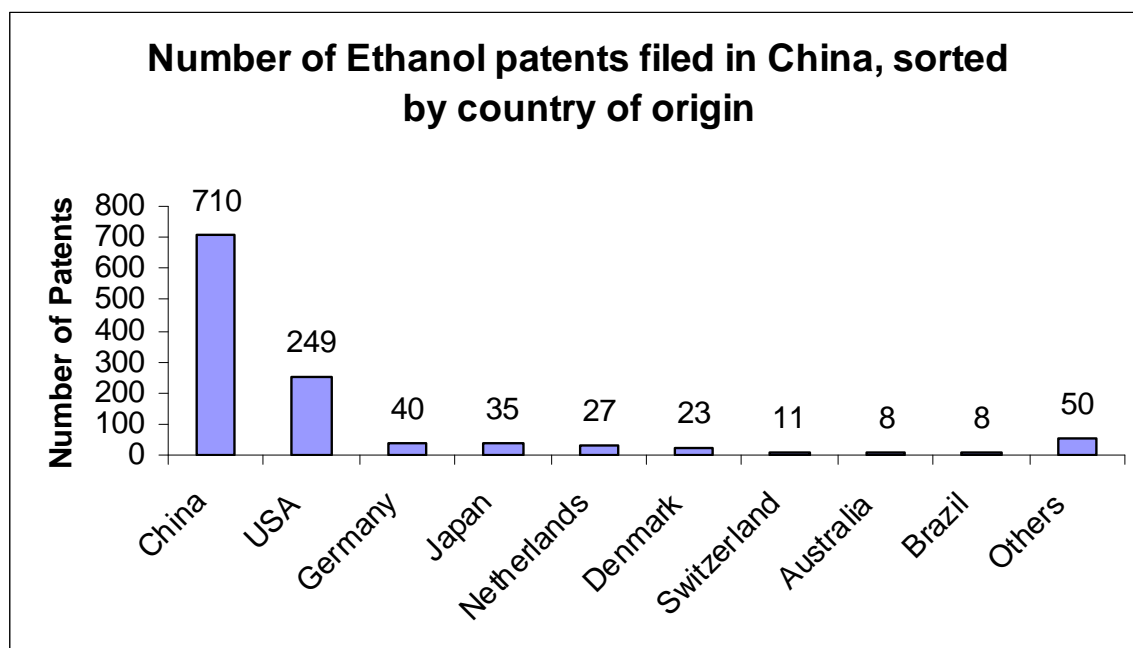
Regarding to the use of biotechnology in the development of ethanol related technologies, graphic 35 shows that Brazil is focusing in two different areas: second generation ethanol and use of sugar cane as carbon source. It is also possible to see that Brazil does not develop much technology regarding Genetically Modified Organisms.



Graphic 35 – Brazil is focusing on using sugar cane as carbon source, as expected, and is developing new technologies for producing second generation ethanol, which is more sustainable.

4.2.2.2. China

As Brazil, China is considered as a great market for renewable fuels, since it is one of the biggest economies in the world, nowadays. So, it is important to take a look at the non-residents patent applicants numbers, before draw any conclusion about China's development. Graphic 36 shows the countries that appears most on patent filings in Chinese PTO.



Graphic 36 – By this graphic it is easy to see how China leads ethanol patent filings in its own country. USA comes in second place. Brazil appears on the top 10 applicants.

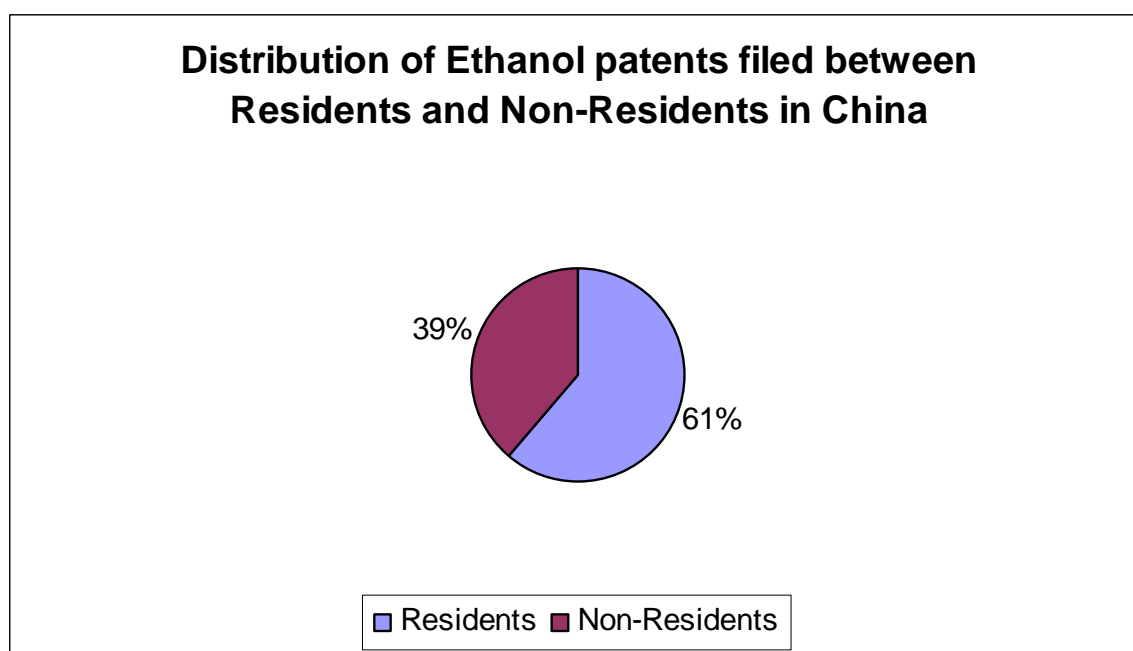
A total of 21 countries filed at least one biodiesel related patent. Those countries are listed on table 11.

Country of Origin	Number of Patents
Australia	8
Brazil	8
Canada	8
China	710
Denmark	23
Finland	2
France	5
Germany	40
India	7
Ireland	5
Italy	3
Japan	35

Netherlands	27
New Zealand	2
Norway	1
South Korea	3
Sweden	6
Switzerland	11
Taiwan	1
United Kingdom	7
USA	249

Table 11 – Countries that has at least one patent application in China’s PTO.

Analyzing the graphic 36 and table 11, it is possible to see that most of the patents in China are filed by resident applicants. In fact, Chinese applicants alone filed more patents than all applicants from other countries together. Graphic 37 shows that in percentage numbers.

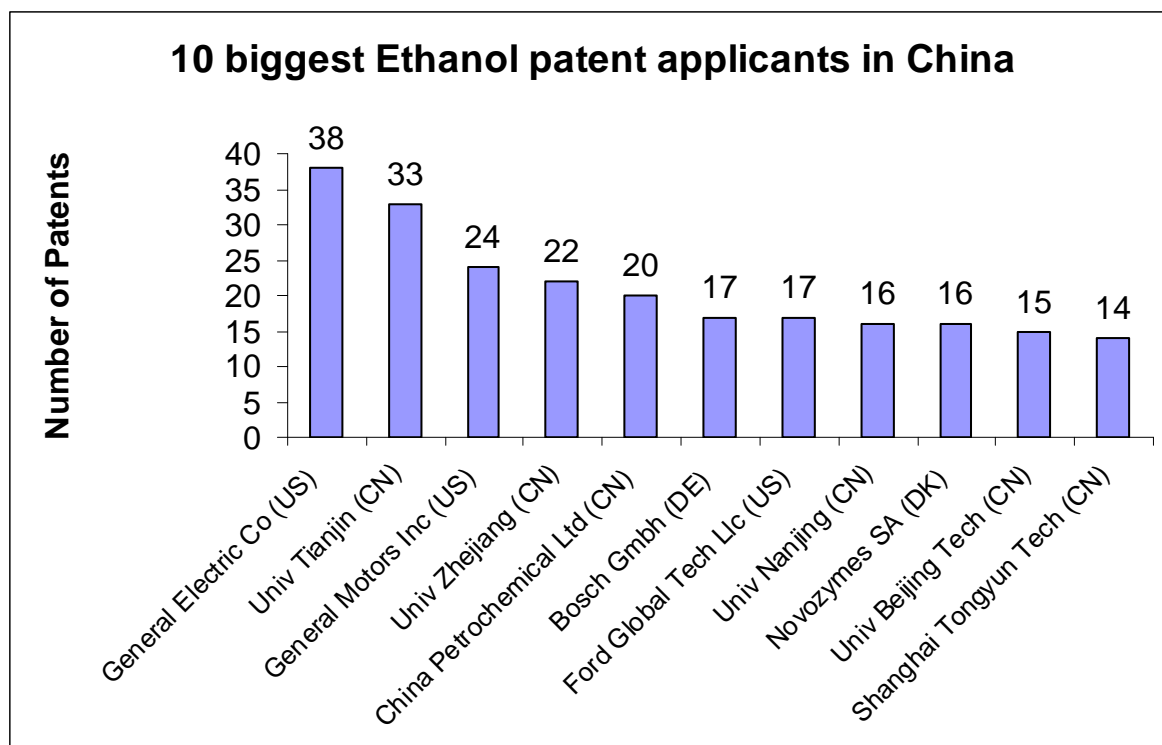


Graphic 37 –Chinese resident applicants dominate patent filings in their own country.

With this numbers it is quite clear that China is not only a big market for ethanol, but also an important supplier of new technologies in the area. The fact that

they have more patent applications than USA in their own PTO shows their sovereignty in protecting ethanol technologies nationally.

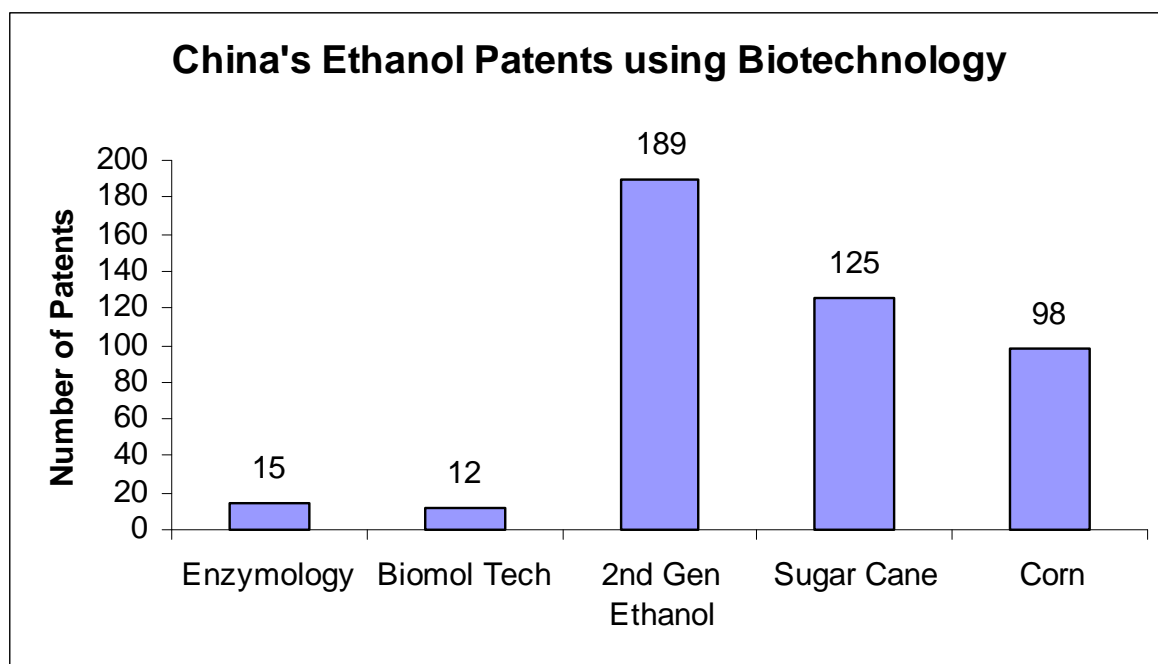
Another evidence of Chinese technological development is that from the 10 biggest applicants, 6 are Chinese. Unites States of America has 3 representatives; Germany and Denmark have 1 each, as shown on the graphic 38.



Graphic 38 - 6 Chinese companies are among the 10 biggest applicants in China. 4 of them are universities. USA is represented by three companies.

China has more universities developing ethanol technologies, than industries. From the 6 Chinese companies shown by the graphic 38, only two are not universities. So, it China still needs to make an effort to transfer this new technologies from the universities to the industries, in order to increase their volume of production and effectiveness.

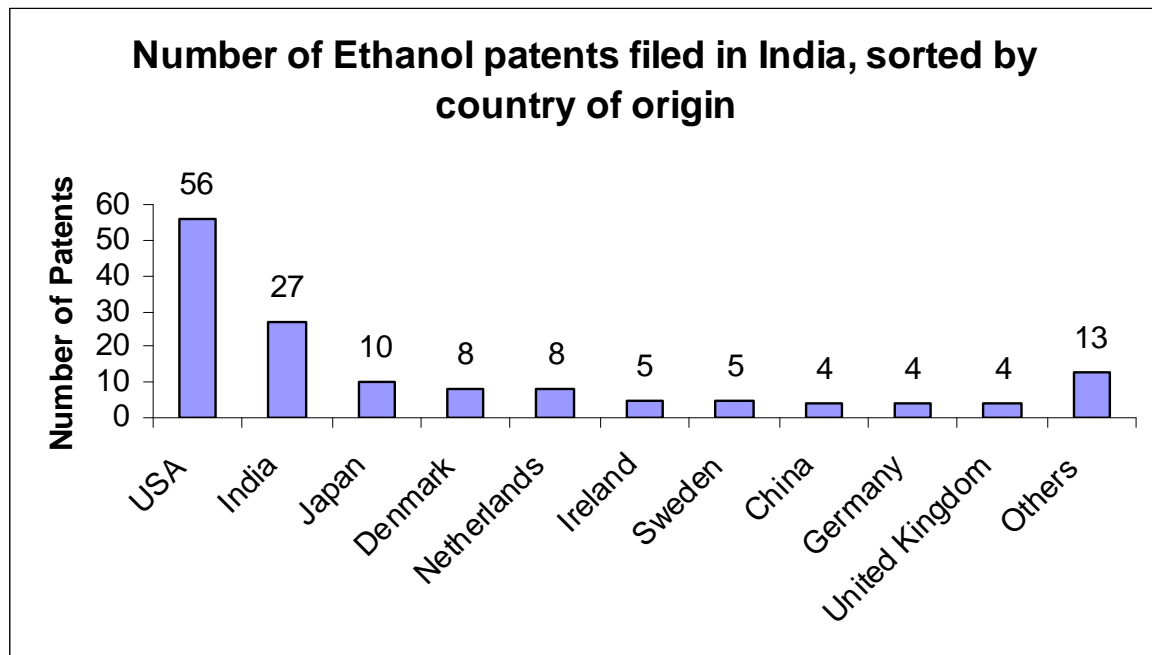
Regarding the use of biotechnology in the development of ethanol related technologies, the graphic 39 shows that China has a similar focus than Brazil, with the difference that there are lots of inventions that use corn as main carbon source for producing ethanol. It is obvious that China has more impressive absolute numbers, but relatively to its total numbers, the development is quite similar.



Graphic 39 – China is developing new technologies regarding second generation ethanol. Also, it is filing patents using sugar cane and corn as main carbon source, differently from Brazil, that focus on sugar cane.

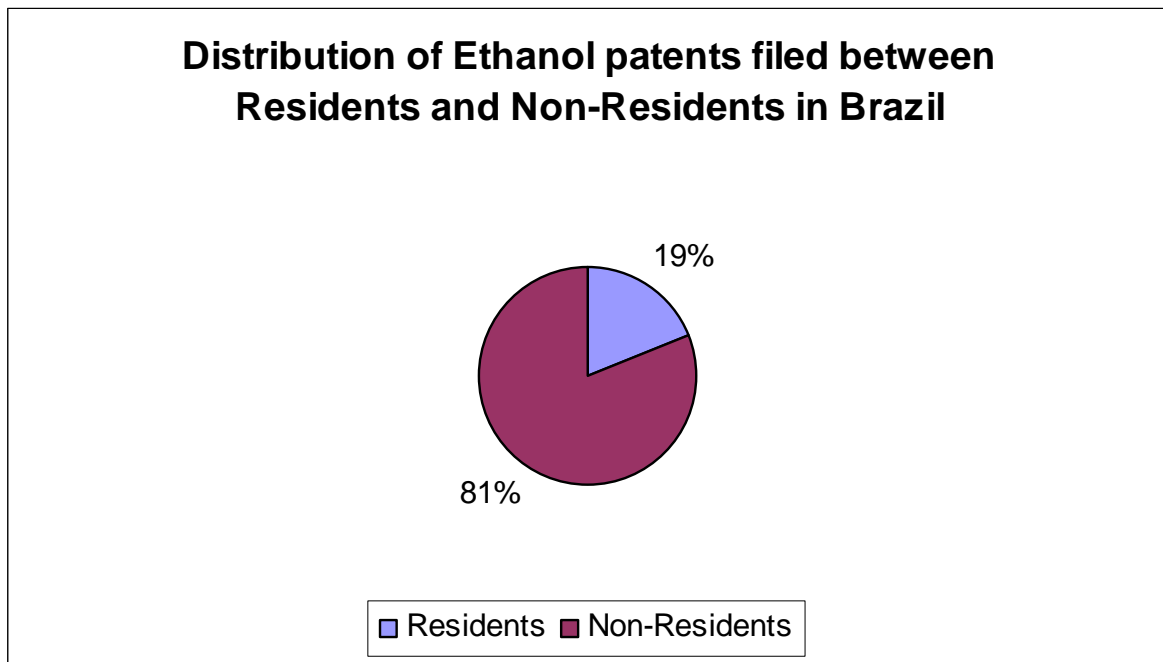
4.2.2.3. India

India does not lead patent filings in its own country. USA has the leadership in that country, with 2 times more than resident application, and several other countries have at least one filing there. Graphic 40 shows this data.



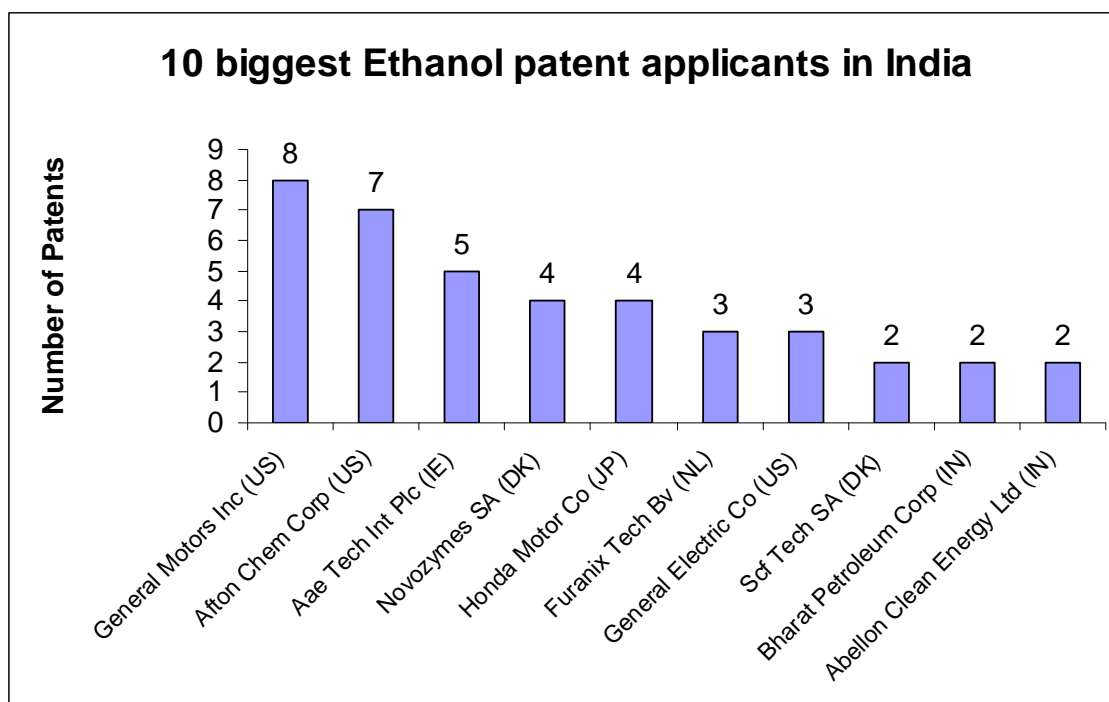
Graphic 40 – USA is the country that filed more biodiesel patents in India, up to now.

This numbers define India as a potential market for ethanol, since a lot of international companies seek protection for their technologies there. Still, India shows modest numbers in their own country, demonstrating that they are not taking ethanol as a priority, currently. To confirm this thesis, graphic 41 shows a comparison amongst the number of patents filed in India by residents and non-residents. As seen, non-residents filed 4 times more patents than residents in India



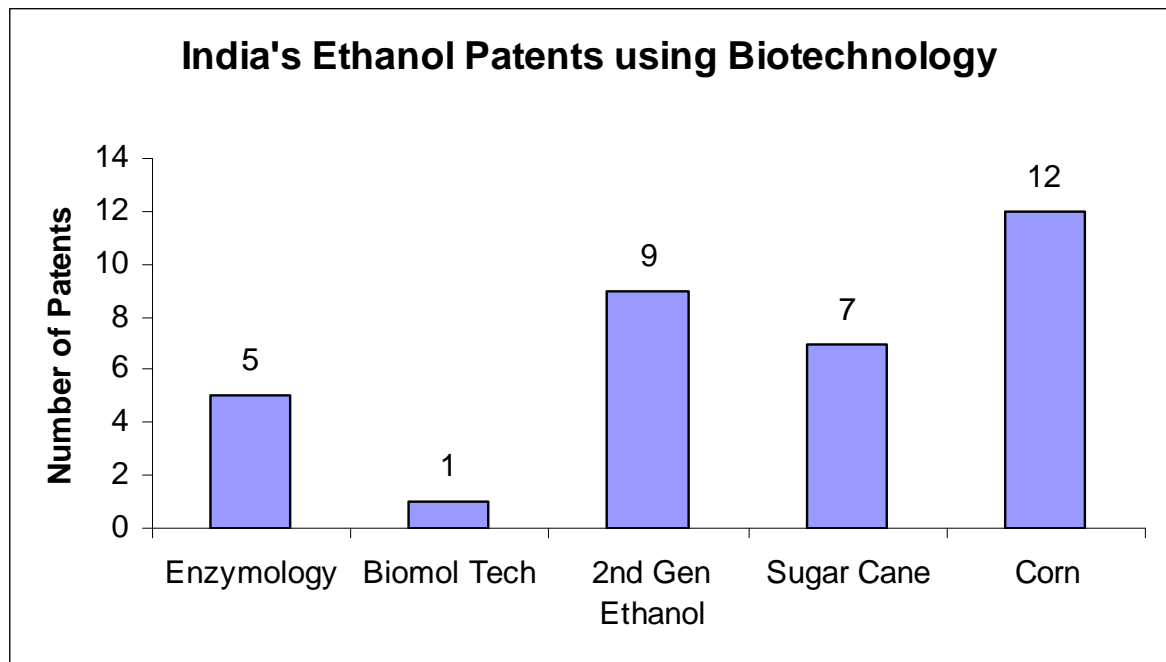
Graphic 41 – The comparison of ethanol patent filings from residents and non-residents in India, highlights that it assumes the role of a consumer market, only.

As expected, only 2 of the biggest 10 applicants are Indian. From the top 10 applicants, 2 are residents, 3 are from USA, 2 are from Denmark, 1 is Danish and 1 is Japanese.



Graphic 42 – Main companies that seek protection for their inventions on ethanol related technologies, in India. The resident country only have 2 companies on the top 10 applicants, what evince their less than average development in the area.

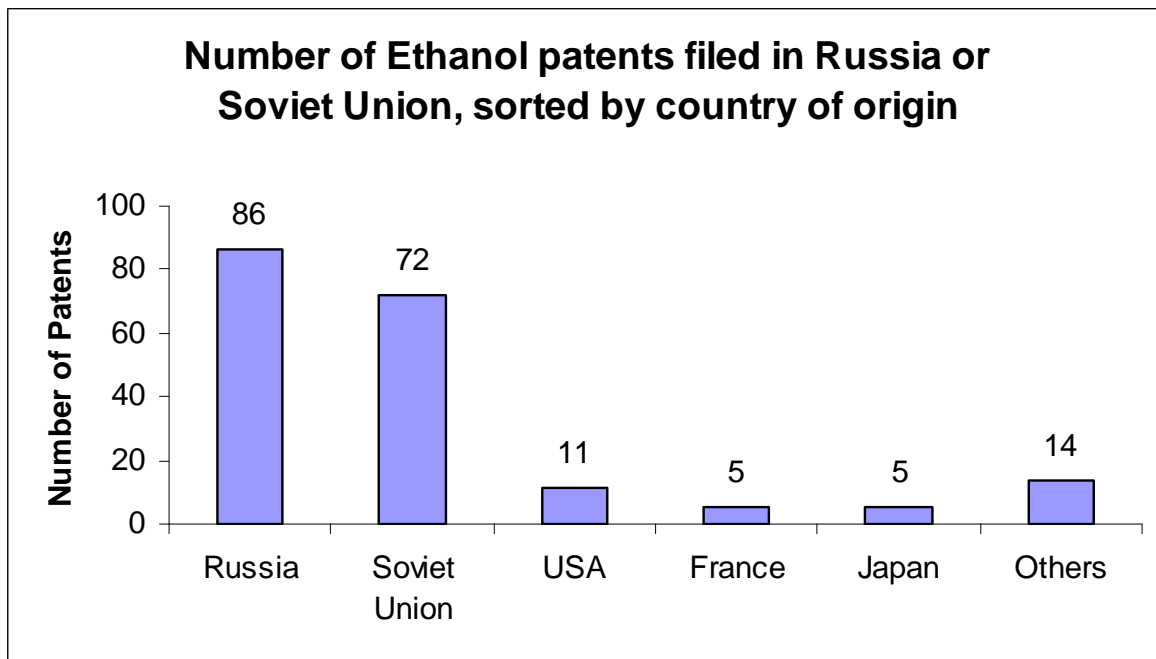
India has very modest numbers, concerning the use of biotechnology to produce ethanol. Within these numbers, they are using corn as main source of carbon and working on second generation ethanol, as priority, as demonstrated in graphic 43.



Graphic 43 – Biotechnology use in Indian ethanol patents is reduced, due to its low development in the ethanol industry, up to now.

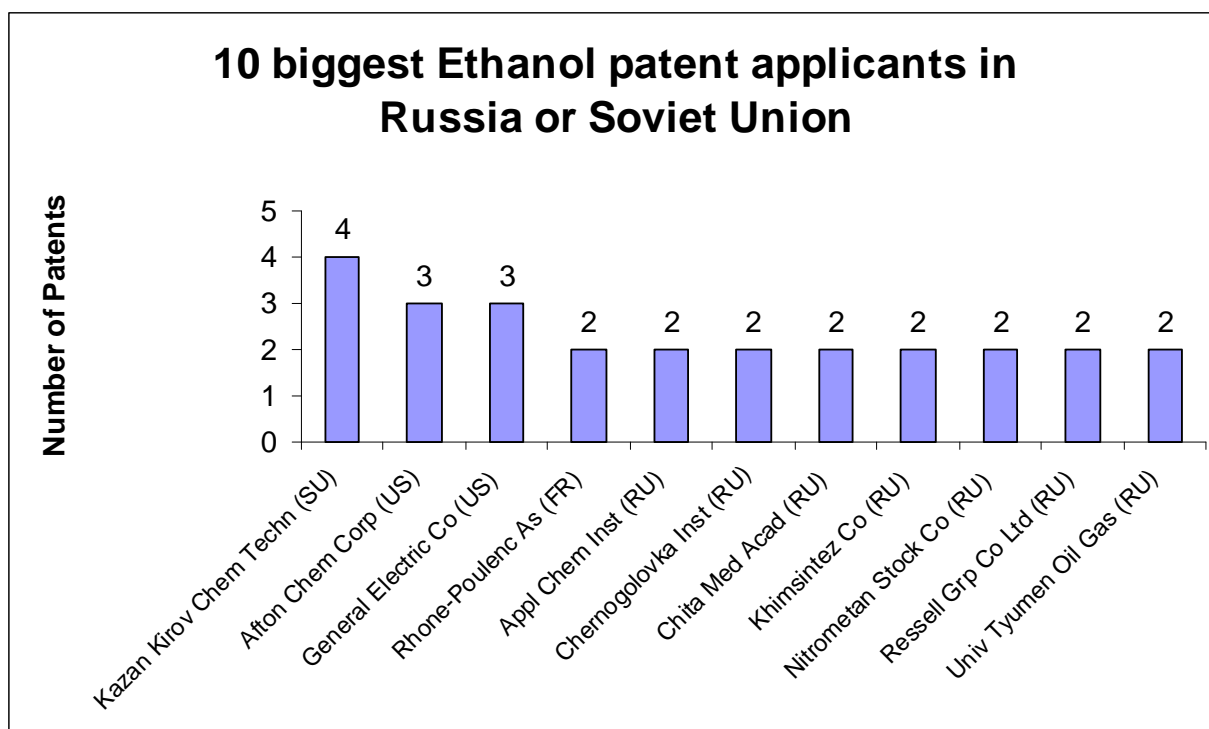
4.2.2.4. Russia

Taking in consideration everything said on the chapter 4.1.2.4, from the graphic 21, it is possible to see that Russia and former Soviet Union leads patent fillings in ethanol in their own country. The lack of protection from other countries leads us to the conclusion that Russia is not considered an important consumer market for ethanol.



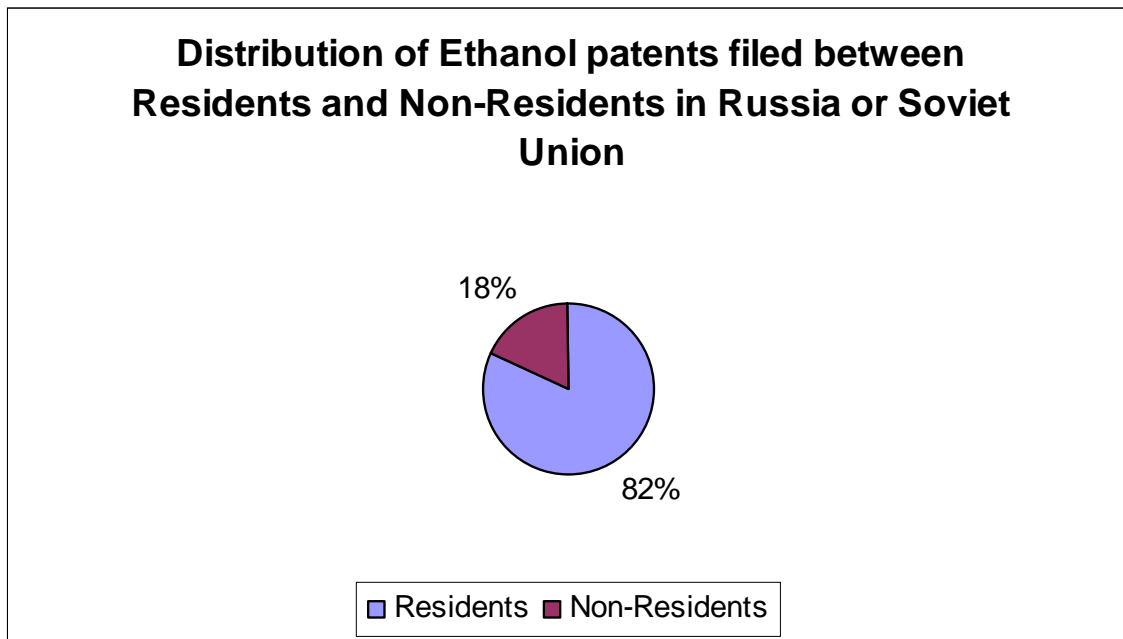
Graphic 44 – The lack of protection of inventions related to ethanol in Russia, leads to the conclusion that the country is not considered as priority market for biodiesel. However, they have some expressive numbers on resident patent filings. Most of them are related to the automotive industry.

The same thing happens with the main applicants in Russia. According to the graphic 45, only 3 companies have more than 2 patent filings in Russia or Soviet Union, being 2 of them foreigners. Individual inventors play an important role on filling patents in Russia or Soviet Union.



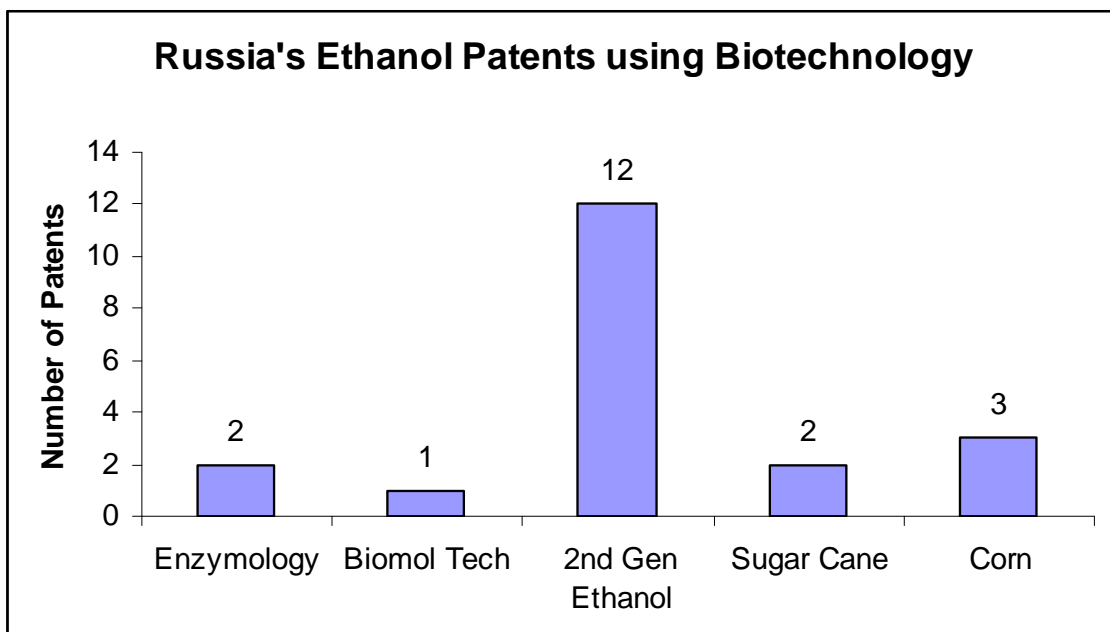
Graphic 45 – From the 10 biggest applicants of patents in Russian Federation or Soviet Union, only 2 are non-residents.

The distribution of resident and non-resident applicants in Russia is quite peculiar, since there are very few non-residents applications. Since Russia is not being considered as a potential market for ethanol new technologies, it can be considered that the country was being prepared to enter the market for ethanol, mainly in the automotive sector, back in the 1980's. The industry, however, did not evolve as expected.



Graphic 46 – Even though residents play a bigger role in patent filings in Russia, we can not imply that the country is well developed, since the majority of patents were filed in the 1980's.

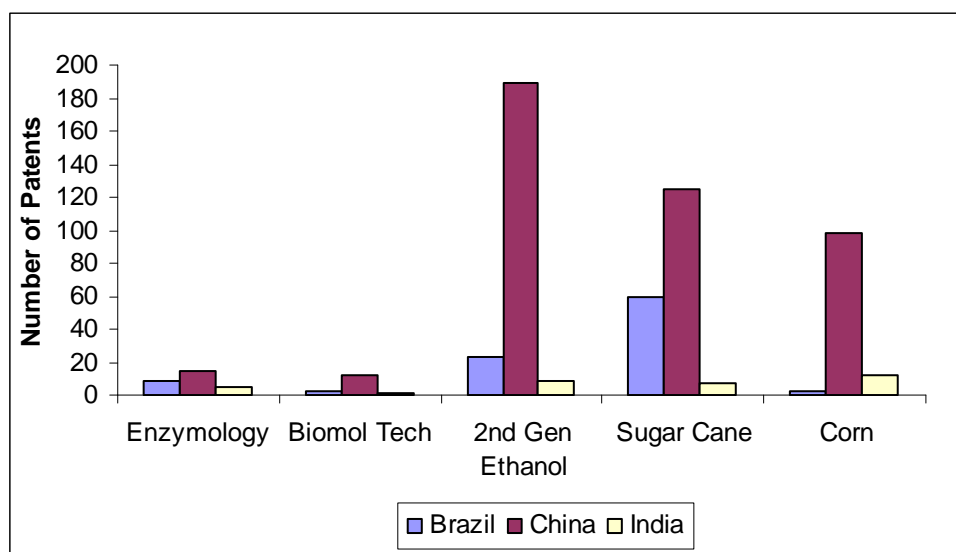
Russia does not have expressive numbers in biotechnology application for ethanol production, what was expected, considering they prioritized the automotive and fossil fuels industry, instead of the biotechnology and bioenergy industries.



Graphic 47 – Biotechnology use in Russian protected inventions. The numbers are not significant.

4.2.2.5. Biotechnology overview

From the graphic 48, it is very clear that China is dominating every Field of biotechnology usage to produce biodiesel. Brazil, however, comes close on the use of sugar cane as mains carbon source, since this raw material is very abundant in Brazilian territory.



Graphic 48 – Comparison between the uses of biotechnology to develop new ethanol related inventions, by the countries of BRIC.

5. CONCLUSIONS

5.1. Biodiesel

Analyzing the results it is possible to see that Brazil, China and India represent big consumer markets for biodiesel, considering the high number of non-resident applicants on these countries. Russia, due to its large production of fossil fuels, stays out of this list.

These results were expected, since China and India can not rely on its fossil fuel's production, and are extremely dependent on its use, nowadays, being big exporters of this kind of energy. However, they can not keep using fossil fuels, as the prices are very volatile, the global production is already reaching its peak and they are not environment friendly. So, they must search for alternative sources, such as biodiesel. Brazil is in a more comfortable position, once it is exporter of fossil fuels and invests in alternative fuels for almost 40 years, aside from the fact that the country holds one of the biggest arable areas in the world, what turns possible the production of grains for oil use, without prejudice to its food usage. Besides that, Brazil also appears as a big market for those kinds of fuels, since lots of countries sees the country as a big supplier of biodiesel in the near future. So, they intend to transfer those technologies to Brazilian companies, so that they can profit more with exportations.

Regarding development of new technologies in biodiesel, it can be concluded that only China and Brazil are making efforts in protecting inventions regarding this biofuels, as they are responsible for 91% of all patents filed by BRIC. China is clearly in advantage here, once it is responsible for 76% of the total filings of patents by BRIC. This scenario can be explained by the expenditures these countries are making in Research and Development each year. According to the World Bank, Brazil expends more than R\$ 5 billion each year, while China expends more than U\$ 30 billion: a huge

difference. Yet, Brazilian production is bigger than Chinese. That can be explained by the fact that Brazil is taking biodiesel production as a priority for its research and development efforts, as said by the USDA, on its Biofuel Annual Report. So, they are able to produce more, even with less cutting edge technologies. India and Russia does not have any considerable numbers of biodiesel production.

Regarding the use of biotechnology for applications in biodiesel technologies, it is possible to see a trend on the development of new technologies for enzymatic catalysis of oil transesterification, mainly using lipases, and for use of microalgae to produce oil, to be used as feedstock, in a more sustainable way.

5.2. Ethanol

Analyzing the number of patents filed in Brazil, China and India by non-residents, it can be concluded that those countries are being considered big consumer markets for this biofuels, as it happens with biodiesel. Likewise, Russia does not call much interest to international companies.

China appears as the country that has more filings in the area, even though its ethanol production for fuel uses is not the best one. This happens because China invests a lot more in Research & Development than Brazil, India and Russia. But, recently, government has been cut some investments in new plants for ethanol production, since the food pricing is rising up due to the use of corn to produce ethanol, according to Scott and Junyang (2011).

Brazil commercialize ethanol since the 1970's, has some incentive programs to research & development of advanced ethanol and is the second biggest producer of the biofuels in the world. In theory, the country should have more impressive numbers. However, Cornachione (2011) says that Brazilian companies do not have the habit to

protect their inventions with patents. According to Mercadante (2011), Brazilian scientists have to start protecting its inventions through the patent system. Valor-online (2002) says that the main problem is the lack of knowledge from Brazilian entrepreneurs on the importance of the protecting an invention by the patent system.

Russia appears with some interesting numbers in patent filings for ethanol technologies, due to its automotive industry. In fact, Russia does not have capacity to produce ethanol commercially, yet, according to Smith and Muran (2009).

5.3. Final conclusions

An interesting fact that called our attention is that Brazil seems to be more interested in publishing its advances in biofuels than protecting them. That can be explained by the fact that most of technologies developed in Brazil are made in Universities, which can not have industrial purposes. So, some researchers find more interesting to publish their results than protect them. This fact is changing since 2004, with the Brazilian Innovation Law, that facilitated the transfer of technologies from Universities to Industries.

Furthermore, it appears that Brazil, China and India are being considered as big markets for biofuels production and commercialization. However, only China is making vast efforts to protect their technologies in the area. Brazil has impressive numbers of production capacity, but does not evolve in protecting newer technologies, especially for ethanol, what can cause problems in the future. It is unlikely to say that Brazil does not innovate in the area, since it has considerable numbers of scientific publications. It is more probable that this fact is due to the new technologies being developed mainly inside the universities, as Brazilian industries do not have the habit to use the patent system. India seems to be at the beginning of developing new technologies on biofuels, while Russia has nothing but the potential to do it.

6. FURTHER STUDIES

As suggestions for further studies it is planned to:

- perform studies on other renewable energy sources, such as wind and hydraulic energy;

- extend this study to USA and EU and South Africa, to cover the most important economies in the world;

- perform studies on fossil fuels, to draw a parallel between the development of fossil fuels and biofuels since its appearance to nowadays;

- make a more detailed study on biotechnology tools to produce biofuels.

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