of University Research and the National Innovation Systems; Academic Career Development in Changing Social Context; Academic Profession and Publication Practices) with 16 papers presented. The workshop attracted more than 20 participants of different professional, institutional and geographical background. The attendees and presenters, both well-known STS senior researchers and early career researchers, came fromdifferent regions: *Brazil, India, Italy, France, Lithuania, Mexico and Russia.*The workshop, while interested in papers covering the entire spectrum of topics related to science policy, was particularly focused on papers (both theoretical and empirical) dealing with issues related to the governance of science; the role of science policy in the facilitation of innovation and excellence; the role of science policy in creating and eliminating barriers to global cooperation and the international mobility of scientists; and the implications of neoliberal reforms on academia (both locally and globally), particularly as they relate to new forms of association between industry and academia and the governance of the "entrepreneurial university". The workshop provided opportunities for personal exchanges of scientific results and the strengthening of cooperation among researchers from different parts of the world. RC 23 ISA is extremely pleased to have received a special grant from the International Sociological Association and very grateful to all presenters who has contributed their academic papers. We start to publish the papers of the participants in this Issue of SST journal. These two papers written by Leandro Raizer "Society, Innovation and Energy Policy in Brazil" and Sonia K Guimaraes "Pathways to Technological Catching up: Relationship University-Business Relations in Brazil" have offered a deeper insight into the relation between science policy and science dynamics in Brazil.

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Society, innovation and energy policy in Brazil

Abstract

The study presents an overview of the Brazilian energy policy in the period 2005–2015, with emphasis on the analysis of the socio-technical network of the energy system. Brazil is among the countries with the highest energy potential, non-renewable or renewable (with one of the greatest potential for wind and solar resources). The study is based on empirical research involving the use of statistical data, analysis of interviews with scientists, businessmen and politicians, analysis of Laws and official documents of the energy sector. Among the results of the research, we highlight the existence of a system with reduced capacity for innovation and a centralized and bureaucratic regulation, which has been unable to increase the supply of demand, presenting a risk of collapse in the medium and long term. Among the factors that explain this trajectory (considering the last decade), the study highlights the presence of a peculiar socio-technical network (Latour and Knorr-Cetina), in which the political-business arena gains predominance, being determinant for the reduction of the transformative potential arising from the emergence of a new model of energy development and its societal consequences. In this context, paradoxically, new technologies and values (sustainability) coexist with technologies and practices of the nineteenth century, with the conservation of an extreme unequal society, with great risks (Beck and Giddens), both for social development and the preservation of natural resources and the ecosystem.

Keywords: sociology of science, innovation, energy policy, Brazil, socio-technical network, climate change, alternative energy.

Introduction

Sociology throughout its history has been concerned with studying the most important social phenomena constituting men and societies. Along the way, among the phenomena that have gained most attention are the political revolutions, such as the French Revolution, and then the Russian Revolution. Paradoxically, they were not political revolutions that marked the end of the twentieth century and the beginning of the twenty-first century. Before that, it was a technological revolution, and now a new revolution, which we have called the *energy transition*. The latter and the nascent new automated economy, the deepening of the information revolution, and the ecological crisis, will radically transform the concept of man and society, as well as the relations between man and nature.

Fortunately, some sociologists have looked at the information technology revolution, even without large audiences, and more recently have constructed a set of theories relevant to the analysis of the phenomenon of energy transition and its impacts in a context of ecological crisis and risk.

It was within this scope that in 2007 we started a research dedicated to understanding the phenomenon of development, in a wide way, and ended, in a curious way, by moving forward in a new field called the *sociology of energy*. As Bourdieu asserts, a rigorous sociology must be based on a double rupture, the first with common sense, the second with respect to science itself. Based on this assumption, we approach the theme of development, from an unexplored point of view: energy. Energy understood in the sense of Mauss (1966) as a *total social fact*, which encompasses social, technical, cultural, economic and political elements. In short, it can be said that the way a given society produces and distributes energy is linked to the social totality of its own structure.

Thus, between 2007 and 2011, we conducted an international comparative research, entitled: Society, energy and innovation in Brazil and Canada (Raizer, 2011). In this study we had the opportunity to analyze the Brazilian and Canadian cases. Among the discoveries, the emergence of the phenomenon called energy transition is highlighted, marked by the contradictions and heterogeneity resulting from the search for renewable energy production in the face of the constant growth of the capitalist economy. And also, that international institutions, governments and companies, laboratories and civil society – forming a socio-technical network linked to the mechanisms of translation and chaining – are key players in the national and international development of alternative energies.

And now, 6 years after the realization of this research, we return to analyze this theme, seeking to identify – in the Brazilian case – the continuities and discontinuities – of its energy policy. To do so, we will analyze the Brazilian energy sector: policies, programs and indicators, as well as the broader relations with society, given the context of the ecological crisis, with emphasis on the development of alternative energies. The text is divided into three main parts. The first presents the theoretical framework that guides our work, discussing the relationship between society and energy. The second part presents the Brazilian energy policy, with emphasis on the development of alternative energies and their agents. Finally, the third part presents a critical perspective on the Brazilian case and the current development of the energy matrix, with its social and environmental consequences.

1. Society and energy

Theoretical approach

> Energy choices made in the past and present create dynamics that have significantly affected the environment and social organization for dozens of centuries. Thus, the role of sociology is to show the relation that is intrinsic in the human-nature interaction, through energy and to analyze the determinations and factors that influence this relationship over time and different societies (Raizer, 2011).

In this study of 2011, we showed that energy is one of the most challenging topics to be analyzed by sociology. Not only because it is a *total social fact*, but also given to the context in which it emerges as an object of research: information society, ecological crisis and climate change. Thus, to situate the development context of contemporary energy policy, we think it is essential to consider such concepts.

In his classic work, Castells (1999, 2000, 2002) analyzes the contemporary society which he defines as informational. For this author, the phenomenon of informationalism becomes the shaping center of society and social relations, with several implications on organizations, social movements and individuals. In the information society

> technological activity acquires a reticular scope … It is no longer possible to conceive of modern technological politics without thinking in terms of networks of researchers and integrated and interdisciplinary projects (Castells, 2000, p. 103).

In The Politics of Climate Change (2009), Giddens deepens his analysis of the modern society initiated in previous works, advancing in the concept of ecological risk, with emphasis in the phenomenon of the climatic change. The author also discusses the concept of green policies and their agents.

In addition to the development context of the society-energy relationship, it is necessary to take up elements of the sociology of the science and of the environment.

In the sociology of science we find relevant contributions to energy analysis. In Merton (1979), for example, we have reflections on the unique *ethos* characteristic of the scientific community, and its implications on the process of knowledge production. In Mannheim (Crespi & Fornari, 2000), we have a vigorous discussion about the social genesis of knowledge, and the development of concepts such as *social technologies*, and their implications for broader social development. On the other hand, we highlight the ethnographic laboratory studies carried out by Latour (1979) and (Callon, 2000), and the subsequent development of the concept of socio-technical networks. Also the studies about the phenomenon of innovation and its relation with the development are key to the understanding of the emergence and consolidation of the so-called knowledge-based economy. In this vein, the contributions of authors such as Dunning (2000) and Malecki (1997), as well as the development of the concept of national systems of innovation and development are relevant (Nelson, 2006).

Also are relevants studies on innovation agendas at the national level and national institutions and innovation (Freeman, 1987), innovative business performance (Nelson, 1993), and the production of knowledge at the frontiers of the nation-state Lundvall, 1992). Studies on the process of development and diffusion of new technologies (Patell & Pavitt, 1994), and studies on artifacts and new technologies (Metcalfe, 1995) are also highlighted.

In summary, we can say that

> The relationship between society and technology is one of the most relevant and current issues. The way in which each society structures itself socially, economically and culturally ends up shaping the technological paradigms of each time, at the same time, in which these paradigms have influence on the social transformations. Each of these paradigms is related to discoveries and innovations linked to specific sectors of the economy, characterizing the development model of each epoch and society (Raizer, 2011, 59).

The sociology of the environment also brings relevant elements for the analysis of the development of alternative energies and the phenomenon of energy transition. The relationship between man and nature is at the heart of this process; since the way men produce energy creates social relations and mediations, as well as wide consequences of various orders (Pretty and al., 2007). Indeed, the development of the new ecological paradigm (Dunlap et al., 2002) deconstructs the existence of conceptual and cultural boundaries, which still conceived of man as isolated from the environment.More than that, the developments of alternative energies, and the various innovations implied therein, occur in a context of risk society and ecological crisis (Beck, 1992; Giddens, 2009), and a deep energy crisis and the quest for survival (Lafrance, 2002).

On the other hand, the concept of *active reticular structure* has potentiated the analysis of alternative energy networks, as well as the understanding of the political-business arena in which energy policy development takes place. According to Sales (2012, p. 79)

> By active reticular structure I mean an integrated network of human actors and corporate actors, tied within a systemic logic by common interests that shape, promote or defend as parto f generally complex process, either a modelo of accumulation, or a type of development, a political regime, a vision of the world, a paradgm, a form of historicity as defined by Touraine but far more focused, which weighs upon and restricts the choices of a multitude of agentes who have become dependent.

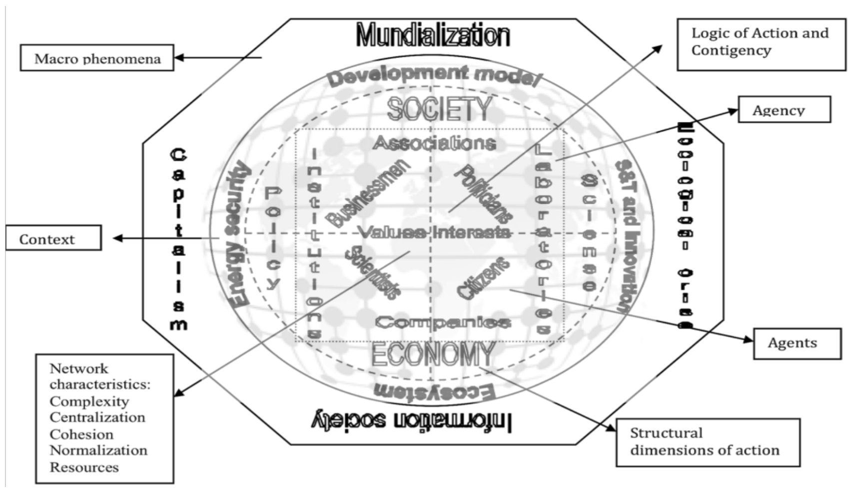
And also, it is only possible to understand the development of these energies based on the contributions brought by the sociology of innovation. As Maciel (2001) concludes, there is an ever closer relationship between immaterial transformations and development. In this context, the existence of an innovative institutional environment (Porter, 1990) is essential for technological advancement.

> From this point of view, thinking about energy does not only mean analyzing how it is produced, distributed, appropriate, but also what implications (externalities, societal effects, unintended consequences) the different forms of energy engender over time, to and from different Societies and generations. Such a proposal encompasses the analysis of macro dimensions: economy, resource management, energy policy, environmental policy, social

> inequality; And micro-dimensions: individuals, groups and the use of energy, consumption habits, and energy culture (Raizer, 2011, 75).

Thus, the theoretical model that has guided our studies can be visualized in the following figure, which illustrates the structural and agency dimensions imbricated in the innovation process of the alternative energy networks.

Figure 1. Agents, dimensions of action, and social context in the analysis of socio-technical networks of alternative energies.



Source: Raizer, 2011.

Finally, alternative energy is considered a strategic element for good governance and the search for security and energy independence by countries. These sources are pointed out in both the Kyoto Protocol and the Paris Agreement as essential elements to mitigate the effects of climate change. Due to this, we will prioritize the analysis of these technologies in this study on the Brazilian case.

The energy transition and its current indicators

The latest report released by the International Energy Agency (IEA) states that

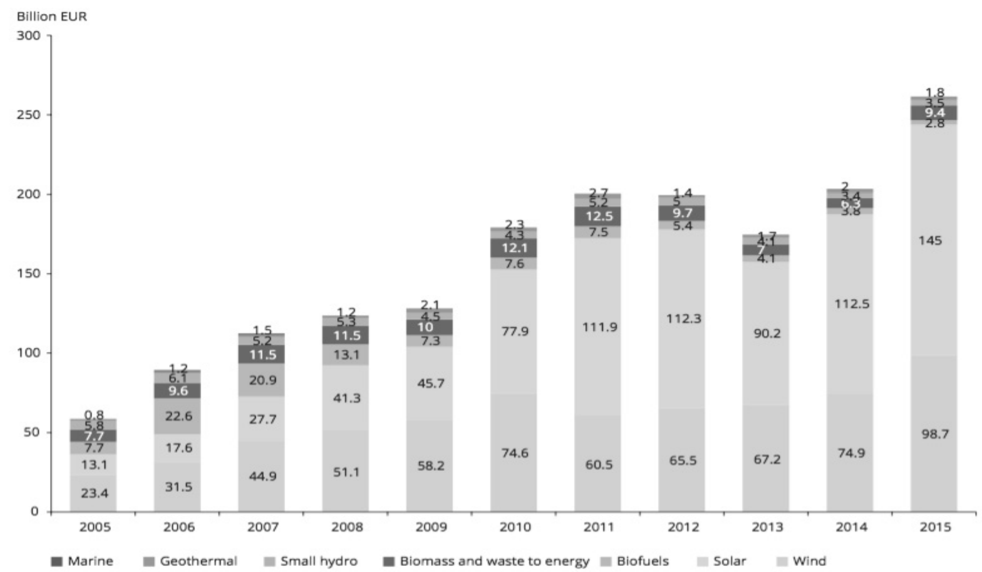
> global renewable energy transition advancing with record capacity additions and rapidly falling costs — more capacity installed for less money, 2016 was the third year in a row where decoupling of economic growth and energy-related CO_2 emissions occurred. However, the progress is not fast enough to reach Paris Agreement goals (REN 21, 2017).

In the European case, for example, the development of alternative energies has been a key element for the energy transition in that continent. Data from the last decade indicate that these fonts account for more than 70 % of all growth in power generation. This trend will be very relevant if the continent wants to get its goal of reaching 2030 with an energy matrix less dependent on fossil fuels (EEA, 2017).

Paradoxically, contrary to expectations — taking into account even the targets established in the Kyoto Protocol and the Paris Agreement, the year 2016 was marked by a reduction of around 23 % in the total global investment in renewable energies. Among the developing countries, this drop reached 30 %. India was one of the few countries to increase investment in 2016, with the United States and Brazil falling by 10 % and 6 %, respectively (REN 21, 2017).

Analyzing in detail the total investment according to the source, in the period 2005–2015, it is noted that since 2010 the amount invested in solar energy has exceeded that invested in other energy sources. In 2015, the investment leadership continues with solar energy, followed by wind, biomass and waste, small hydro, biofuels and geothermal and marine. China has been largely responsible for the growth of investment in solar energy, owning companies that have become dominant in this niche in the country and abroad.

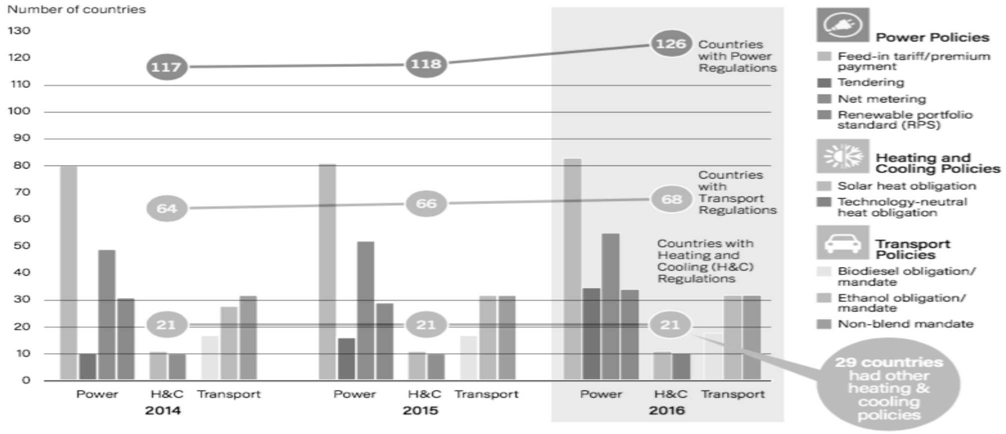
Figure 2. Total global new investment shares by technology, 2005–2015.



Source: EEA, 2017. P. 48

As pointed out by studies and reports, it has been fundamental (together with the expansion of investments), the creation of regulatory framework for the development of alternative energies and consolidation of the energy transition. In this scope, it's clear the world trend in increase the number of countries that have developed regulatory frameworks to deal with energy transition, with regulation on incentives and policies, as shown in the following figure. As can be seen, the energy generation sector is regulated in 126 countries, followed by transportation, with a total of 68 countries, and 21, over other sectors.

Figure 3. Number of Renewable Energy Regulatory Incentives and Mandates, by type, 2014—2016

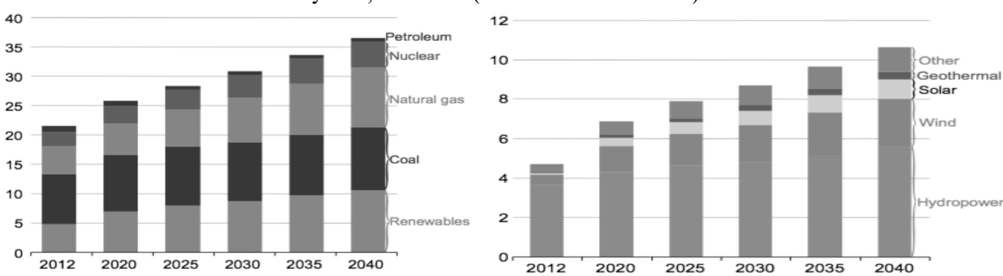


Source: REN 21, 2017.

The energy transition and the near future

Despite the efforts to generate clean energy, the world's energy matrix continues to be dominated by fossil fuels, and this trend should not be changed any time soon, at least until 2040, as shown in the figure below. As can be seen, the expansion of energy demand in the coming decades will still be largely supported by non-renewable energies, that is, by maintaining a highly polluting and destructive energy matrix.

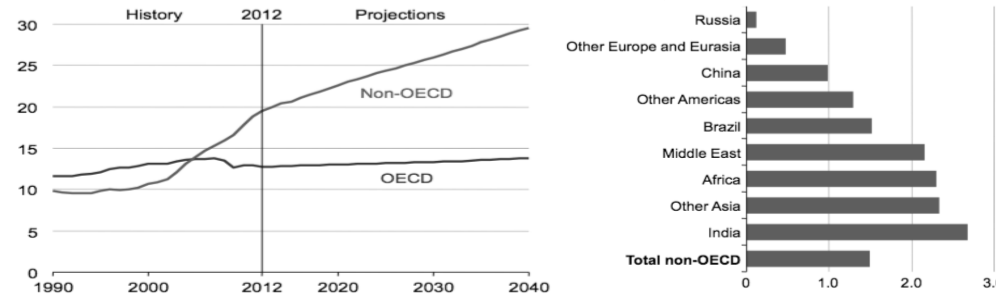
Figure 4. World net electricity generation and World net lectricity generation from renewable power by fuel, 2012—40 (trillion kilowatthours).



Source: U. S. Energy Information Administration (EIA), 2016, p. 83—84. Note: Other generation includes biomass, waste and tide/wave/ocean.

This assertion gains even more strength with the recognition that the implementation of renewable energy generation will mainly occur through the hydroelectric source (massively by large power plants) implying damage to the rivers and wather basins, flora and fauna, and the need for removal of entire populations from regions and cities. Another serious issue that must be considered is that climate change is directly affecting rainfall, which means restricting water resources, which should be primarily allocated to the maintenance of populations and the ecosystem. Because of this, it is clear that there is no prospect of reducing CO2 emissions linked to power generation. On the contrary, as shown in the following figure, there will be a large increase in these emissions in most countries and regions of the world. The only exception ocurrs in the case of OECD countries, where it is expected a slight increase.

Figure 5. OECD and non-OECD energy-related carbon dioxide emissions, 1990—2040 (billion metric tons) and Average annual growth of energy-related carbon dioxide emissions in non-OECD economies, 2012—40 (percent per year)



Source: U. S. Energy Information Administration (EIA), 2016, p. 139 and 145.

Countries such as Africa and India should have an average annual growth of more than 2% in CO_2 emissions, followed by Brazil with 1.5% and China with 1%. Such indicators leave no doubt that the energy transition should not be considered as just a change in energy policy or in the use of technology. More than that, as Sales & Raizer (2010, p.339) argues,

> we cannot begin to cut our use of fóssil fuels without at the same time redefining our version of "material civilization" (in Fernand Braudel's sense) and our intimate relationship with nature.

2. The Brazilian energy policy

Brazil has the fifth largest population in the world, with a total of 205 million inhabitants. The country has the seventh largest economy, behind only China, the United States, India, Japan, Germany and Russia. In relation to the energy sector, the country has suffered in the last decades recurring energetic crises, with serious consequences, including with the reduction of the productive capacity of the country. In addition to the so-called "blackouts", and in the absence of a consistent energy management plan, integrated with national and international CO_2 reduction targets, the country insists on the use of coal thermoelectric plants and construction of large hydropower plants. This mismanagement has resulted not only in the limitation of the installed energy potential, but also in the last five years the value of the electric energy tariff increased by more than 61%, compared to only 28% of inflation in the same period. Even the production of hydroelectric power has been suffering from the serious water crisis that the country is going through, with tendencies to become an endemic problem in the country, given the progress of deforestation and the impacts of climate change. In terms of energy demand, the country occupies the seventh position, corresponding to 2.2 % of total world demand in 2014. Its consumption of electric energy occupies the ninth position, reaching 2.4 % of world demand.

Energy policy is managed and is carried out in Brazil by the Ministry of Mines and Energy (MME), which produces 10-year energy plans (PDE) and the National Energy Plan (PNE). The country occupies the 11th position in the use of fossil fuels for energy generation, corresponding to 1.6 % of the world total. It occupies the same position in the CO_2 emission ranking, being responsible for 1.5 % of the total. In relation to renewable sources, it occupies the 4th position, corresponding to 6.4 % of total production, behind only China, India and the United States. The country occupies the eighth position in the production of wind energy, and the third in hydroelectric.

As the most recent MME report (2016) points out,

> The current 2024 Brazilian Energy Expansion Plan, compared to the last plan (PDE 2023), shows a shorter economy expansion. The estimated Gross Domestic Product (GDP) growing rate is 3.2 % p. a. between 2014 and 2024 (4.3 % p. a. in PDE 2023), and Domestic Energy Supply (DES) — the energy required to boost the economy — grows 2.7 % p. a. (3.7 % in PDE 2023 and 4.8 % in PDE 2022). In the energy matrix, renewable sources maintain a high share of 45.2 % in 2024, compared with the 39.4 % observed in 2014. The aggregate “other sources” (wind, biodiesel, solar and black-liquor) is the major contributor for renewables growing, followed by hydro energy and sugar cane products. In fossils, oil and gas reduce their participation, in the opposite of coal. Nuclear energy grows due to the entry into operation of Angra 3 power plant. Carbon dioxide emissions related to energy usage are expected to reach 577 million tCO2 in 2024 (660 Mt in PDE 2023), resulting in 1.44 tCO_2/toe of energy, an indicator 38 % lower than the World’s in 2014, of 2.34 tCO_2/toe. The Domestic Electricity Supply reaches in 2024 the total of 941 TWh (934 TWh in the last PDE), with an annual increase of 4.2 % over 2014, a higher rate than GDP’s. In the Domestic Electricity Supply, the hydropower supremacy will continue in 2024, standing for 65.8 % of the total power energy, an indicator little higher than the verified in 2014, 65.2 % (including imports). Wind, solar and biomass generation, together, now account for 20.4 % of the total offer, more than the double of 2014 indicator (9.4 %). The Brazilian electricity generation installed capacity will reach 212.5 GW in 2024 — a 78.6 GW expansion over 2014 –, distributed as follows: an increase of 73.5 GW in the National Interconnected System (SIN), decrease of 1.7 GW in Isolated Systems, growth of 6.8 GW in captive self-producer, with ANEEL registration. Renewables account for 85 % of the expansion. With imports and generation by oil E&P, power supply reaches 223.9 GW in 2024.

It should be noted that the MME classifies the generation of energy through hydroelectric and biofuels as renewable, and often as an alternative source to fossil fuels. However, as Raizer (2011, 157) argues,

> with the exclusion of the percentage of hydroelectric power generation and by-products of sugarcane, only 3.8 % of the Brazilian energy matrix is based on alternative sources of energy. This percentage is at the same time low and worrying. If considering the potential of alternative energy generation, only considering the estimated wind potential (Atlas of Brazilian Wind Potential), the country could meet more than 130 % of all electricity demand through this source.

Despite Law 10.438 (2002), which created the Incentive Program for Alternative Sources of Electricity – PROINFA, Brazil invested only U$ 265 million in renewable energy in 13 years (from 1999 to 2012), equivalent to 0.0013 % of GDP. While the United States invested US $ 1.78 billion in 2012 (0.0118 % of GDP) and Germany € 265 million (0.005 % of GDP), also in the same year (IPEA, 2015). In comparative terms, as shown in the following figure, Brazil accounted for 8 % of total global investment in renewable energy in 2007. Since then, this value has been falling, reaching only 2 % in 2015.

Table 1.

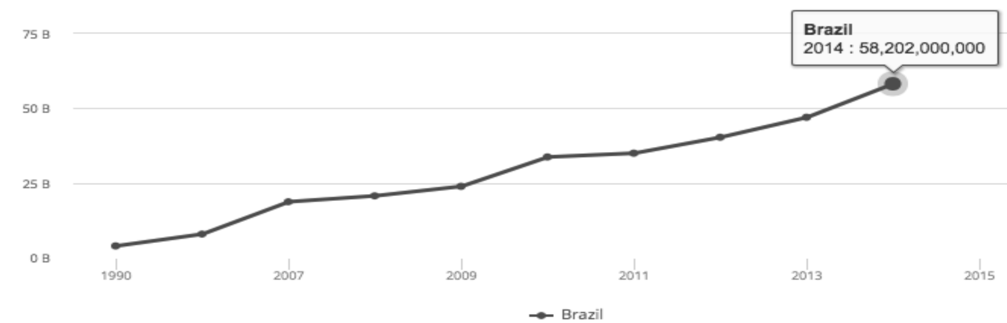
Share of global new investments (%) in renewable energy per region, 2005–2015

World region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Europe (including CIS)	46	42	43	45	46	47	43	35	25	21	17
China	11	10	11	14	22	16	18	25	27	31	36
ASOC (excl. China and India)	13	9	8	7	8	8	9	12	19	18	17
United States	16	26	21	19	14	15	18	15	16	14	15
Americas (excl. United States and Brazil)	5	3	3	3	3	5	3	4	5	5	4
Middle East and Africa	1	1	2	1	1	2	1	4	4	5	4
Brazil	4	5	8	7	4	3	4	3	2	3	2
India	4	4	4	3	2	4	5	3	3	3	4

Source: EEA, 2017, p. 46.

PROINFA’s main objectives are: diversification of the Brazilian energy matrix, increasing security of supply; valorization of regional and local characteristics and potential, with job creation, training and training of labor; reduction of greenhouse gas emissions. Considering the expansion of installed alternative resources capacity in the country, between 2014–2015, there was a growth of 212 % in the wind generation, followed by 16 % in thermal-biomass. Otherwise, there was a growth of 10 % in thermal coal (non-renewable), and 3 % in hydroelectric generation.

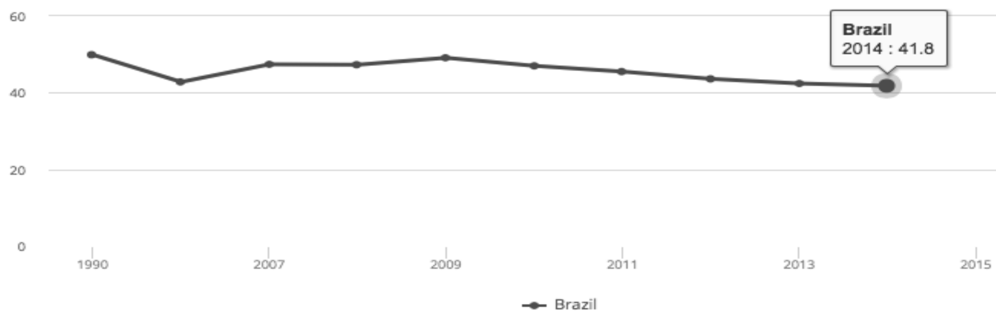
Figure 6. Electricity production from renewable sources, excluding hydroelectric (KWh), Brazil (1990–2014)



Source: World Development Indicators.

Even with the growth of energy generation from alternative sources, excluding hydroelectric power plants, as shown in the figure above, the total percentage of energy consumed from renewable sources has been falling since 2009, as shown in the following figure. In other words, the national energy matrix increased its dependence on non-renewable energies.

Figure 7. Renewable energy consumption (% of total final energy consumption), Brazil (1990–2014)



Source: World Development Indicators.

Although PROINFA has been relevant to expanding installed power from alternative sources, it's clear that there is no intention of transforming this program in a dedicated national plan, strategy, or government agency for alternative energies. The consequences of this scenario reflect in the placement of the country in front of the other economies. As can be seen in the following figure, although Brazil ranks third in the capacity of renewable energy generation (including hydroelectric), this placement is because of the production in large hydroelectric units.

Figure 8. Total capacity or generation as of End-2016, top five countries.

	1	2	3	4	5
POWER					
Renewable power (incl. hydro)	**China**	United States	Brazil	Germany	Canada
Renewable power (not incl. hydro)	**China**	United States	Germany	Japan	India
Renewable power capacity *per capita* (not including hydro³)	**Iceland**	Denmark	Sweden/Germany		Spain/Finland
Bio-power generation	**United States**	China	Germany	Brazil	Japan
Geothermal power capacity	**United States**	Philippines	Indonesia	New Zealand	Mexico
Hydropower capacity⁴	**China**	Brazil	United States	Canada	Russian Federat.
Hydropower generation⁴	**China**	Brazil	Canada	United States	Russian Federat.
CSP capacity	**Spain**	United States	India	South Africa	Morocco
Solar PV capacity	**China**	Japan	Germany	United States	Italy
Solar PV capacity *per capita*	**Germany**	Japan	Italy	Belgium	Australia/Greece
Wind power capacity	**China**	United States	Germany	India	Spain
Wind power capacity *per capita*	**Denmark**	Sweden	Germany	Ireland	Portugal

Source: REN21, 2017.

Thus, although Brazil has one of the greatest potential for alternative energies, critics of the model adopted by the country point out the limited use of alternative resources available, the discontinuity of investments, the prioritization of certain technologies to the detriment of others, as well as the insecurity generated by the cancellation of auctions, as the main points responsible for the low and slow development of the alternative energy sector in the country.

In an interview with O Globo newspaper (2017), the executive secretary of the Ministry of Mines and Energy states that

> No matter how we try, we can not choose a segment and say that it is isolated from the crisis of the country and that we will give it What no one has, a guaranteed demand … no matter how justifiable, my role has been, in the technical field, to say no.

This position of the Brazilian Government clearly shows that there is no national commitment to a new energy model, nor a real commitment to the Kyoto Protocol or the Paris Agreement. On the other hand, although the number of agents active in the alternative energy sector in Brazil has increased considerably in the last decade, the presence and concentration of the new ventures under international companies such as Bosch, GE, Gamesa, Vestas, BYD, andCanadian Solar, among others. Such an unfavorable scenario for innovation is evident from the fact that there is no national renewable energy plan in Brazil. As stated by Ivo Pugnaloni, president of the Enercons group,

> The sector needs growth prospects, not just the policies dictated by the auctions. So it would be possible to program. A national renewable energy program exists in every country in the world. This issue must be favored (Jornal do Brasil, 2014).

Among the reasons for the lack of a national plan is the fact that the Brazilian government itself owns the companies producing fossil fuels in the country, as well as large hydroelectric projects, and has direct control over this market. As well as the government get political use of this control and profit, including notorious cases of corruption related to the sector, either with financial deviations or covering the social and environmental damage caused. The action of such agents has consolidated a potent political-business arena, quite reactive to the implementation of innovation in the national energy matrix.

This conflict of interest is clear, even in the Legislative, where the concentration of interests in fossil and hydroelectric investments, in detriment of alternative sources, is evident. Also in the case of biofuels (like ethanol), there is a clear relationship between the government and sugarcane sector that has a great influence on the energy sector in the country. In a public hearing held at the Brazilian National Congress in 2017, it is clear the existence of dissatisfaction of companies and politicians with the national energy policy, as well as the lack of a minimum consensus on the national energy development:

> Congressman Sérgio Vidigal (PDT-ES), who proposed the debate, pointed out that Brazil is a world reference in renewable energy, but noted that more than 60% of the energy matrix comes from hydroelectric plants. According to him, the generation of energy from other clean sources, such as solar, has not grown as desired in the country. "The environmental impact today of implanting new hydroelectric plants is very large," he said. The executive director of the Brazilian Association of Solar Photovoltaic Energy, Rodrigo Sauaia, also stressed that the advance of solar energy has fallen short of the sector's expectations.

He defended support from Congress, the Ministry of Mines and Energy, and the National Bank for Economic and Social Development (BNDES) for this energy source to advance in Brazil. The entity's projection is that solar energy, which today represents 0.02% of the Brazilian energy matrix, reaches 10% of the matrix in 2025. "We need a legal, regulatory and incentive framework to achieve these goals," he said. "The representative of the Brazilian Wind Energy Association, Francisco Silva, highlighted the great growth in the generation of this type of energy in Brazil since 2009. Today, the country occupies the 9th position of the world in the installed capacity of energy generated by the wind. According to him, the great incentive was the regular auctions of the government for the contracting of this type of energy. He criticized, however, the cancellation of the only auction predicted for the last year, generating insecurity in investors. Many of the companies do not know if they stay in Brazil or leave," said Silva. In his view, the government needs to issue "appropriate signals for wind power investments to continue." He called for the predictability of the auctions to be maintained. Deputy Vitor Lippi (PSDB-SP) lamented the cancellation of the auction last year, on the eve of its completion, and called for the resumption of the events. "It was at least a disrespect and will bring grave consequences," he said. Deputy José Rocha (PR-BA) also asked the government to carry out more auctions for the contracting of wind energy (Agencia Câmara Notícias, 2017).

This arena of dispute between the different agents, especially companies and governments, presents global trends. Thus, the force of the fossil lobby on governments is not only characteristic of power relations in Brazil. A former energy minister from Portugal said that *the energy lobby has conditioned governments* (Francisco, 2017). In the US case, Huang et al. (2007, p. 75), argues

[…] investigated factors influencing the adoption or intention to adopt renewable portfolio standards (RPS) by individual states in the United States (U.S). Theory of adoption of innovation was applied as a conceptual framework. A logistic model was used to achieve the task. Gross state product (GSP), growth rate of population (GRP), political party dominancy, education level, natural resources expenditure, and share of coal in electricity generation were used as explanatory variables. Results indicated that the model predicts the dependent variable (state's choice of adopting or not adopting RPS) 82 times correctly out of 100. Results also suggested that education followed by political party dominancy, GSP and GRP are shown to have large impacts on the probability of RPS adoption.

Billionaire Buffett, for example, advocates expanding investments in clean energy, but lobbies to bar solar microgeneration in homes. On the other hand, there are big companies investing in clean energy generation, as is the case of Google.

3. For a critical sociology of energy

How long will the government and fossil companies manage to halt the development of alternative sources of energy is an interesting question? According to the oceanographer Wallace Smith Broecker, the man who coined the term *global warming*,

The energy companies — their whole value is what's in the ground, and if it's not going to be burned their stock isn't worth very much. So they're going to do everything they can to burn what they got — $5 trillion dollars or so worth of stuff. And India, China, and Mexico are going to start using more energy, so if rich nations cut down, it's still going to be overwhelmed by the others. Unless something really dramatic happens, it seems like we're on a course where we've been going up in fossil fuels 3 percent every year. It's still accelerating (Wallace-Wells, 2017).

Even more serious is the behavior of many governments that continue to subsidize the fossil fuel industry and other non-renewable sources. As the REN 21 report states (217, p. 14)

a major barrier to the rapid uptake of renewables more generally is the continued subsidising of fossil fuels (and nuclear power), despite many international commitments to phase them out. By the end of 2016 more than 50 countries had committed to phasing out fossil fuel subsidies, and some reforms have occurred, but not enough. In 2014 the ratio of fossil fuel subsidies to renewable energy subsidies was 4:1. In other words, for every USD 1 spent on renewables, governments spent USD 4 perpetuating our dependence on fossil fuels. This is distorting the market in very unproductive ways.

Recently, in 2016, former President Dilma, faced with a serious political and fiscal crisis, withdrew from the Plurianual Plan (2016–2019) items related to the objectives, goals and initiatives aimed at support renewable sources in the Brazilian energy matrix, contradicting his speech at the Paris Conference in December of that year. In addition, the government made large use of coal power plants to supply additional demand that was not being met by hydroelectric plants in the country, while canceling the contracting of new wind farms. In this way, the country has failed to take advantage of the window of opportunity that was opened in the last decade, when the country had additional resources to invest, but which were directed towards a timid alteration of the energy matrix.

Looking at the US case, Sovacool (2009) asks

If renewable power systems deliver such impressive benefits, why do they still provide only 3 percent of national electricity generation in the United States? As an answer, this article demonstrates that the impediments to renewable power are socio-technical, a term that encompasses the technological, social, political, regulatory, and cultural aspects of electricity supply and use. Extensive interviews of public utility commissioners, utility managers, system operators, manufacturers, researchers, business owners, and ordinary consumers reveal that it is these socio-technical barriers that often explain why wind, solar, biomass, geothermal, and hydroelectric power sources are not embraced. Utility operators reject renewable resources because they are trained to think only in terms of big, conventional power plants. Consumers practically ignore renewable power systems because they are not given accurate price signals about electricity consumption. Intentional market distortions (such as subsidies), and unintentional market distortions (such as split incentives) prevent consumers from becoming fully invested in their electricity choices. As a result, newer and cleaner technologies that may offer social and environmental benefits but are not consistent with the dominant paradigm of the electricity industry continue to face comparative rejection.

Already in the European context, Marques (2010) argues that

The results suggest that both the lobby of the traditional energy sources (oil, coal, and natural gas) and CO_2 emissions restrain renewable deployment. The objective of reducing energy dependency appears to stimulate renewable energy use. Our results robustly support the EU decision to create a directive promoting the use of renewable sources (Directive 2001/77/EC).

In summary, Colomer (2017) points out that

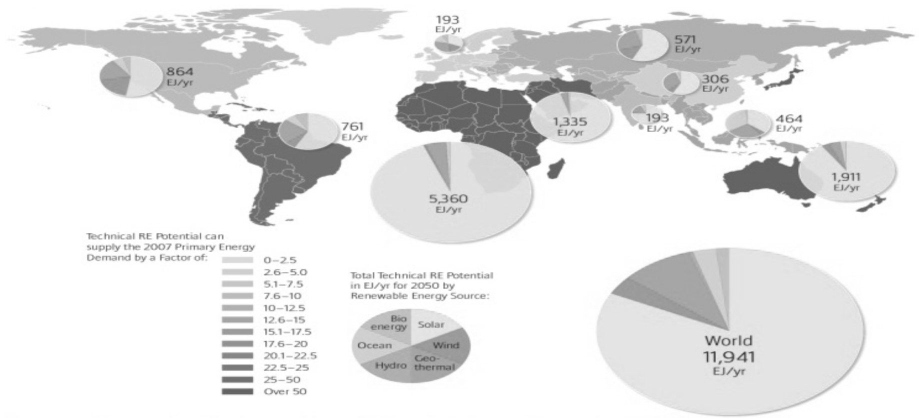
The literature also suggests that oil companies act as a lobby group to influence regulation. For example, four large oil companies (BP, Caltex, Mobil and Shell) have been winning the battle against the Australian government in removing the regulation of gasoline prices in Australia (Valadkhani, 2013). Similarly, Marques et al. (2010) identified important lobbying actions by oil companies against alternative energies in order to protect their own interests. This finding is supported by Huang et al. (2007) and Sovacool (2009), who note that the lobby of traditional energy sources has resulted in a delay in the use of alternative energies.

Why companies and governments tend to have this behavior? First, due to what Sales says (2012, 84), that is,

today, the energy-industrial complex founded on fóssil fuels constitutes a particularly effective active reticular structure for meeting the huge demand for energy, industrial production, transportation and growing households needs, but whose negative externalities on the environment and several local populations are considerable.

Second, because alternative energies tend to be "anarchic", so that consumers and companies (producing their own energy in an ecological way) could become independent of the national energy grid, thus failing to raise taxes and fees, companies and energy conglomerates. In addition, because an accelerated energy transition could reverse the axis of power and domination in the world in the medium and long term, as shown in the figure below, given that the greatest potential for renewable energy production lies in the Southern Hemisphere, Africa, Oceania, India and Latin America.

Figure 9. Total technical renewable energy potential in EJ/yr for 2050.



Source: REN 21, 2017.

On the other hand, the effectiveness of the Paris Agreement, as well as the Kyoto Protocol, becomes impractical, without the contribution of the energy transition in the whole process of reducing CO_2 emissions, and mitigating the effects of climate change. More than that, as Sales & Raizer (2010, 346) points out, the use of renewable energy for climate stabilization

requires much more than a technological and economic tour de force. It needs a huge proactive effort consolidated in economic and political agreements involving states, public and private international organizations, corporations, farmers and citizens worldwide.

Conclusion

There is still an important and difficult journey to be undertaken by the world towards the energy transition process. As pointed out by several reports analyzed throughout the text, more support is needed for the development of renewable energies, especially alternative energy sources.

Global investment in these energies is still far below what is needed, corresponding to only 16% of the total invested in energy in the world. Considering also that global demand for energy is expected to increase substantially in the coming decades, especially in developing countries, a national and international effort is needed to mitigate the environmental impact of the current and expanding energy matrix. Without such effort, the targets set in the Kyoto Protocol and the Paris Agreement will not be met, resulting in damage to the present and future generations, significantly increasing the irrivestibility of the current sixth mass extinction.

Countries that have large natural resources such as Brazil face the challenge of abnegating profit and rapid return from fossil fuels, to look for a sustainable way of development. The country is responsible for 9% of all world hydroelectric production, having increased its electricity generation capacity by 5% from that source in the last year, while its wind production increased by only 2% in the same period (REN 21, 2017). This data, together with the analysis of the composition of the national energy matrix in the last decades, which shows a decrease in the final percentage of renewable energy use, shows that the country does not want to change its energy matrix substantially, only a small percentage, and just in the case of a system expansion.

Considered one of the countries with the greatest energy potential, with large renewable resources, the country maintains a medium trajectory in the development of alternative energies. Among the factors that explain this trajectory, the study highlights the presence of a peculiar socio-technical network (Latour, Knorr-Cetina), in this context, paradoxically, new technologies and values (sustainability) coexist with technologies and practices of the nineteenth century, with the conservation of an extreme unequal society, with great risks (Giddens) to the preservation of natural resources and the ecosystem (Raizer, 2017). The Brazilian energy policy must be understood in terms of the power of the *active reticular structure* of the fossil fuel sector, as well as by the socio-technical network of the alternative energy sector, which suffers influence from the political-business arena configuration, that continues to be dominated by the govenement and lobbying from companies and groups interested in maintaining the national energy traditional way.

On the other hand, it is clear that as long as the country does not reconcile energy development (through PDEs and PNE) with climate change policy, and with a new development model (distancing itself from dependence on commodities), there is little that to expect in terms of the continuity of policies and actions committed to the goals of the Kyoto Protocol and the Paris Agreement on reducing CO_2 emissions and mitigating the effects of climate change.

The energy transition model adopted in Brazil

> is very conservative in that it does not provide audacious stimuli or goals that could make feasible and leverage the development of the sector. The process of energy innovation comprises a slow and complex cycle, in which the changes take time to be installed and have a long productive life. Faced with this and, given the window of opportunity that is open to the development of alternative energies, Brazil runs a serious risk of not being able to overcome the technological gap that already gains significant proportions in the sector (Raizer, 2011, 158).

In this direction, it should be noted that it is already possible to identify a trend towards centralization of the network in the development of alternative energy production, reproducing values and the modus operandi of the traditional fossil fuel network. Thus, the innovation potential and the positive externalities of the derivatives tend to be reduced due to the lobbying of fossil fuels, and the clear pro-fossil and pro-hydroelectric tendencies that exist in the regulation of the energy sector in the country.

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Pathways to technological catching up: Relationship University-Business Relations in Brazil

Insofar as knowledge and innovation are considered key to economic growth, universities have been called to collaborate with the productive sector in order to contribute to transform scientific knowledge into technological development, aiming at the development of the companies' innovative capacity. In the case of countries like Brazil, the university-company relationship becomes still more important, due to the companies' low capacity to absorb the knowledge to produce higher level innovations. The paper presents preliminary results of a research in process that investigates university-firms relationships considering eight Brazilian universities located in the south and southeast regions of the country that are characterized by the presence of technological parks and incubators acknowledged as having satisfactory performance. The preliminary data analysis indicates an increasing number of research groups collaborating with companies, in all fields. However, despite the increase in the numbers of research groups maintaining external interactions, the data suggest that the impact of those relationships on the economic sector innovative performance would be not significant. The article main conclusion is that state incentives through laws and other public measures cannot, by themselves, overcome unfavorable features that are present in society.

Keywords: Brazil — innovation – technological catching up – university-industry relations.

Introduction

This paper is part of a research project in progress that deals with the university – enterprises relationship. Companies becomes increasingly dependent on science-based production and services, since scientific knowledge becomes the true raw material and the central source for wealth creation, on which depends economic growth and a solution for societies' current problems – as global warming, food security, population aging, among others. (DEIACO et al., 2012; NOWOTNY et al., 2003). The complexity, costs and risks of research activities and the short life cycle of an innovation force companies to seek external collaborations. The university have been pressured to adapt their organizational structures, skills and strategies breaking away from the Humboldt model tradition – centered on the rigid separation between academia and market interests – also due to the reduction of public resources per researcher, contributing for the universities to accept partnerships with the productive sector. The interaction between the productive sector and the university is considered even more necessary in developing countries, for that collaboration can contribute to improve the companies' capacity in order to carry out the process of catching up.

The links between the university and business are not new: the University of Venice, in the 15th century, created a discipline of mathematics oriented to navigation relying on the economic impacts that would follow; in the 19th century, the industries of Electricity, Chemistry and Pharmaceuticals had the partnership of universities and, throughout the