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Energy Technology Innovation in Brazil

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ABSTRACT: The Brazilian electricity sector has witnessed numerous technological changes and has evolved to become a global leader in clean technology sales, both to the domestic and foreign market. A lot of factors contributed to the innovative activities in its electricity sector which includes both government and FDI contribution. This paper reviewed the past and current technology innovation in the country's electricity sector with some concentration on the patent, and research and development. Some advanced economy such as Korea, USA, Japan, Germany and France were also compared in reference to their patent data, policies and renewable energy attractiveness to identify the options that contributes to their innovative capability in renewable energy technologies. Some policy recommendations were provided in order to foster innovation in Brazil.

Keywords: Brazil; Innovation; Technology; Electricity Sector; Renewable Energy
JEL Classifications: Q28; Q50; Q55

1. Introduction

Innovation can be defined as a new idea or an introduction of something new, which maybe a device, equipment or process (www.merriamwebster.com). Innovation can also be the application of a better solutions to a problem that meet new requirements, inarticulate needs or existing market needs (Maranville, 1992). This is accomplished through more effective products, processes, services, technologies, or ideas that are readily available to markets, governments and society. The term innovation can be defined as something original and, as a consequence, new, that "breaks into" the market or society (Frankelius, 2009).

Energy is an important factor for the socioeconomic development and economic growth of any nation while electricity is an important facet of any nation's development (Vincent & Yusuf, 2014; Emodi et al., 2014).The field of energy have seen various forms of innovation which ranges from solar PV to solar thermal heaters, onshore wind to offshore wind turbines, hydrogen to fuel cells, etc. all these technologies have the primary aim of meeting the energy needs of man in the society. Most innovative activities previously had their root in developed countries due to the economic capability to pursue new ideas in order to solve their economic needs but this has changed as most developing countries have taken the lead in innovative activities. These activities are as a result of the acquired knowledge from developed countries which usually begin with foreign direct investment or government sponsored projects. The most valuable part of the investment is the "spill-over effect" and most government of developing countries are more focused on it.

Among the most successful developing countries in the world are Brazil, Russia, India, China and South Africa. These countries are called the BRICS and they represent the emerging economies (SouthAfrica.info, 2011). The BRICS are all newly industrialized countries and distinguished by their large, fast growing-growing economies and significant influence on regional and global affairs (BBVA Research, 2012). However, the objective of this paper is analyze the current status of innovation in the energy sector in Brazil. We focused on the renewable energy innovation activities and compare it with Korea, United States of America (USA), Japan, Germany and France.

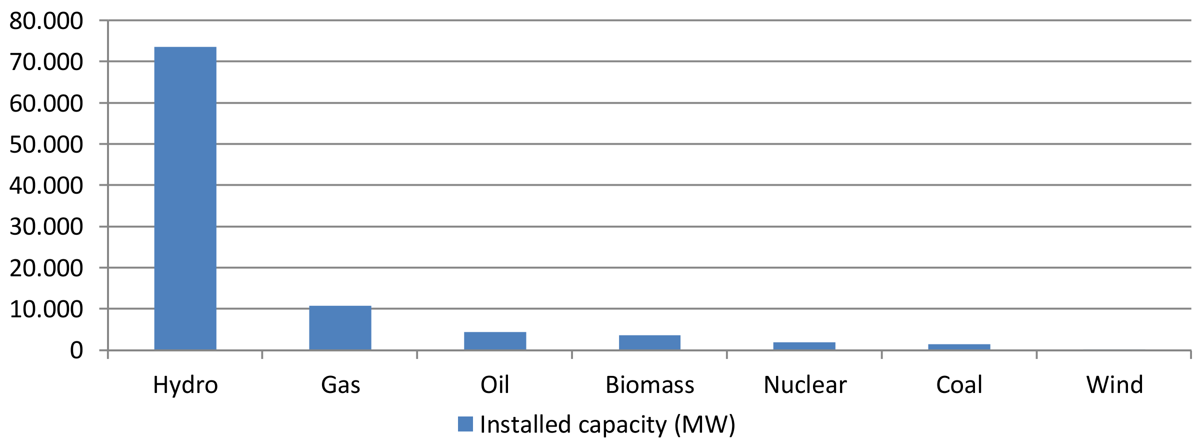
The reset of this paper is arranged as follows. Section 2 gives a general overview of the electricity sector in the three countries. The reason for technological innovation in the electricity sector discussed in Section 3. Some issues are raised in Section 4 in relation to technological innovation. Section 5 presents some comparisons with Korea, USA, Japan, Germany and France. Some policy recommendation and conclusions are given in Section 6 which concludes our paper.

2. Overview of the Electricity Sector

Brazil is the largest country in South America, world's fifth largest country, both by geographical area (8,515,767 KM^2) and population (202,656,788) in 2014 (www.census.gov). In terms of economy, Brazil is the world's seventh largest by GDP ($2.244 trillion) and purchasing power parity ($3.073 trillion) in 2012 (www.worldbank.com, www.cia.gov). Brazil is the member of the BRIC group and by 2010 was one of the fastest growing economy in the world with its economic reforms that gave the country a new international recognition and influence (Alin, 2008). In energy, the country is the tenth largest consumer in the world and the largest in South America, while being the important producer of oil and gas, and the second largest ethanol fuel producer. The country's Ministry of Mines and Energy (MME), National Council for Energy Policy (CNPE), National Agency of Petroleum, Natural Gas and Biofuels (ANP) and the National Agency of Electricity (ANEEL) are government agencies responsible for the country's energy policy (OECD, Project Closing Report, 2005). The major players in Brazil's energy sector are state-owned companies Petrobras and Eletrobras.

In the Brazilian electricity sector, its electricity market is the largest in South America with installed capacity comparable with that of the United States and Italy but have a larger transmission network. The country is highly dependent on hydroelectricity and has the largest water storage in the world (OECD, Project Closing Report, 2005). The country's access to electricity is 97% but its dependence on hydroelectricity makes it vulnerable to shortage in power supply when drought sets in as it occurred during the 2001-2002 energy crisis.

Figure 1. Installed capacity (MW)

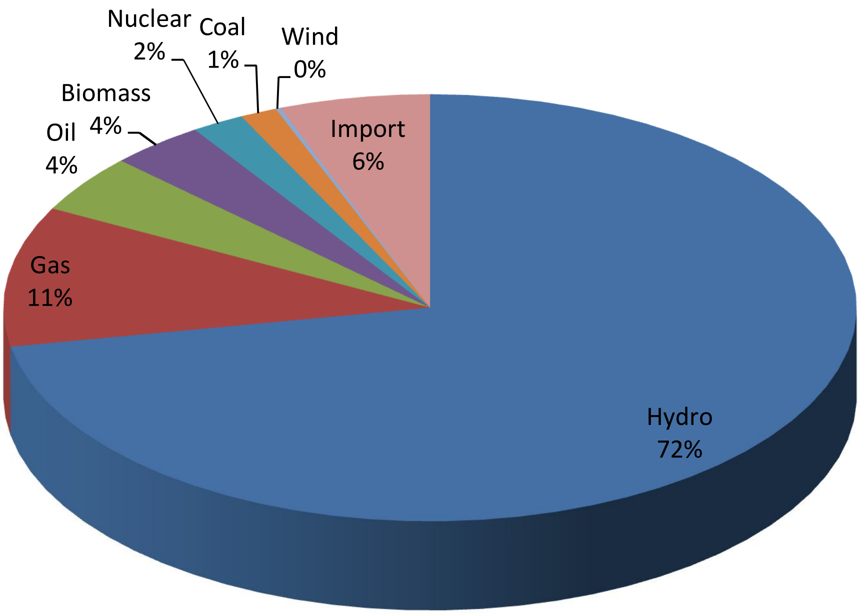


Source: Ministry of Energy and Mines (2007)

The reform in the Brazilian power sector was lunched in the mid-1990s in 2004; a new regulatory framework was applied. About 387 TWh of electricity are produced by the 86.5GW installed generating capacity (www.iea.org). During the 2001 electricity crisis, the Brazilian government launched a program to build 55 gas-fired power stations with a total capacity of 22 GW, but only 19 power stations were built with a total capacity of 4,012 MW (Baker Institute, 2004). Figure 1 shows the Brazil's total installed generating capacity, Figure 2 shows the percentage source of electricity generation and electricity generation by fuel source from the period of 1990 to 2012 is shown in Figure 3.

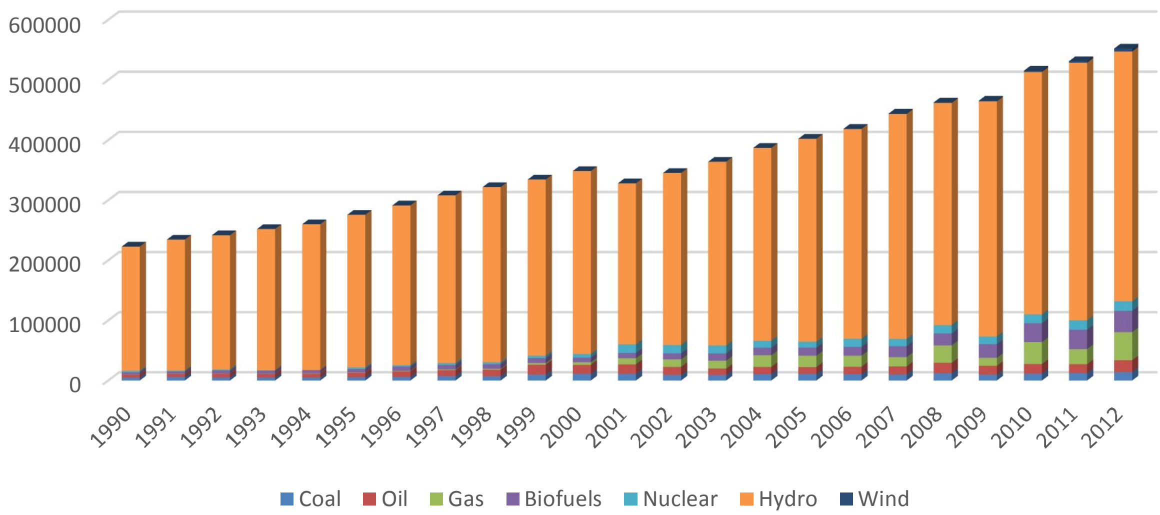
The Brazilian government created a Program to Foster Alternative Sources of Electricity Power (PROINFA) in 2002 with aim of increasing the participation of wind power sources, biomass sources and small hydropower systems of supply into the country's grid through Autonomous Independent Producers (PIA). The medium to long-term objective (20 years) of the program is that the previously mentioned source will supply 15% of the annual market growth until they reach 10% of the nation's annual electricity power demand (www.iea.org).

Figure 2. Electricity source (%)



Source: Ministry of Energy and Mines, (2007)

Figure 3. Electricity generation by fuel source



Source: IEA

2.1 Government entities and responsibilities

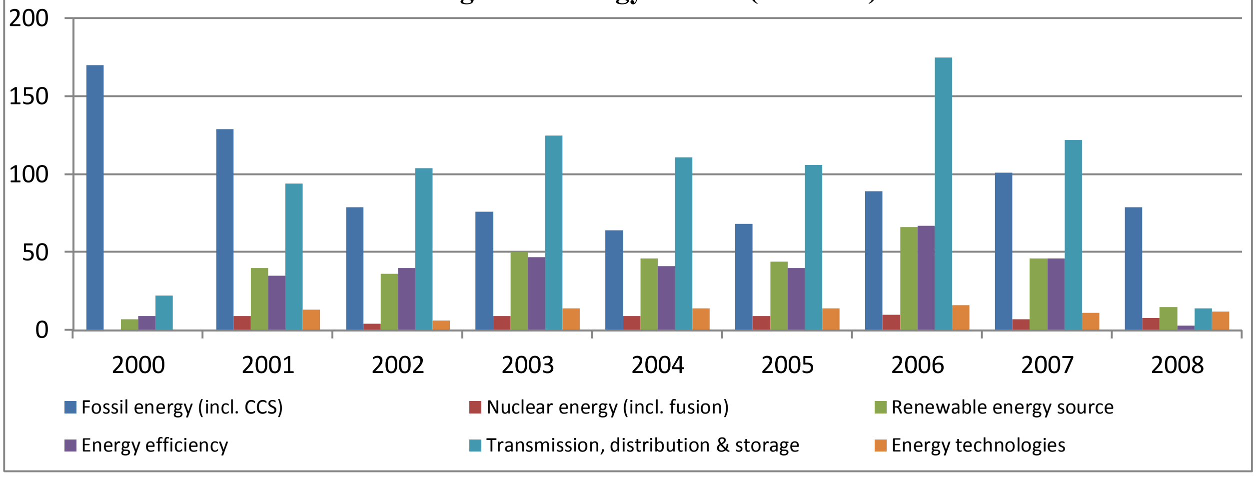
As earlier stated the Ministry of Mines and Energy (MME) coordinates energy policy while the Ministry of Science and Technology (MCT) is responsible for the defining and implementing the National Policy of Science and Technology. The MME is responsible for the Energy Research Company (EPE) which was formed as a subsidiary in 2004 and published its National Energy Plan 2030 and its National Energy Balance 2030 with the aim of including a greater share of cane sugar and gas as domestic energy source and a reduction in imported gas and hydroelectricity (Guerreiro, 2009). The MCT regulates three sectorial funds for the energy sector which was created to ensure solid and permanent investments in R&D. They include; (a) CT-Energy finances Projects and programs in the energy sector which special concentration on energy efficiency. About 0.75% to 1% of the net sales of generation, transmission and distribution companies are directed to this fund. (b) CT-Petro handles the simulation of innovation in the production chain of the oil and gas industry. Funding comes from the royalties of oil and natural gas production with about 25%. (c) CT-Infra provides funds for infrastructural R&D which includes hydrogen and fuel-cell technology (Kempener et al, 2010).

The Ministry of Education (MEC) plays an indirect role in shaping Brazil's innovation policy by funding universities, also the Ministry of Development, Industry & Foreign Trade (MDIC) also plays indirect role. The international commission on Climate Change was established by the Brazilian government in 1999 and this developed the "National Plan on Climate Change" with the policies of (a) increasing energy efficiency to decrease electricity consumption by 10% in 2030, Maintain high level of renewable electricity supply, Increasing the use of biofuels in the transport sector, and reducing deforestation by 70% by 2017 and eliminate net loss of forest coverage by 2015 through reforestation (Kempener et al, 2010).

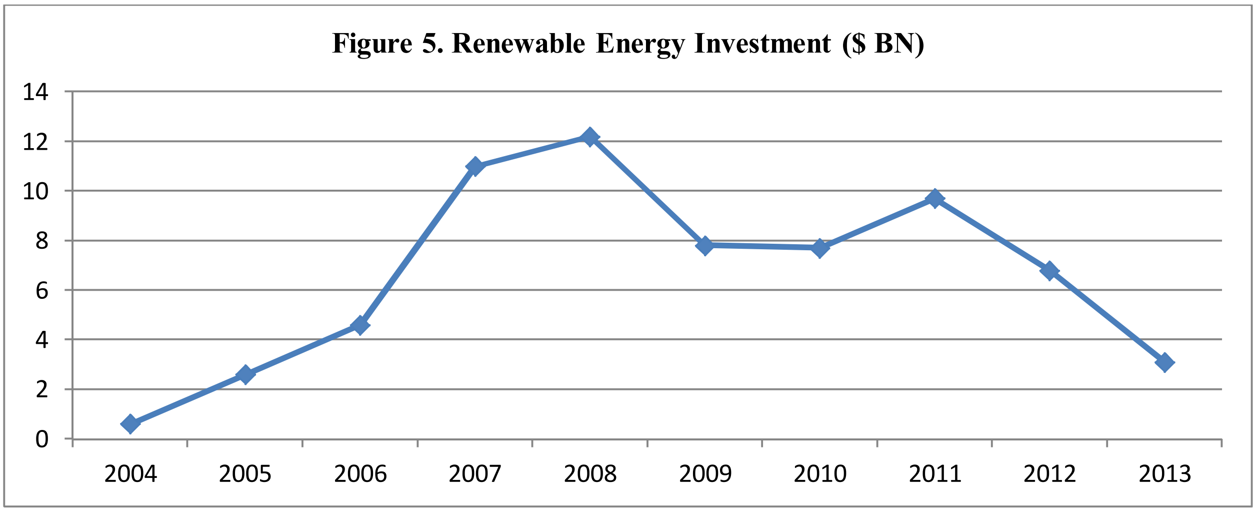
2.2 Research, Development & Deployment Allocation

The energy research, development & deployment (RD&D) in Brazilian electricity sector is monitored, evaluated and allocated by the electricity regulator ANEEL (Act 9,991/2000). As previously stated, RD&D funds are provided by mandatory contributions from electric energy utilities. This fund depends on the minimum percentage of the utilities net operating income and the type of utilities in question. The R&D funding goes to the search for innovations to address the technological and market challenges facing the electricity sector on one hand and the energy efficiency funds go to the demonstration projects in the market (Kempener et al, 2010). Figure 4 shows the government expenditure on Energy RD&D from 2000 to 2008. Figure 5 shows the government investment on Renewable energy.

Figure 4. Energy RD&D ($ Million)



Source: Kempener et al. (2010)

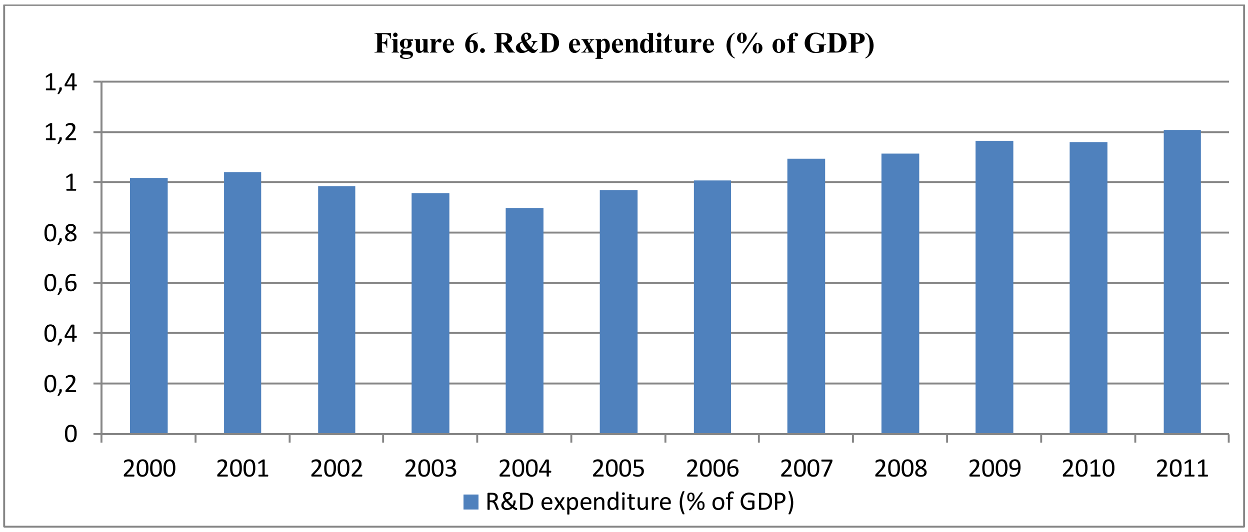


Source: Bloomberg New Energy Finance

3. Technology Innovation in the Energy Sector

3.1 Government Investment in Innovation

Technology innovation in Brazil's energy sector has been improving since the government made effort to improve on the country's energy mix which heavily depended on hydropower. The government has invested a lot into innovation (R&D, demonstration projects and commercialization) in order to create the capacity to absorb technology and create valuable partners for technology cooperation. The Brazilian innovation system has far exceeded that of China and India in many ways for more than half a century. However, R&D spending has been just 1% of the nation's GDP for the last decade (Agarwal et al, 2010). Figure 6 shows the Brazilian government spending on R&D for the year 2000 to 2011.



Source: Worldbank

Investment in the public sector innovation is mainly carried out by the government especially in ethanol and agriculture. An example is the Brazilian Bioethanol Science and Technology Laboratory (CBTE) which was established in 2009. The CBTE conduct R&D on sugarcane and ethanol cycle and provide demonstration facilities for second generation ethanol production. The aim is CDTE is to provide researchers with solutions in reducing the bottlenecks experienced when improving energy efficiency and productivity in the fuel market. From Table 1, we can see that biofuels have the highest patent coming from Brazil. In agricultural biotechnology, university based research contributes to improvement in biofuels as well as R&D and commercialization activities sponsored by the Brazilian Agricultural Research Corporation (EMBRAPA). These companies are usually not under the Federal government control and they invest in fundamental innovation, an example is Petrobas with large investment in R&D for biofuels and CCS.

The government also promotes innovation in the private sector in the private sector by lending funds at preferential rates to foreign and domestic companies. This is a form of subsidy provided by the government to encourage investment since the loans are cheaper for the companies than going for market rates (Levi et al. 2010).

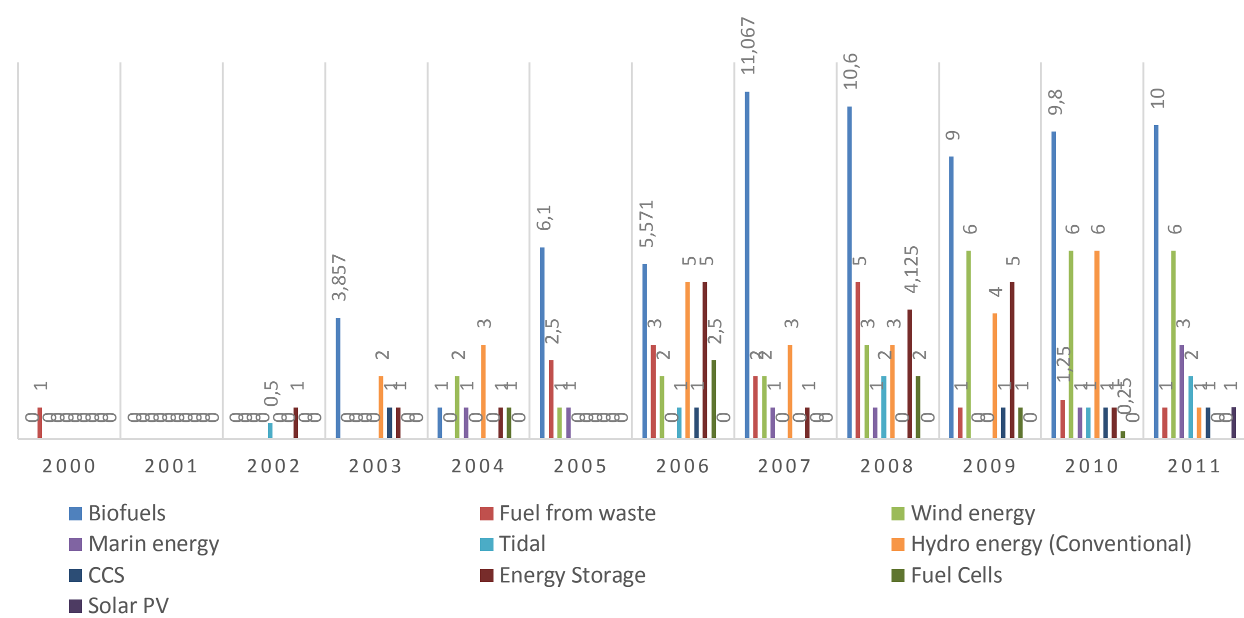
3.2 Intellectual Property Protection

Technology diffusions are promoted when firms allow other firms to access their technological knowledge, even if under strong intellectual property protection. Innovation is accelerated when firms make their inventions public under IPR protection, since others can build on their discoveries. Brazil has generally been supportive of IPR but has its own view of it as public good exception. Considering the limits of IPR protection in Brazil, a large number of multinational investments have flown in to the country's R&D intensive manufacturing sector (Levi et al. 2010).

Brazil's experience with clean energy has encouraged international companies to bring their most cutting-edge technology with the available market in the country. The international companies buy local companies or set up theirs instead of using license agreements. This ensures added intellectual property protection since the owning company is in a good position to control the use of its IPR throughout the market. IPR in Brazil has been improving and now has some IPRs to protect in both the domestic and international market (Technology Transfer and Innovation, 2012).

A "bottle-neck" experienced by the Brazilian commercial enterprises is that smaller and lesser known companies find it extremely difficult to protect their intellectual property right. This hinders proper technology transfer to the host country because they are weak in protecting their own IPR and those of others from abroad. But this has no significant effect as current joint ventures and acquisitions in the country are bringing technical information and knowledge know-how into the country. Figure 7 shows the available energy patent in Brazil from 2000 to 2011.

Figure 7. Patent From Brazil



Source: OECD

3.3 Foreign Trade and Investment

Technology transfer can be reduced or increased through barriers to trade of low-carbon technologies in such way that if sales of the technologies are negatively affected and the cost of its component are too high, domestic manufactured technologies become more costly and less attractive to purchase. This will increase the price of foreign technologies and encourage overseas firms to deploy their factory into the country and manufacture the product/technology into the country rather than import them. This will indirectly yield technology transfer (Levi et al. 2010).

Brazil is a latecomer to economic liberalization but still have average tariffs of about 10%. Meanwhile, tariffs on various capital goods like machinery and manufacturing equipment are very low in order to improve foreign direct investment (FDI) and boost productivity. Before 2009, the government demanded that 60% of wind projects value added should be locally sourced. By 2010, the government removed the law for advanced turbines but increasing them for smaller machines. The country has long removed its barriers to trade and encouraged domestic firms who specialize in clean energy technology using locally sourced materials (de Paiva, 2006).

Brazil is fast becoming a preferred destination for FDI with a favorable investment climate. Biofuels have caught the attention of investors who discovered the country's resource availability, technological capability and market potential for both the present and future. FDIs have also invested in wind energy technology by setting up production facilities in the country which will improve technology transfer and knowledge spillover

3.4 Industrial Structure

The economic structure of a nation determines the rate of adoption and adaptation of foreign technology into its context. For technology transfer to occur depends on the business climate and historical milestone of the host country. The private sector in Brazil has proven capable adopting and adapting to foreign advance technology. A large number of multinational companies have been created their own subsidiaries, joint ventures with local firms in economic sectors with high value added technologies.

By 2009, Brazil was second in leading venture capital and private equity financing for renewable energy and energy efficiency. However, the market for commercial loans, private and public equity are relatively new and so may be difficult to discover if they actually promote technology transfer. Generally, access to capital is usually limited to well-established domestic and international firms, the Brazilian Development Bank (BNDES) and private financial markets have not adequately funded for small and medium-enterprise (SMEs) which makes it difficult for new technology commercialization(Levi et al. 2010).

The local banks give out commercial loans to both domestic and foreign investors which are in line with some recent banking regulations to aid in market expansion. The continuous expansion of the Brazilian economy goes in line with business interest from foreign investors who flourish due to the availability of funds from banks, private equity groups and hedge funds. The Brazilian stock exchange (BOVESPA) which is the ninth largest in the world is an avenue for provision of funds and technology acquisition (The Global Power for Brazilian agribusiness, 2010).

3.5 Clean Technology Sales

The spread of advance technologies to developing economies indirectly turns the developing country into an exporter of the advance technologies. As previously stated Brazil is the world largest exporter of biofuels and fast becoming a global leader in clean technologies. The country has high aspiration to increase its export of low carbon technology such as genetically engineered sugarcane plants, high efficiency milling technology and technology for flex-fuel cars. These technologies have been made for export and domestic market alike. Most of the exported technologies are made by the private sector which has the most competitive cost structure for biofuels in the world and sees sizable market opportunities overseas. This indirectly comes from the government who works through the foreign ministries to promote the biofuel technology and use it to solidify bilateral relationships with other developing countries (Levi et al. 2010).

4. Energy Policy[1]

The Brazilian government has intensified efforts to reduce the country's dependence on foreign energy supplies and stimulate the development of domestic energy sources. These policies and their outcome benefited the country's balance of trade, national security, and capital goods industry and labor market. From the lessons learned from Brazil's past experience, so many new energy policies and initiatives have helped the country advance socially, economically and achieve a sustainable

[1] This section was adopted from "Corporate Clean Energy Investment Trends in Brazil, China, India and South Africa". Carbon Disclosure Project (CDP).

energy development. In this section, we will review only the renewable energy and energy efficiency policies (*See* Carbon Disclosure Project);

4.1 Renewable energy policies

Program of Incentives for Alternative Sources of Electric Energy (PROINFA): the program was setup in 2004 with the aim of increasing the participation of wind, biomass and small hydropower (SHP) in the National Electric System. The total energy generated from this program benefits from guaranteed 20-year supply contracts with Eletrobras.

Brazil's Hydropower Program: the program was setup in 2004 and mandate hydropower projects to sell their power at public auction. Distribution utilities and project developers sign contacts in which generators benefits from the guaranteed 15 to 30 year of Power Purchase Agreement.

Mandatory Biodiesel Requirement: the law was established in 2005 and required that biodiesel (which is a mix of vegetable oil and sugarcane ethanol) to be blended with standard diesel. The blend content increased to 5% from January 2008 to January 2010. Funds for investment in biodiesel were provided by the National Economic and Social Development Bank (BNDES). One of the measures was a 25% extension in the total loan payoff period for the purchase of machinery that uses at least 20% biodiesel fuel.

National Climate Change Plan: established in 2008, the plan targets goals relating to renewable energy such as:

- Charcoal: increase consumption of sustainable charcoal to replace coal in steel plants, mainly through the encouragement of forestation in degrading areas.
- Solar Heating: encourage the use of water solar power heating systems, reducing electricity consumption by 2,200 GWh per year starting from 2015.
- Hydroelectricity: 34, 460 MW from new hydropower plants to be added to the system in accordance with the schedule of works of the Ten Year Energy Plan (2007-2016).
- Energy from wind and sugarcane bagasse: increase the share of these sources in the electricity matrix through auctions of renewable energy.
- Photovoltaic Solar Energy: seek the expansion of the national photovoltaic industry and the use of this energy source in systems that are both isolated and grid connected;
- Ethanol: encourage industry to achieve an average annual consumption increase of 11% in the next ten years and technical cooperation with other countries.

Electric Power Auctions for Biomass (2008) and Wind (2009): energy distributors are required to enter into long term contracts for all of their electricity demand via a reverse auction system. Under the auction system, there are specific auctions for existing energy sources, and those for new energy sources (including renewable energy). Brazil's electricity regulatory agency (ANEEL) carries out reserve energy auctions, designed to purchase additional energy supply for the National Integrated System (SIN) in order to reduce operational costs of the system.

4.2 Energy Efficiency Policies

National Electrical Energy Conservation Program (PROCEL): the program was established in 1985 with the objective of reducing inefficiency in electricity use, and to seek energy efficiency in the electricity sector. The program offers training courses, seminars, and conferences to industrial and commercial consumers, concession-holder staff and public organizations to combat energy waste. PROCEL also helps utilities obtain low-interest financing for major energy efficiency projects from a revolving loan fund within the Electric Utilities sector.

Utility Energy Efficiency Obligation: set up in 1998, the concession contracts signed between electric power distribution companies and the Brazilian energy regulator ANEEL establish their obligations and responsibilities. One of these is to annually invest an amount not less than 0.5 % of the company's net operational revenue in activities aimed at reducing inefficient use of electricity.

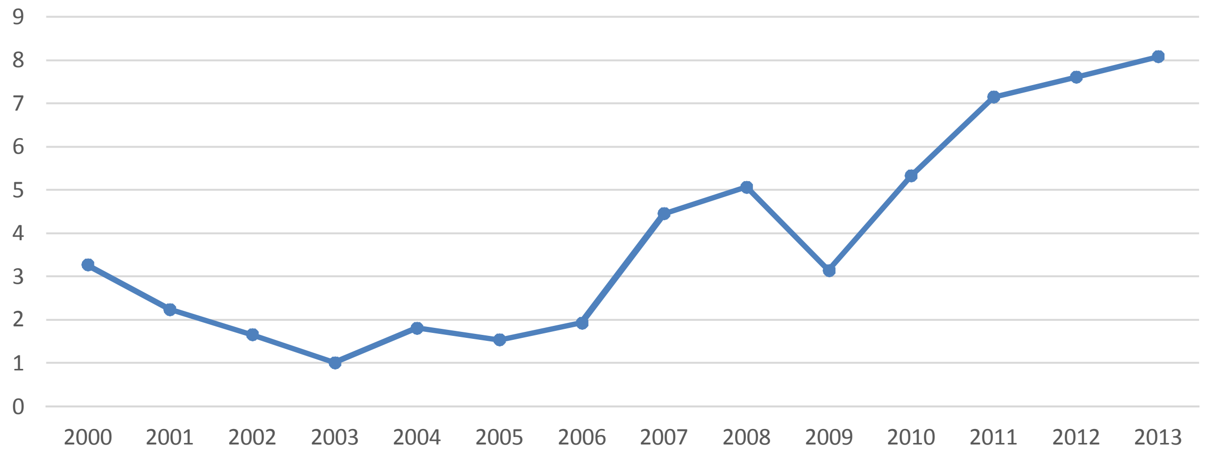
National Policy on Climate Change: the Brazilian government approved this policy in 2009 and it includes the creation of a voluntary national emissions reduction target of reducing between 36.1% and 38.9% of projected emissions by 2020. Half of the reductions are expected to come from improved energy efficiency in construction, farming and industry. The main goals of the policy include:

- Implementation of the National Policy for Energy Efficiency that will result in a gradual energy saving up to 106 TWh/year to be reached in2030, avoiding emissions of around 20 Million tons of CO_2.
- Reduction of non-technical losses in the electricity distribution at a rate of 1,000GWh per year over the next ten years. This will represent a reduction in energy wastage of 400 GWh per year.

5. International Clean Technology Transfer

Technology transfer from developed to developing country is an important means to foster clean energy development. This is mainly done my multinational companies who represent a large number of private sector in Brazil. FDI in Brazil has grown over the years with USD$ 32 billion in 2000 to USD$ 80 billion in 2013 (See Figure 8).

Figure 8. FDI investment net inflows



Source: Worldbank

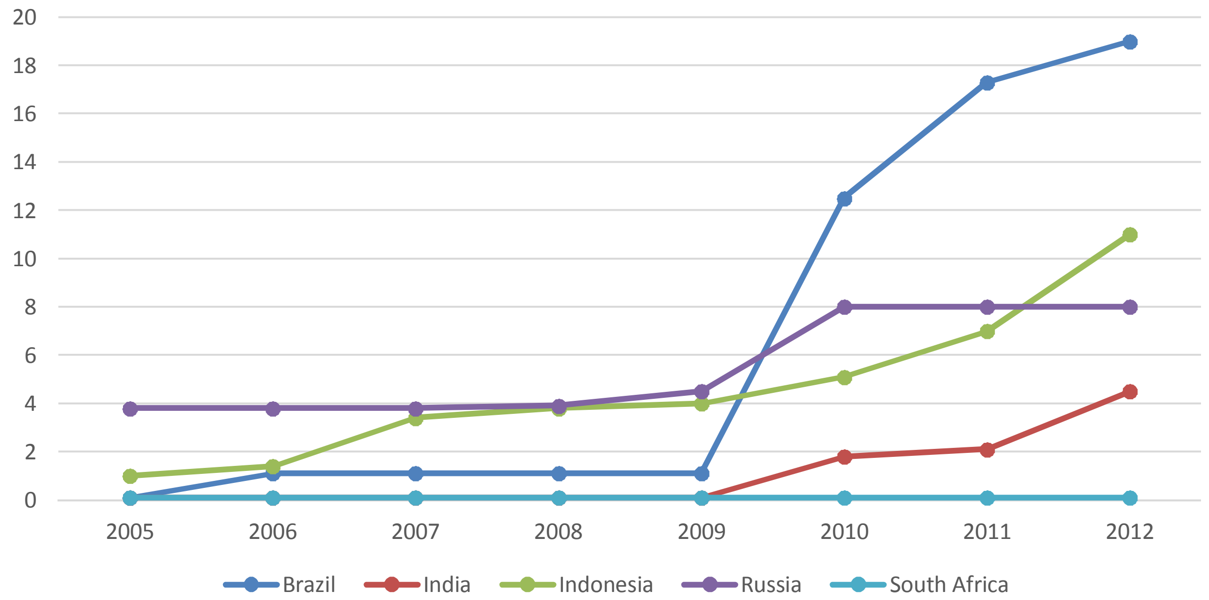
Joint venture and licensing are means of technology transfer which is easy in Brazil. However, the Brazilian government eliminated industrial products tax and value added tax on PV modules and cells, solar water heaters and wind generators in 2000 and these improved technology transfer, joint ventures and licensing of renewable energy and energy efficiency technologies in the country. Import duties still exist in solar PV systems and wind technologies (17 to 21% import tax) and solar water heaters (30% import tax). Besides this, the government still provides funds for promoting R&D in the energy sector as a whole such as CT-ENERG which aims to stimulate technology transfer, adaptation, development and testing of new energy technology options for Brazil (Szklo & Geller, 2006). We will discuss on two important technology transfer that is important to Brazil and they are; Wind energy and Biofuels.

5.1 Wind energy

The relationship between Brazil and other developing countries have greatly improved the extent of technology transfer from other countries to the Brazilian economy. Among these countries is China which has been improving its technology investment and transfer in Brazil. China has been a global leader in technology development for over a decade. The energy sector in Brazil has absorbed investment of more than USD$ 18.2 billion from China which is the highest as compared to other developing countries where China has high investment. This can be seen in Figure 9

China intensified its investment in Brazil in 2004 when they set up the CBHCC and added a subcommittee on energy and mining in 2006. By 2009 as shown in Figure 4, China became the biggest trade partner to Brazil and in 2010 the CBHCC produced a joint action plan that details support for investment projects, as well as the intention to increase co-operation in energy technology. China's main interest in Brazil's energy sector is in the area of oil and gas, wind and transmission.

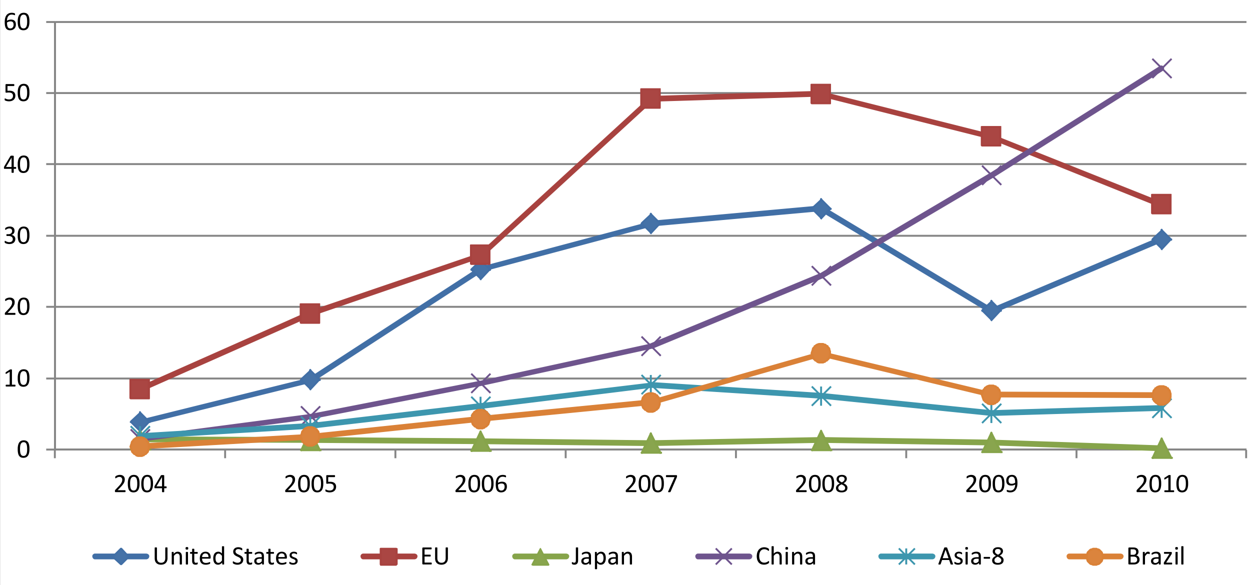
Figure 9. Cummulative Chinese energy investments in key IEA countries (USD$ BN)



Source: Heritage Foundation, 2013

Brazil's location for wind energy technology has the highest capacity in the world with high market potential but is lacking in the area of wind energy deployment. China's ability as an independent supplier of wind turbines, its components and large investment in wind farms made it possible to ensure technology transfer to Brazil. The country has been making a lot of investment in wind technology which by 2010 was the fourth largest in the world after the USA, EU and Japan as shown in Figure 10.

Figure 10. Wind energy investment ($ Bn)



Source: Heritage Foundation, 2013

However, China have been having IPR issues because some components supplied by China have been subject to scrutiny for potential IPR infringements one hand and the local content demanded by the government is also presenting a some challenges to the Chinese investors. The government through the BNDES has targeted the assembly of wind turbines as part of its move to increase locally produced content by giving manufactures target that should be met. (Dechezlepretre, A. et al. 2009).

Wind energy can be onshore or offshore wind installation but Brazil is mainly produces onshore wind turbines. The wind turbines make up the single largest component of the capital expenditure (CAPEX) required for an onshore wind installation, roughly 63% of the total cost. The remaining components include concrete foundations, on-site electrical and site-preparation and transport. Depending on a project site's location relative to the manufacturing facility supplying the turbines, transportation costs can cause total CAPEX to increase substantially. Wind turbines produced in Brazil are less expensive compared to other countries due to the availability of high quality wind resources. According to Bloomberg New Energy Finance, Brazil's onshore wind turbines CAPEX and operating expenditure (OPEX) may not be as competitive compared to the other countries (See Table 1) but its capacity factor and Levelized Cost of Energy (LCOE) is very competitive. The Brazilian government auction scheme has encouraged the massive boom in the wind technology deployment. Brazilian wind technology has also benefited from access to affordable financing from the Brazilian Development Bank (BNDES) (World Energy Perspective, 2013).

Table 1. Levelised cost of wind by country

Country	CAPEX (USD/MW)	OPEX (USD/ME/yr)	Capacity factor (%)	LCOE (USD/MWh)
India	1.08–1.25	10,694–24,391	15–33	47–113
China	1.36–1.37	17,000–25,138	19–35	49–93
Brazil	1.67	24,000	23–45	55–99
United States	1.83	24,000–24,400	20–46	61–136
Australia	2.27–2.45	33,907	30–42	71–99
Europe	1.61–1.94	23,000–28,750	20–36	71–117
UK*	1.43–1.52	28,750	28–31	72–74
France	1.43–1.52	20,000–22,500	26–31	75–82
Germany	1.36–1.46	19,000–21,500	24–27	79–82
Sweden	1.59–1.71	19,000–21,500	28–33	79–83
Netherlands	1.44–1.61	20,000–22,500	25–31	79–84
Denmark	1.51–1.61	20,000–22,500	26–30	80–85
Italy	1.46–1.6	20,000–22,000	24–30	87–95
Spain	1.39–1.63	20,000–22,500	26–29	88–91
Poland	1.52–1.73	23,000–24,500	25–30	93–97
Romania	1.61–1.85	22,000–24,500	24–30	100–107
Bulgaria	1.57–1.88	22,000–23,500	24–29	105–106

Source: Bloomberg New Energy Finance

5.2 Biofuels

Being the largest exporter of ethanol and second in ethanol production to the USA, Brazil's ethanol delivers 20 percent of the nation's transport energy needs. The biofuel industry served mainly the domestic market but with the current improvement in technology with application in foreign technology has turned the country into the world second largest exporter (See Table 2).

The establishment of the Brazilian sugar-based industry was created with the sole aim of reducing the countries dependence on foreign oil and ensuring a clean sustainable supply with its home grown biotechnology industry. The government also supported the ethanol industry by directly investing public money in R&D to increase the efficiency and productivity of sugar cane production. Several universities have also received funds from the government to conduct research on sugarcane biotechnology.

The biofuel industry has also benefited from the Center for Sugarcane Technology (CTC), which develops more productive varieties of sugar cane. The closeness of this industry to the government without government involvement makes it particularly well positioned to adapt technology for industrial use. The center's partnerships with BASF and Novozymes speak of the international acknowledgement of its quality as well as its participation in the cross-border transfer of commercial technology (Torres et al., 2011).

Table 2. Biofuels Global Production, Top 16 countries and the EU-27, 2013

COUNTRY	FUEL ETHANOL	BIODIESEL	HVO	TOTAL	COMPARISON WITH TOTAL VOLUMES PRODUCED IN 2012
USA	50.3	4.8	0.3	55.4	1.2
Brazil	25.5	2.9	0	28.4	4.1
Germany	0.8	3.1	0	3.9	0.2
France	1	2	0	3	0.1
Argentina	0.5	2.3	0	2.7	-0.3
Netherlands	0.3	0.4	1.7	2.5	no change
China	2	0.2	0	2.2	-0.1
Indonesia	0	2	0	2	0.2
Thailand	1	1.1	0	2	0.5
Canada	1.8	0.2	0	2	0.1
Singapore	0	0.93	0.9	1.8	0.9
Poland	0.2	0.9	0	1.2	0.3
Colombia	0.4	0.6	0	0.9	no change
Belgium	0.4	0.4	0	0.8	no change
Spain	0.4	0.3	0	0.7	-0.2
Australia	0.3	0.4	0	0.6	no change
EU-27	4.5	10.5	1.8	16.8	1.3
World	87.2	26.3	3	116.6	7.7

Source: Renewables 2014 Global Status Report

6. National Innovation System in Brazil[2]

Many economists and researchers have given various definitions of National Innovation systems. Freeman defines it as a "network of institution in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987). Lundvall defines it as "the elements and the relationships which interact in the production, diffusion and use of new and economically useful knowledge and are either located within the borders of a nation" (Lundvall, 1992). For an innovation system to be complete there needs to be a flow of knowledge between the actors in innovative system who includes firms, universities, and research institutions within them to ensure a smooth transition within the system.

In Latin-American region, Brazil stands as a leader in R&D investment with a 1.02% which may be little compared to developed economies. Science and technology institutions have a long history in Brazil. Two government institutions were created in 1951 which are; the National Council for Scientific and Technological Development (CNPq) and Capes, with the objectives of regulating and promoting scientific and technological activities in the country. The key actors on the Brazilian Innovation System can be divided into: Scientific and Technological Institutions, like Universities and Research Institutions; Funding Institutions at Federal and Regional level; private/public companies which promote innovative activities; and qualified human capital. Universities and Research Institutions play a key role in the Brazilian ST&I.

The higher institutions in Brazil are composed by 2165 universities with 89% being private and the Federal Government maintains 44 Federal Universities and 39 Federal Institutes (Demos, 2008 in Maldonado, 2009). In terms of funding, CNPq, CAPES and FINEP are the major actors where CNPq and FINEP depend on the Ministry of Science and Technology and CAPES from the Ministry of Education. As earlier mentioned, BNDES is a major actor in the innovation system and associated with the Ministry of Development, Industry and Foreign Trade, which goal is to provide long term finance for activities that contributes to economic development.

[2] This section was adopted from Maldonado, M. U.(2009) A Preliminary Framework for Modeling Innovation Systems in Latin America: The Brazil Case.

The Ministry of Science and Technology (MCT) ensures sectorial funding in key strategic areas and the Business Incubators National Support Program focused on developing and sustaining incubators and science and technology parks, among others. The Small Business Support Service (SEBRAE) which was established in 1972 with the objective to provide technological, financial and marketing orientation and consulting for SME. It uses a cluster perspective, for supporting different policies at regional level.

In the area of R&D expenditure, 52.66% comes from the government while 47.34% comes from the private sector [MCT, 2009]. Some sectors of the economy are forced to spend a percentage of their revenue on R&D activities which need to be developed by the universities and research institutions. This is observed in the energy sector who contribute 1.0% of their Net Operational Revenue on R&D and its broken down as follows; 0.4% is spent on R&D projects supervised by Electric Energy National Agency (ANEEL), another 0.4% goes to the Science and Technology National Fund (FNDCT) while the last 0.2% goes to the Energy Research Company (EPE). This law affects companies nationwide who generate, distribute and sell electricity which maybe state owned or private owned. These funds aids in the development of research activities that contributes to the creation of scientific and technical knowledge.

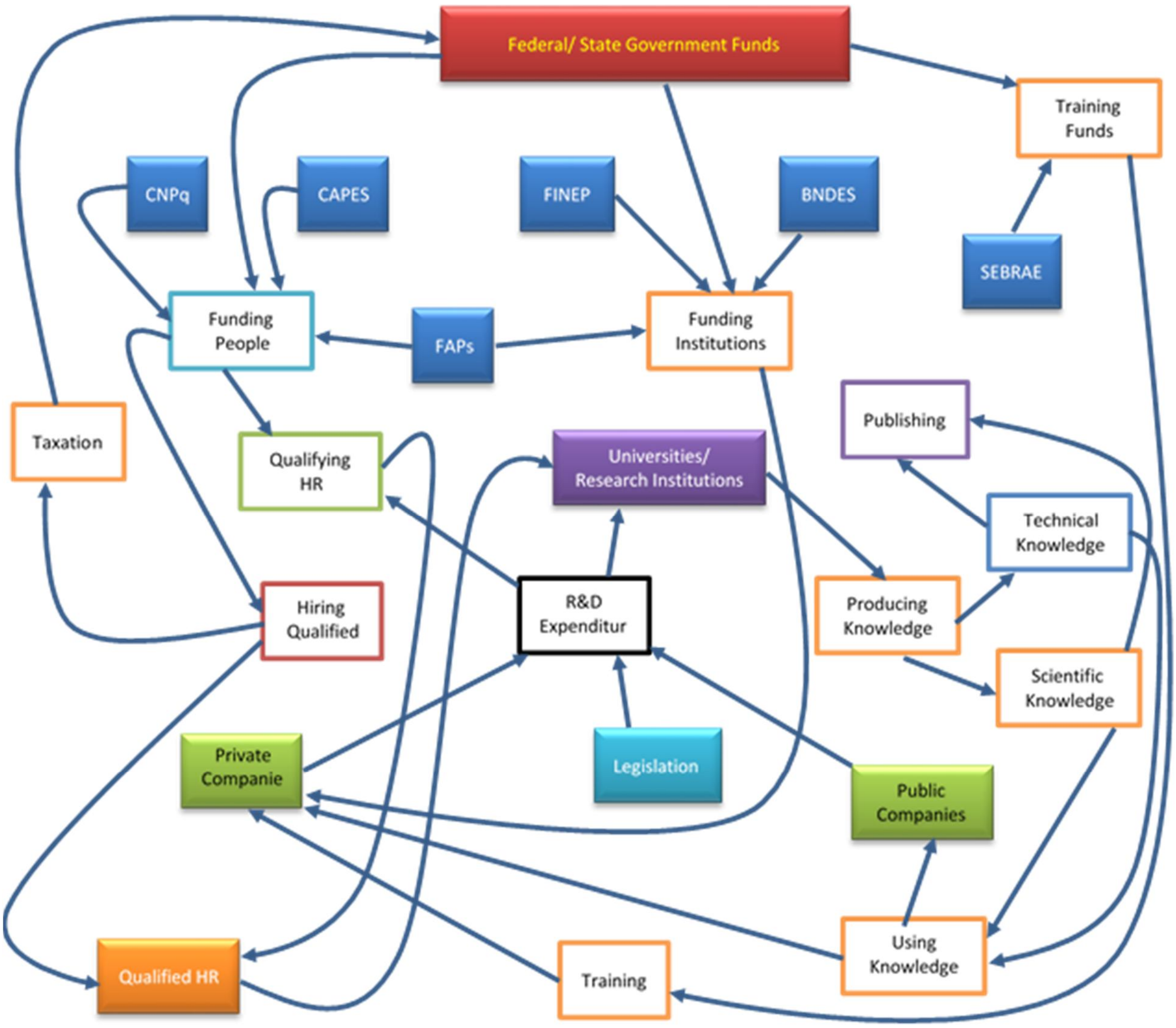
According to the framework proposed by Maldonado (2009), we can explain the National System of Innovation in Brazil as it pertain to the energy sector. Maldonado (2009) framework contains the following components (See Figure 8); Federal/State Science and Technology Institutions or Agencies, Private/Public Companies, Legislation, Universities/Research Institutions and Qualified Human Resources.

From Figure 11, we can observe interrelationships among the various actors in the Brazilian innovation system. The CNPq, CAPES, FINEP which are Federal Science and Technology Institutions and FAPs which is a State Science and Technology Institution promotes innovative activities in universities, research institutions, companies and by legislative means (Innovation Law, Good Law, PAC, etc). Qualified HR (Human Resource) are Doctorate degree holders or equivalent and they are qualified inside the Universities/Research Institutions.

The Federal and State Science and Technology Institutions provide some resources such as financial aids from CNPq, CAPES and FAPs in order to assist in the process by providing forming researchers with scholarships. Qualified HR is the most important element for knowledge creation, both scientific, technical and tacit. The integration of some Qualified HR into private firms are promoted by legislative incentives, while the other qualified HR are inside Universities, Research Institutions and the Public Sector. The legislative incentives aid the Research Institutions in working together with Qualified HR in R&D activities which will produce innovative ideas for the public and private companies.

From Figure 8, Funds are allocated to various Government Science and Technology Institutions and Agencies by the Federal and State Government. The various Government Science and Technology institutions provide funds for universities, research institutions, public and private companies, through several mechanisms such as scholarships for people and loans for companies. The Science and technology Agencies also provide funds to support R&D expenditures from companies which help in qualifying Human Resources that contribute academically, by producing knowledge that can be published and contribute to both the private and public companies, by transferring scientific and technical knowledge. The new knowledge is being acquired by the Companies and this create revenue and contributes to both the state and federal funds by the means of tax policies (Maldonado, 2009).

Figure 11. The Brazil Innovation System (Adopted from Maldonado, 2009)



7. Country Comparison with Korea, USA, Japan, Germany and France

7.1 Patent Application

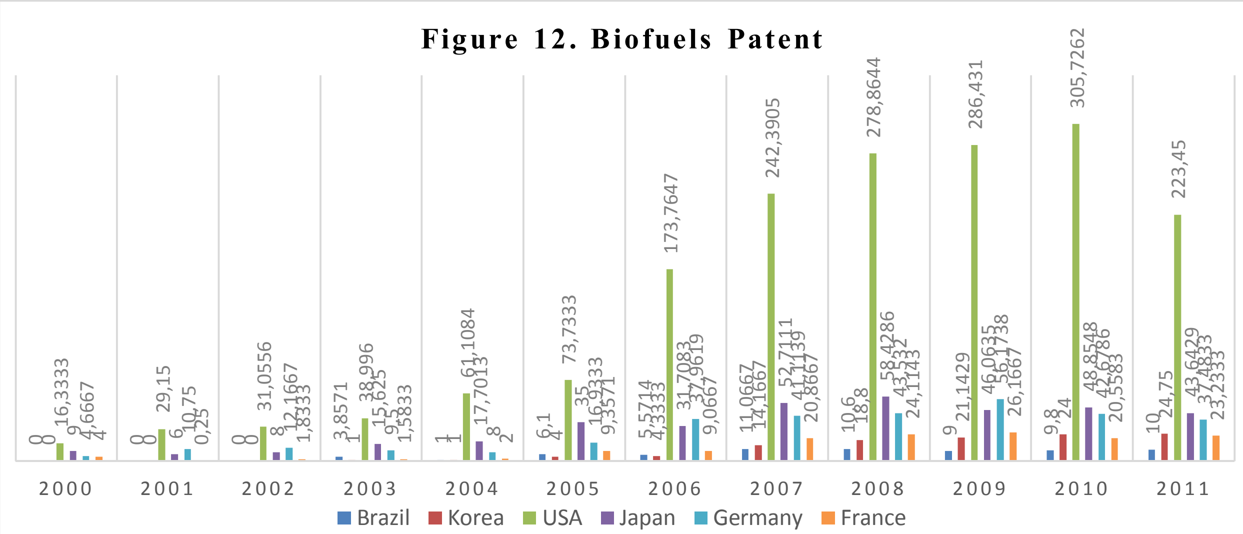
Measuring technological innovation is not easy per-say as economist have tried to figure out the best possible measure it. But there are still some ways in which we can measure technological innovation. We will use the some indicators such as patent applications in the various energy technology that Brazil is engaged with. This is not a perfect indicator in measuring the innovative performance of an economy since it focus on inputs. Patent application provides a wealth of information on the nature of the invention and applicant. In N. Johnstone et al., (2010) citing Griliches (1990), explained that a strong correlation exist between R&D expenditure and patent application. But the problem is that data for Brazil's Energy R&D expenditure is difficult to obtain in order to carry out a proper analysis. However, despite the limitation due to data availability, we will take the first step in comparing the patent application in the various energy technology that Brazil is engaged with.

We used data from the OECD-ilibrary database and made use of the data for "Patent application filed under the PCT" from the period of 2000 to 2011. PCT stands for Patent Cooperation Treaty (PCT) which is an international patent law treaty and provides a unified procedure for filling patent applications to protect inventions in each of its contracting states. A patent application filed under the PCT is called an international application or PCT application [www.en.wikipedia.org].

We begin our country patent application from OECD i-library comparison in the following order; Biofuels (Figure12), Solar PV (Figure 13), Wind Energy (Figure 14), Hydro Energy (Conventional) (Figure 15), Tidal Energy (Figure 16), CCS (Figure 17), Energy Storage (Figure 18).

7.1.1 Biofuels

Brazil filed for its first patent in 2003 after a long a long period of biofuel use in the country. Brazil lunched a National Alcohol Program (Proalcool) in response to the 1973 oil crisis in order to diversify its energy mix. However, this produced some innovative activities as the sector grew overtime and started to file for patents. As compared to other countries, Brazil still lack behind in the biofuel technology innovation despite the fact that it's the second largest producer and exporter of Biofuel in the world after the USA. From Figure 9, it's observable that the USA have been leading the way in biofuel innovation followed by Japan and Germany. As we mentioned earlier, patent count is an imperfect means of measuring technological innovation since when we talk about innovation, we are also talking about technology commercialization.



Source: OECD

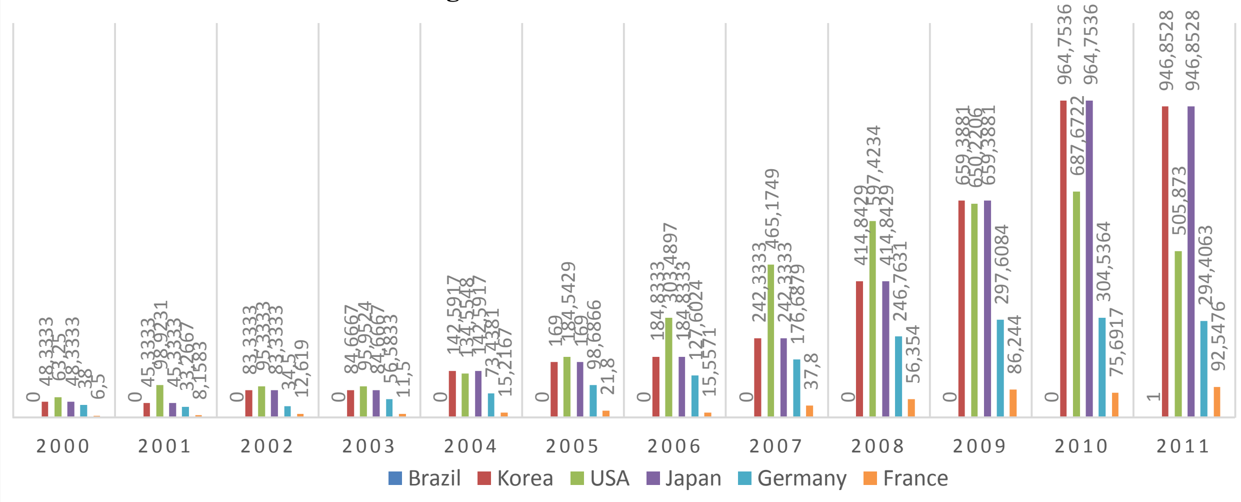
7.1.2 Solar PV

The high cost of Solar PV systems has hinder its development in Brazil even with the government tax incentives such as; Tax on Circulation of Goods and Services and Tax on Industrialized Product. These policies have not had effect on the Solar PV technology in Brazil, but in the year 2010, the government intensified its interest in the Solar PV technology and increased its budget in order to reduce cost. This produced some results as the first patent application was filed the next year (see Figure 10). Other countries (Korea, Japan, USA and Germany) have been on the forefront on Solar PV innovative activities by filling many patents. Most energy policies in the previously mentioned countries which are more developed focus on promoting innovation of Solar PV systems but this may not be commercialized as can be seen in countries like Korea and Japan where they carry out a lot of innovative activities but lack the main ingredient which is commercialization.

7.1.3 Wind Energy

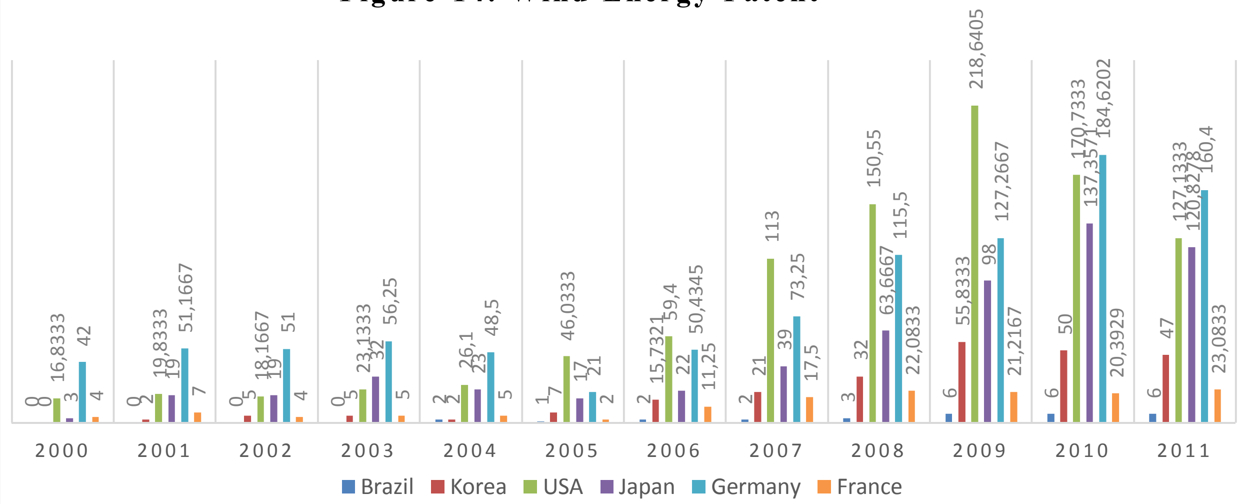
The Brazilian government's effort to boost wind energy technology produced some results and this gave rise to the rapid advance in wind technology. The Brazilian government gave subventions grants and the Ministry of Mines and Energy supported projects with US$ 21 Million for the development of wind turbines, converters, parsers, towers and transformers. The auctioning of wind farms by the government increased electricity generation in the country which required more turbines and the local industries were ready to supply. Between 2004 and 2009 (see Figure 9 and 10), wind energy investment has increased which in-turn raise the need for country based technology. As can be observed in Figure 11, the first wind patent was filed to the PCT in 2008 after much technology accumulation. However, as compared to other developed countries, wind energy patent is still low but wind energy commercialization and sales is very high in Brazil.

Figure 13. Solar PV Patent



Source: OECD

Figure 14. Wind Energy Patent

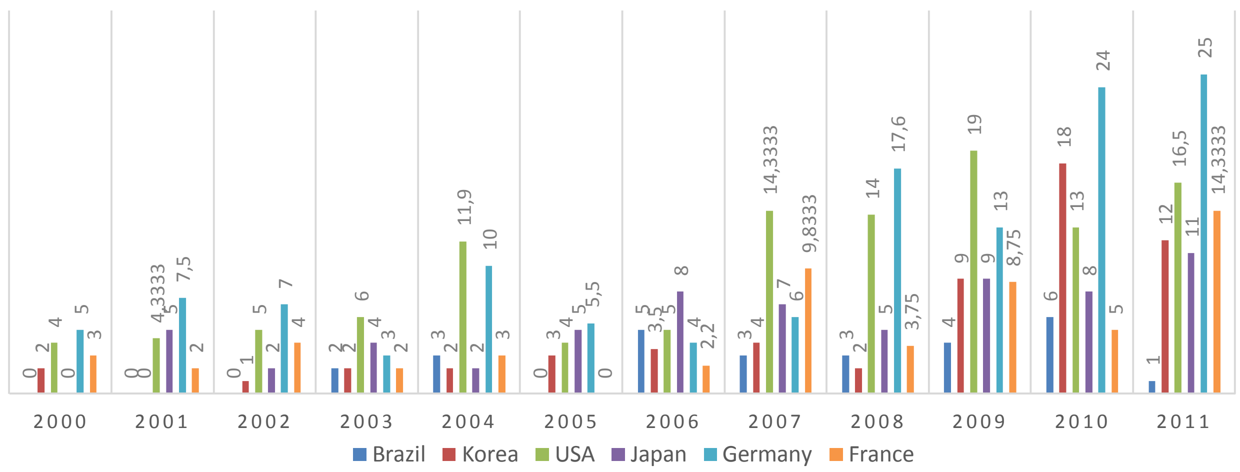


Source: OECD

7.1.4 Hydro Energy (Conventional)

Being among the top countries with hydroelectric storage, Brazil has been making remarkable effort to be innovative in Hydroelectricity. From Figure 12, we can see that the countries first patent for Hydro energy was filed in 2003 which was after the 2001-2002 energy crisis when drought struck the country and the government was keen to invest in innovative design in order to mitigate such occurrence again. Brazil has been doing well as compared to some countries but still lacks falls behind developed countries such as Germany, USA, France and Korea. Hydroelectricity technology requires huge investment in its R&D and so may be the reason why Brazil has not been filing in more patent as compared from 2011 but the number of patent for other countries have been increasing as can be clearly seen in Figure 12. Germany has intensify efforts to cut-down on CO_2 emission and provide funds for Clean Energy Technologies, this contributes to the number of patent the country has filed for. Other countries (USA, France, Korea and Japan) are also making progress in hydroelectricity innovation.

Figure 15. Hydro Energy (Conventional) Patent

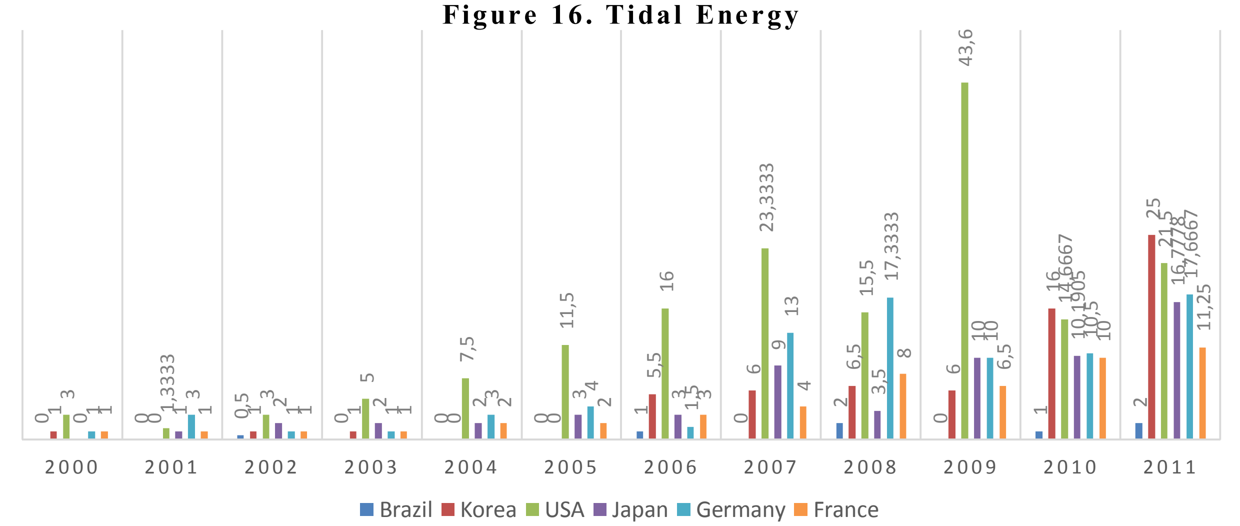


Source: OECD

7.1.5 Tidal Energy

Tidal energy patent in Brazil have been low since its first patent was filed in 2004. The Brazilian government has not done much for the development of tidal power in Brazil. Other countries such as the USA had the highest patent throughout the period of our observation except for 2010 when Korean increased its number of patent application.

Figure 16. Tidal Energy

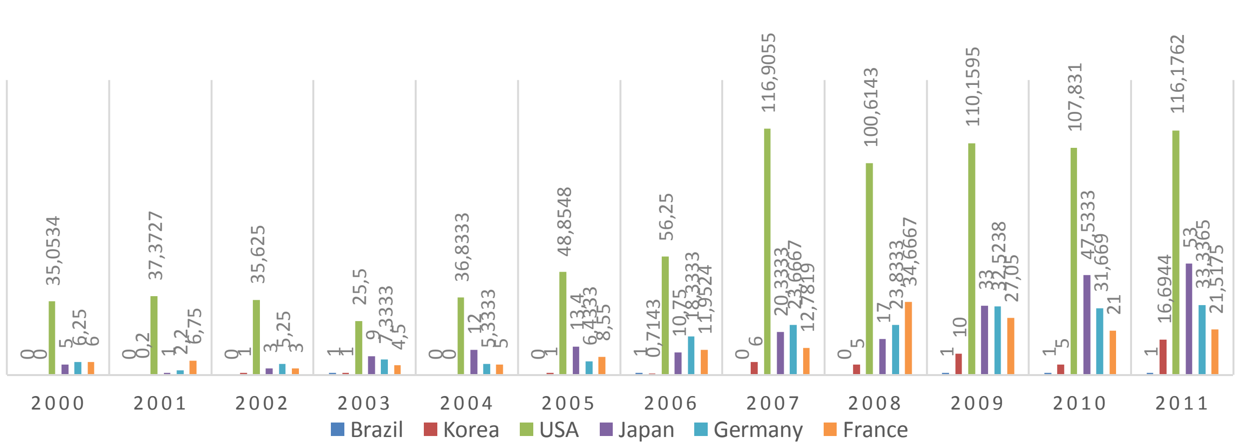


Source: OECD

7.1.6 Carbon Capture Storage

The CCS patent in Brazil is the lowest throughout our observation period. From 2003 to 2011, there have been only one patent per year with exception in 2004, 2005, 2007, and 2008. The USA have been the leader in CCS technology followed by Japan and these countries have enacted policies and funds to promote the development of clean energy technology.

Figure 17. CCS Patent

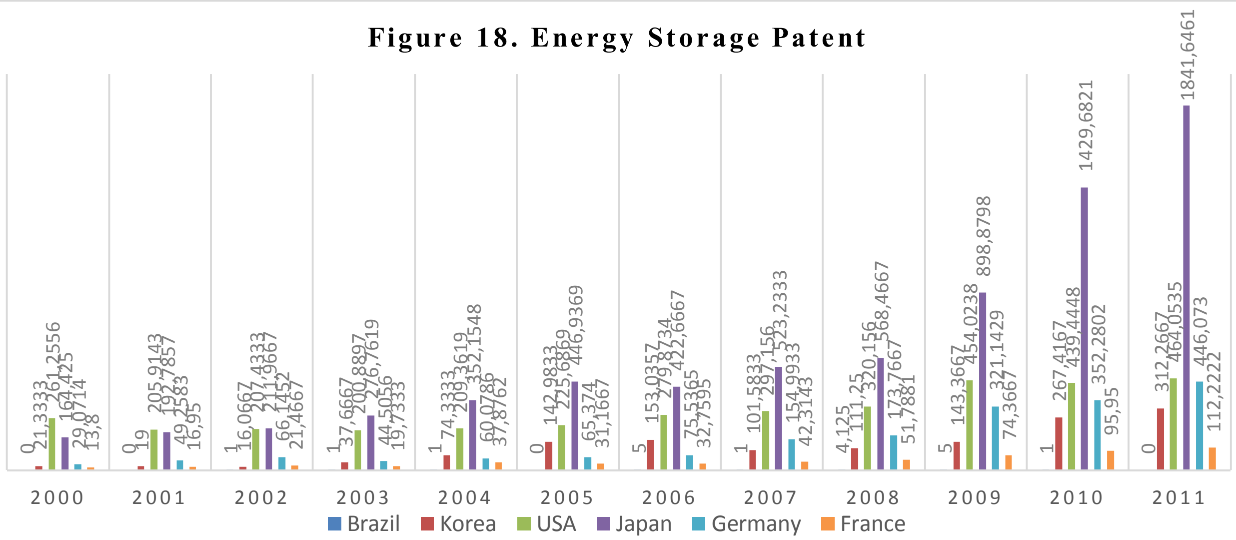


Source: OECD

7.1.7 Energy Storage Patent

Energy storage technologies holds a great potential for the future as it can hold electricity when demand for it is low or absent and can be used when demand for it increases. Energy storage patents in Brazil have not increased from 2000 to 2004, in 2005 there was no patent filed but the number increased in 2006. Japan has been leading in energy storage innovation from the period of 2002 when it over took the USA in energy storage patent count. Government policies in Japan in the area of energy storage have been healthy to foster innovative activities. Also funding from the private companies aid in the increased number of patent filed.

Figure 18. Energy Storage Patent



Source: OECD

7.2 Renewable Energy Support Policies

Policymakers in various countries around the world have come up with several policies to promote the development and deployment of renewable energy technologies. These policies have the primary objectives of reducing health and environmental impact of energy use, such as greenhouse gas emissions and enhance energy access and security as well as improving education, provide jobs, develop rural communities and reduce poverty in general. Most renewable energy policies are being driven by developed economies previously but this has changed as developing countries are catching up. Renewable energy policies are being adjusted in response to the changing domestic and international market condition.

Table 3. Renewable Energy Support Policies

Country	Renewable energy targets	Regulatory Policies							Fiscal Incentives and Public Financing				
		FiTs/ Premium payment	Electricity utility quota obligation/ RPS	Net metering	Tradable REC	Tendering	Heat obligation/ Mandate	Biofuels obligation/ Mandate	Capital subsidy or rebate	Investment or production tax credits	Reductions in sales, energy, CO_2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants
Brazil	O			O		R	OS	R		O	R		R
France	R	R			O	R		O	O	R	O		O
Germany	O	R					O	O	O	O	O		O
Japan	O	O	O	O	O	O			O				O
Korea	O		O	O	O			O	O	O	O		O
USA	R*	R*	R*	R*	OS	R	OS	R	O	X	O	O	R

Note: O: existing national, OS: existing sub-national, R: revised, X: removed/expired, *: sub-national
Source: Renewables 2014 Global Status Report

Renewable energy support policies are given in Table 3 for the six countries that we are comparing. From the table we can observe that for renewable energy target, France have revised their renewable energy target while the USA have revised its target revised in some states. States like California have new standards requiring the deployment of additional 600 MW of RPS goal to make it possible for small consumers to purchase about 100% renewable electricity from their utilities. Another state, Massachusetts raised its 2020 solar PV capacity target to 1.6 GW after achieving its goal of 250 MW four years early and has also set a goal for solar power to generate 10% of its state electricity by 2030. Korea ended 2013 without meeting its goal to add 100 MW of wind power before the end of 2013. Brazil and Japan have not changed its renewable energy target while Germany have lowered its offshore wind target from 10GW to 6.5 GW by 2020, and from 25 GW to 15 GW by 2030.

Feed-in-Tariffs (FiTs) have been revised in many countries. Germany have been reducing its FiTs for solar PV and it goes in line with the amendments of the Renewable Energy Act early in 2014. Japan also reduced their solar PV FiTs rates by 10% in 2013 and by additional 11% in early 2014. Japan also raised its FiTs rate for offshore wind by 63% in 2013. France has raised its FiTs rates for rooftops solar PV systems by 5% and enacted a 10% FiTs bonus for PV systems manufactured within Europe. In the USA no new FiTs were added in the last two years and kept the number of FiTs in each at five.

RPS in the USA have been revised in 16 states and by the end of 2013, they were 29 RPS. The RPS was revised by the government in some states and new regulations allowed public utilities to increase their RPS requirement while others were reduced. Net Metering Policies have been adopted in Brazil, Japan and Korea. In the USA, net metering policies have been revised in 4 states while 43 states, Washington, D.C and 4 territories have their net metering policies unchanged.

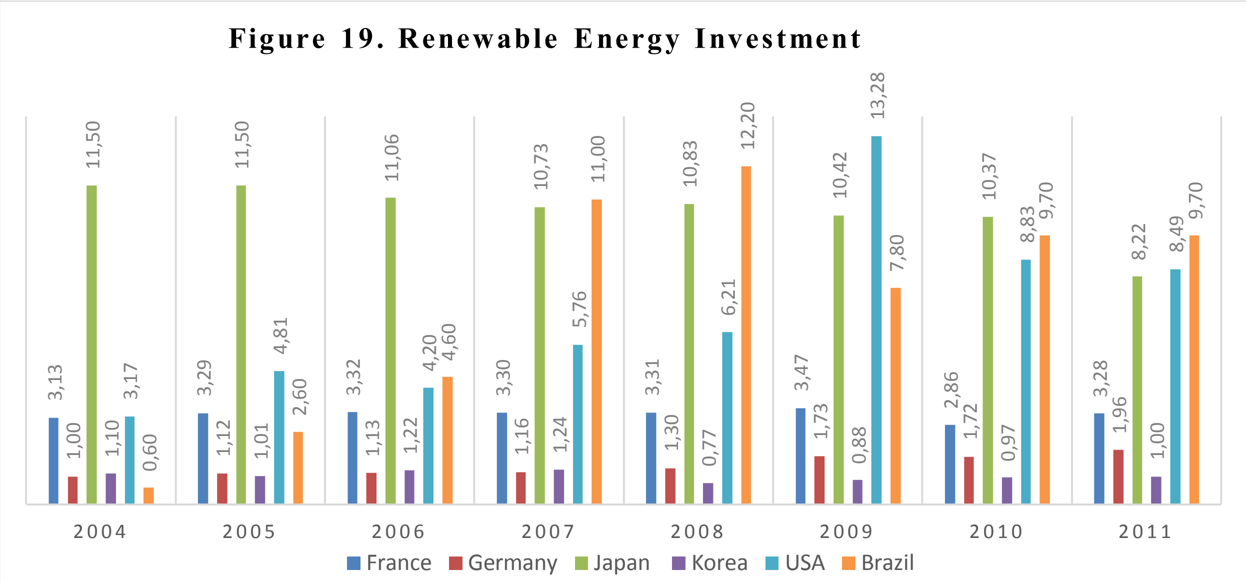
Tradable REC is currently not adopted in Brazil and Germany while some states in the USA have tradable REC. Policy Competitive bidding or tendering have been revised in Brazil, France and the whole of the USA. Brazil which has held tenders for wind power for several years including solar power projects for the first time in November with 2.7 GW of solar power qualifying for A-3 auction. Brazil's total auctions awarded 4.7 GW of new wind capacity, 122 MW of solar PV, 700 MW of small hydropower, 162 MW of bio-power in 2013. France launched a USD 275 million (EUR 200 million) tender for the construction of 80 MW of pilot ocean energy capacity, as well as a tender of USD 4.8 billion (EUR 3.5 billion) for 1,000 MW of offshore wind capacity.

The heat obligation is adopted in various states in Brazil and the USA while other countries lack the policies. This policy is similar to the electricity utility quota obligation. The Biofuels obligatory mandate has been revised in Brazil and USA. Brazil has increased its blend from the national ethanol blend level from E20 to E25 and has begun the study for a possible increase in its biofuel blend from B5 to B7. In the USA, many state have their different blends of biofuels.

Capital subsidy have been adopted in all countries except Brazil Investment/ production credits exist in Brazil, Germany and Korea while France have revised their production credit policies. This policy have been removed from the USA. Energy production payment policy are not in place in all the countries except in the USA. The public investment, loans or grants have been adopted in all countries while Brazil and the USA have revised theirs (See Renewables 2014 Global Status Report).

7.3 Renewable Energy Investment

Renewable energy investment has been increasing globally. From Figure 19 we can see the comparison among the 6 countries and clearly observe that Brazil began considerable investment in 2005 with USD$ 2.6 billion. However, in 2004, Japan had the highest investment in renewables with USD$ 11.50 billion followed by the USA which was USA$ 3.17 billion. Brazil has been increasing its investment in renewable energy with wind and biofuel being one of its highest investment priority as can be seen in Figure 4, and this made it the highest country with renewable energy investment in 2007. Other countries such as France, Germany and Korea have not made much increase i renewable energy technology but Japan is making a lot of effort with 10.73 billion in the same year.



Source: Renewables 2014 Global Status Report, IEA

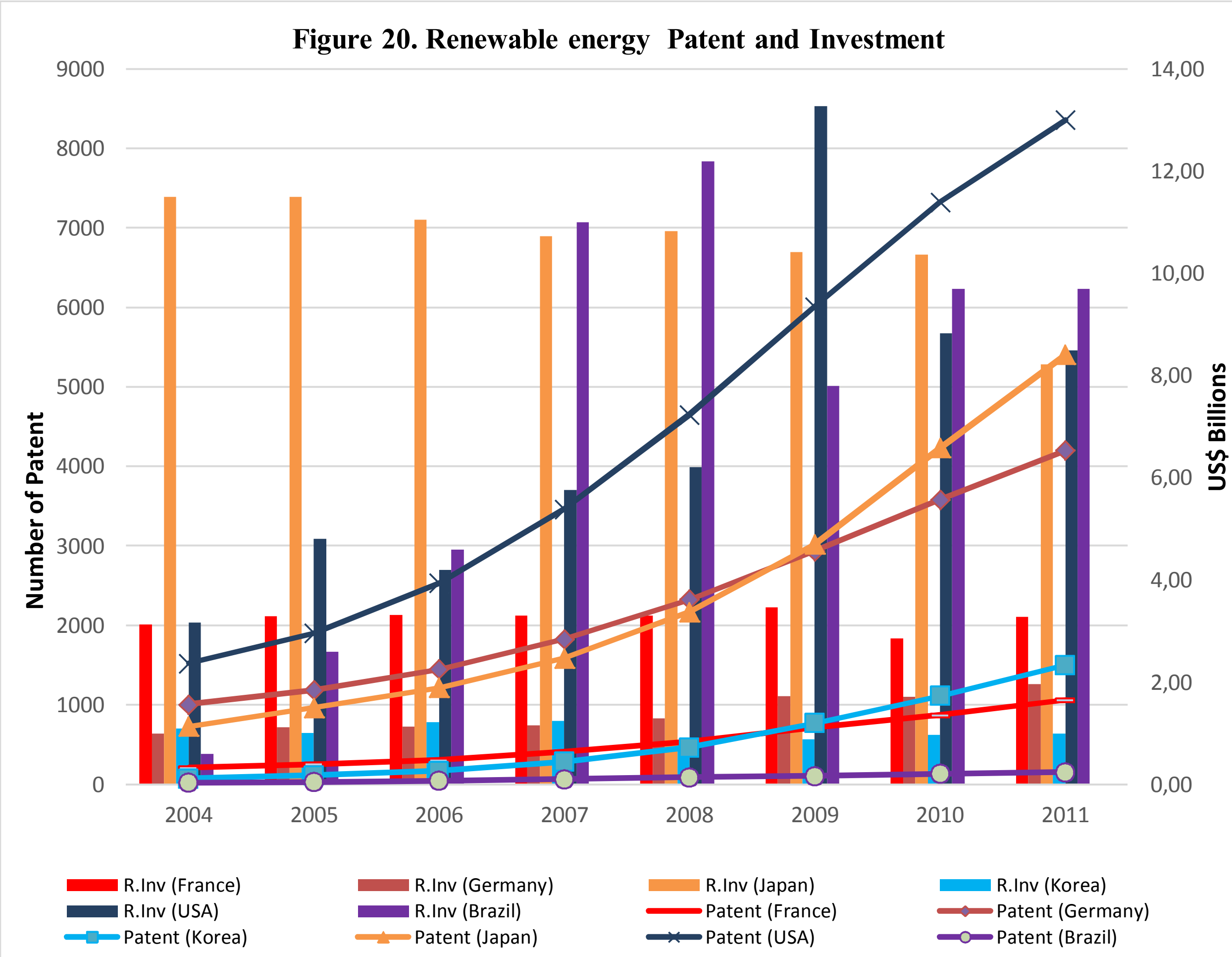
The USA had the highest investment in renewable energy in 2009 but this has declined according to reports and it's based on the shale gas boom and uncertainty over renewable energy policy continuality. Germany has not increase its investment for renewables and this is attributed to the policy uncertainty faced by investors in the renewable energy sector. Other factors for the low R&D budget for renewables are the price of solar PV which has been reduced and the substandard qualities have affected its budget spending. However, by 2011, Brazil was the country with the highest budget for renewable energy in our data set with 9.70 billion in investment.

7.4 Renewable Energy Patent and Investment[3]

We intend to compare the increase in patent in relation to the investment made in renewable energy from the period of 2004 to 2011. As we can clearly observe, France have had a steady investment of not more than US$ 3.47 billion throughout the period while the number of patent has been increasing from 207.227 in 2004 to 1062.88 in 2011. A similar situation is also observable in Germany with a lower investment of not more than US$ 1.96 billion but its patent count has far exceeded France. Korea's investment in renewable energy has not improved instead was reduced in 2008 to 2011 but its renewable energy patent has been increasing and by the end of our period of observation has exceeded past the patent count of France. Japan holds the highest spot for renewable energy investment throughout our period of observation except for 2011and its patent count have increased remarkably from just 730.085 in 2004 to 5409.58 in 2011. Figure 20 shows the renewable

[3] Due to data availability, we used the amount of renewable energy investment from Renewables 2014 Global Status Report and the Government R&D investment in renewable energy from the IEA.

energy patent and investment comparative chart where the renewable investment is in US$ Billions and patent are in numbers.



Source: Renewables 2014 Global Status Report, IEA, OECD

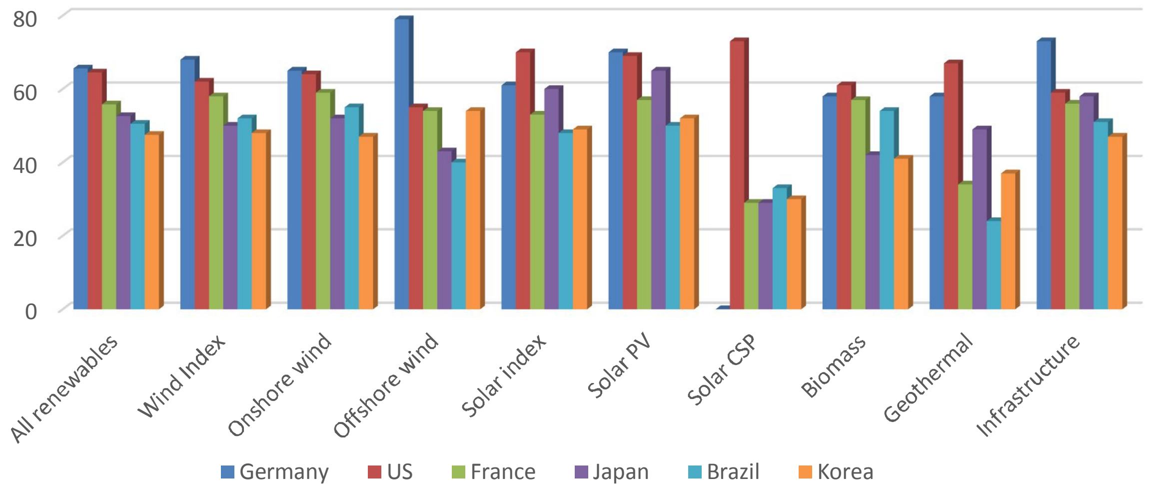
The USA's investment in renewable energy began to increase from 2005 and peaked in 2009 to be the highest in our data set with US$ 13.8 but has been on the decline ever since. However, the USA's patent has been increasing year by year as can be clearly observed in the tables below (Table 6 and 7). Brazil began increasing its investment in renewable energy from 2005 and by 2007 was US$ 11 billion and US$ 12.20 billion. The figure declined the following years for its renewable energy investment and its renewable energy patent has been slowly increasing with 18.8571 in 2004 to 152.245 in 2011. India's renewable energy investment increased from US$ 2.90 in 2005 to US$ 6.30 billion in 2007, but its highest peak was recorded in 2011 with US$ 12.60 billion. India's patent follows the same step as Brazil with just 22.6333 patent in 2004 to 206.793 in 2011. Investment in renewable energy in New Zealand has been poor considering our data set. Its investment only peaked in 2008 and 20009 with US$ 0.58 billion in each year. Meanwhile, the number of patent in New Zealand has been low with 21.387 in 2004 to 88.4592 in 2011.

7.5 All Renewable Index (ARI) at November 2012

To compare how a country is trying hard to process their renewable energy, we could use the renewable energy country attractiveness indices. The Ernst & Young Country Attractiveness Indices (CAI) score 40 countries on the attractiveness of their renewable energy markets, energy infrastructure and the suitability for individual technologies. The indices provide scores out of 100 and are updated on a quarterly basis. The CAI take a generic view and different sponsor or financier requirements will clearly affect how countries are rated. This index provides an overall score for all renewable energy technologies. It combines individual technology indices as follows:

- Wind index — 55% (comprising onshore wind index and offshore wind index)
- Solar index — 32% (comprising solar photovoltaic (PV) index and concentrated solar power (CSP) index)
- Biomass and other resources index — 13% Individual technology indices

Figure 21. All Renewable Index (ARI)



Source: All Renewable Index, 2012

From Figure 21, the order is Germany, USA, France, Japan, Brazil, and Korea. In the Wind index, it shows that Germany is very well in this part. This reason is mainly because Germany's Government recently increased the country's renewable target from 35% of electricity to 40% by 2020, and is being proactive in implementing policy measures to create sustainable growth, more immediate changes are likely to put a strain on the clean energy market.

In Solar Index, Germany is attractive in solar photovoltaic (PV) index while they are not producing concentrated solar power (CSP) index. In concentrated solar power (CSP) index, the US is better than any other country.

In Biomass part, US is doing well also, Brazil shows the high point than Japan. In geothermal, the USA is the most attractive and this is because in their geothermal sector, it occupied almost 14% of national electricity supply.

Brazil is also same situation with India, However, Brazil do more invest in hydropower, Biodiesel and Fuel ethanol production not in wind and solar section. In Brazil, hydropower expansion is expected to become increasingly constrained by environmental sensitivity and the remoteness of much of the remaining resource. In 2013, Wind power was excluded from one of Brazil's auctions because it was pricing all other generation sources out of the market.

8. Policy Recommendations and Conclusion

8.1 Policy Recommendations

We have reviewed the current situation in the energy sector (focusing on the Renewable energy in particular). Although Brazil is economically progressing in terms of innovation, we will give some policy recommendation on the short, intermediate and long run.

Short Run:

- Adopt renewable energy portfolio standards.
- Expand the production and use of ethanol fuel.
- Promote more efficient CHP systems using bagasse and other sugar cane products.
- Develop and stimulate the adoption of new bioenergy sources.
- Establish a new national energy efficiency agency.

Intermediate:

- Stimulate solar PV use in remote, off-grid areas.
- Adopt energy codes for new commercial buildings.
- Provide an effective financing mechanism for energy service companies.
- Adopt tradable renewable energy certificate program.
- Initiate R&D evaluation agency.

Long Run:

- Expand R&D and capacity building for hydrogen and fuel cell technology.
- Stimulate the adoption of solar water heaters.
- Stimulate the adoption of solar water heaters.
- Adopt Feed-in-Tariffs.
- Adopt capital subsidy.
- Adopt demand-side bidding and energy planning

These policy recommendation are based on the observed situation of Brazil.

8.2 Conclusion

Innovation is vital for the sustainability of an energy sector in an economy. The Brazilian energy sector has seen various forms of innovation in the last two decade. This article reviewed the current status of the energy sector in Brazil and found it to be actively growing in innovative activities. Although the country has high performance in wind energy and biomass, more areas of renewable energy needs to be explored. The number of renewable energy patent in Brazil is quite low compared to other countries that was compared with it. However, this paper discovered that investment in renewable energy is high and the rate of technology transfer is satisfactory. Policy comparison between Brazil, Korea, USA, Japan, Germany and France, and it was discovered that some policies that will improve the current status of innovation in renewable energy are missing. Some policy recommendation have been provided and this article believes that these recommendation will contribute to the improvement in innovative activities in the field of renewable energy.

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