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Sustainability of Energy Policy in Brazil: an analysis based on a set of relational indicators

Sustentabilidade da Política Energética no Brasil: uma análise a partir de um conjunto de indicadores relacionais

Sostenibilidad de la política energética en Brasil: un análisis basado en un conjunto de indicadores relacionales

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KEYWORDS
Energy. Sustainability. Policies.

Abstract: The sustainability of a nation's energy policy is related to the conditions of access to energy, to the way it is used and explored, which can be made possible by the diversification of the energy matrix and processes of political-institutional articulation among the agents involved with the activities of generation, transmission, distribution, and commercialization of energy. This article proposes to evaluate the sustainability of the Brazilian energy policy from a set of pre-selected energy indicators, considering the adequacy of these indicators to dimensions such as: access to electricity, energy efficiency, diversification of the matrix, and political-institutional articulation. To achieve the objective, a set of secondary data on energy policy and planning in Brazil was used, which were analyzed qualitatively, using the content analysis technique. The results obtained point out that the Brazilian energy policy is developed through actions that seek to promote access to energy, energy efficiency policies, and programs that aim at the diversification of the matrix, while the process of political-institutional articulation was considered as a base dimension to promote the other conditions and that the energy policy in Brazil focuses on sustainable actions, but still in need of more focus for its consolidation.

PALAVRAS-CHAVE
Energia. Sustentabilidade. Política.

Resumo: *A sustentabilidade da política energética de uma nação está relacionada com as condições de acesso à energia, a forma como é aproveitada, explorada e utilizada, o que pode ser possibilitada pela diversificação da matriz energética e processos de articulação político-institucional entre os agentes envolvidos com as atividades de geração, transmissão, distribuição e comercialização da energia. Este artigo se propõe a avaliar a sustentabilidade da política energética brasileira a partir de um conjunto de indicadores de energia pré-selecionados, considerando a adequação desses indicadores a dimensões como: acesso à eletricidade, eficiência energética, diversificação da matriz e articulação político-institucional. Para o alcance do objetivo foi utilizado um conjunto de dados secundários sobre política e planejamento energético no Brasil, os quais foram analisados de forma qualitativa, através da utilização da técnica de análise de conteúdo. Os resultados obtidos sugeriram que a política energética brasileira é desenvolvida através de ações que buscam promover acesso à energia, políticas de eficiência energética e programas que visam a diversificação da matriz. Já o processo de articulação político-institucional foi considerado como dimensão fundamental para promover as demais condições/dimensões e que a política energética no Brasil tem seu desenvolvimento voltado para ações sustentáveis, porém com necessidade de um esforço maior para sua consolidação.*

PALABRAS CLAVE
Energía. Sostenibilidad. Política.

Resumen: *La sostenibilidad de la política energética de una nación está relacionada con las condiciones de acceso a la energía, la forma en que se utiliza y explora, lo que puede ser posible gracias a la diversificación de la matriz energética y los procesos de articulación político-institucional entre los agentes involucrados con las actividades de generación, transmisión, distribución y comercialización de energía. Este artículo propone evaluar la sostenibilidad de la política energética brasileña a partir de un conjunto de indicadores energéticos preseleccionados, considerando la adecuación de estos indicadores a dimensiones tales como: acceso a la electricidad, eficiencia energética, diversificación de la matriz y articulación político-institucional. Para lograr el objetivo, se utilizó un conjunto de datos secundarios sobre política y planificación energética en Brasil, que fueron analizados cualitativamente, utilizando la técnica de análisis de contenido. Los resultados obtenidos señalan que la política energética brasileña se desarrolla a través de acciones que buscan promover el acceso a la energía, políticas de eficiencia energética, programas que apuntan a diversificar la matriz, mientras que el proceso de articulación político-institucional fue considerado como una dimensión base para promover otras condiciones y que la política energética en Brasil se centra en acciones sostenibles, pero aún necesita un mayor enfoque para su consolidación.*

Introduction

The understanding about the social, economic, political and environmental impact that the use and generation of energy have on society has driven governments to develop more sustainable energy policies. In this sense, energy policies are developed considering the reality of each nation in terms of access to energy, availability of energy resources, use and articulation between the agents that structure the energy system. This process allows the implemented energy policy to approach more fairly the structure of society that are fundamental, such as human well-being and the natural environment, which are part of debates related to sustainable development.

When related to the energy issues, these debates focus on the need of ensuring a safe and fair supply of energy and reduce the impacts from greenhouse gas (GHG) emissions, caused by use of fossil fuels (Abbasi & Abbasi, 2011; Davy, Gnatiuk, Pettersson, & Bobylev, 2018). The excessive use of fossil fuels results in less diversified energy matrices, which brings crisis risks to the energy system and environmental impacts related to climate change (Soares & Cândido, 2019). In this way, the evaluation of a country's energy policy should be understood as necessary to point out issues related to the actions implemented by the energy sector and their impacts on the nation's well-being. In this perspective, the set of indicators developed by the International Atomic Energy Agency (IAEA) has been used in the evaluation process of energy policies in several countries, including Brazil, in order to monitor the current and future implications of these policies in social, environmental and economic terms (International Atomic Energy Agency - [IAEA], 2005; Vera & Langois, 2007).

The praxis of this evaluation process requires tools that can be adapted to the analysis context reality and question the results and progress of energy policy regarding essential issues for promotion of sustainable development, since the integrated and sustainable use of energy resources is related to dimensions addressed by this type of development. These dimensions can be represented by indicators capable of expressing the actions that energy policy promotes, like improving conditions of access, diversification and use of energy. However, the promotion of these conditions involves in itself a political process of articulation between the agents that structure the energy system when developing, implementing and executing actions foreseen in the policy.

Moreover, the reality of each nation is different when comparing energy conditions, especially in relation to the types and availability of energy resources, which implies approaches that consider the specificities of each country. Brazil, as the object of analysis of this study, is considered one of the countries with the most sustainable energy matrix in the world. However, this does not necessarily imply that its energy policy is sustainable, since it is necessary to consider issues that go beyond the use of sources of lower environmental impact, like considering its impacts on the social, economic and political dimension of the nation.

In this sense, despite the IAEA indicators dealing with dimensions of Sustainable Development, there is still a gap related to a political dimension, which is pointed out by the methodological framework itself (IAEA, 2005). In addition to it, there is still the fact that the set of general indicators does not consider differences from one nation to another, which is assumed to be directed to assess energy policies in diverse contexts. For a broad assessment of sustainability, the most appropriate methodology should be considered. Nevertheless, when seeking to understand the energy policies of a country, such as Brazil, which has very peculiar characteristics in its energy system, the methodology needs adjustments for better evaluation.

For this article, it was considered that to assess the energy sustainability of a nation, one should investigate issues that drive or inhibit sustainable development and that are related to the use and energy generation. Vera and Langois (2007) warn of the conditions of access to basic energy services and dependence on non-commercial sources as one of the limiting bottlenecks of this type of development. The use of fossil fuels and their implications on the rise in global temperatures is another issue that points as urgent the need for a matrix diversification and replacement of these sources for others of lower environmental impact (Owusu & Asumadu-Sarkodie, 2016; Soares and Cândido, 2019) and for more sustainable energy policy, it is fundamental to develop energy

efficiency policies to promote a better use of energy.

Thus, the objective of this study is to evaluate the sustainability of the Brazilian energy policy from a set of pre-selected energy indicators, considering the adequacy of these indicators to dimensions such as: Access to Electricity, Energy Efficiency, Diversification of the Matrix and Political-Institutional Articulation. Regarding to methodological terms, the selection of indicators was based on a bibliographic survey, (Helio International [HI], 2011; Organization for Economic Cooperation and Development [OECD]- International Energy Agency [IEA], 2014; Keirstead, 2007; Kruyt, Van Vuuren, de Vries & Groenenberg, 2009; Latin American Energy Organization [OLADE], 2000; Organization for Economic Cooperation and Development [OECD], 2005; International Atomic Energy Agency [IAEA], 2005; Patlitzianas, Doukas, Kagiannas & Psarras, 2008; World Concil Energy [WCE], 2016) and the evaluation of energy policies was carried out through content analysis, to identify the indicators selected in documents related to Brazilian energy policy.

Besides this introductory content, the article explores in its theoretical foundation themes about energy sustainability and energy policy. Then, the methodological procedures adopted for data collection, management and analysis. Afterwards, comes the results and final considerations.

Theoretical elements of the research

Development, Sustainability and Energy

The process of evolution of society is always marked by the use of some source of energy. From the discovery of fire as a source of heat to oil and, more recently, due to the need of replacing polluting sources for others with a lower environmental impact, society has experienced a process of growth, "development", economic, social, political and environmental transformations. This happens because energy represents the propelling fuel of these transformations, sometimes bringing benefits, sometimes bringing negative impacts.

Although significant, the economic growth process was also devastating, from the industrialization process of modern society that took as a basis the use of wood until coal discovery and, later, oil and natural gas. The high levels of pollutant emissions and an unprecedented exploitation of natural resources have long been seen as a necessary sacrifice to ensure capitalist society's growth and consumption patterns.

However, events such as London *smog*; the world energy crisis in the 1970s and 1980s because of the "scarcity " of oil; oil spills on the high seas; pollution of water sources, such as what happened in Minamata; Chernobyl accident, and many other situations, led world organizations to rethink the strategic role of energy in society (Seiffert, 2011).

The greatest warning was given by the report *The Limits to Grow* in the 1970s, in which a group of experts presented a projection of the use and consumption of natural resources and levels of environmental degradation concerning the current production and consumption model. Since then, in 1987 discussions culminated with the publication of the Brutdland report, which warns of the search for a development that is sustained, to ensure that the next generations have access to the same resources as the present generations (Meadows, Meadows, Randers & Behrens, 1972).

In this regard, energy occupies a prominent position in the list of discussions because it is fundamental for the progress of nations. It is a natural resource of the environment and ecosystems that is essential to human activity development and a driving force for socio-economic development, being necessary to improve human living conditions and well-being (Pan, Shao, Zheng, Zhang, Ma & Zhang, 2023).

On the other hand, depending on the form of exploitation, purpose, and type of energy resource used, environmental problems stand up as a concern, especially those related to the emission of pollutants, since energy also has effects on the environment (Intergovernmental Panel on Climate Change [IPCC], 2022).

In this way, energy is directly linked to discussions on sustainable development, since it promotes human well-being, its material condition and natural environment (UNITED NATIONS [UN], 2015). An example of global scope and such discussions is the 2030 Agenda for Sustainable Development, adopted at the United Nations Sustainable Development Summit in 2015, which presents 17 specific Sustainable Development

Goals (SDGs), in which SDG 7 (accessible and clean energy), suggests the pursuit of energy development by 2030, through solving problems of energy pollution, energy backwardness, and poverty (Pan, et al., 2023).

Therefore, energy is part of agendas that address issues such as climate change, energy efficiency, development and combating poverty, all fundamental to sustainable development.

Energy Sustainability

Energy sustainability assumes that the energy system of a nation contributes to the promotion of sustainable development and refers to a process of exploration and use of energy resources that considers the limitations of the planet and its level of entropy regarding the negative impacts that the use of non-renewable resources and pollutants may cause. Moreover, it promotes social and economic well-being, because it can transform the reality of many communities, especially the most vulnerable ones, through access to electricity. (IAEA, 2005; Vera & Langois, 2007; Soares & Cândido, 2019; Sovacool & Drupady, 2012; Owusu & Asumadu-Sarkodie, 2016; International Energy Agency [IEA], 2017; Zhang, Shi, Zhang & Xiao, 2019).

However, it is difficult to find concepts of energy sustainability in literature, due to the multiple approaches that different authors present when dealing with energy and its impacts on society and the environment. In general, all the approaches are related to the concept of sustainable development coined in 1987 in the Brudtland report.

Rosen (2009; 2012) considers that energy sustainability is related to the provision of energy services in a sustainable way, so that everyone has access to the provision of this service to meet their basic needs, now and in the future, without generating environmental impacts. That is an approach that indirectly considers matters such as access, exploitation and use of energy and the environmental impacts arising from the use of polluting energy sources, which is related to concern for future generations. These concerns are present in the 2030 Agenda for Sustainable Development and specifically in the Sustainable Development Goal –[SDG]-7, related to energy.

Rosen (2009; 2012), Xu and Zhang (2019), Nerini, Tomei, To, Bisaga, Parikh, Black, Borrio, Spataru, Broto, Anandarajah, and Milligan (2018) and Akter, Fu, Bremermann, Rosa, Nattrodt, Väätänen, Teplov, and Khairullina (2017) propose in their studies that energy development can contribute to improve access to energy and fight poverty, by medium of generation of employment and development of new industries, as well as to save energy through energy efficiency actions that subsidize more infrastructure to alleviate poverty and, promote the use of energies of lower environmental impact to improve climate conditions and reduce environmental pollution.

From this perspective, Soares and Cândido (2020) present a discussion on energy sustainability related to dimensions such as access to energy, diversification, energy efficiency, and political-institutional articulation. The last dimension refers to the performance of different agents that make up the energy system of a nation, also the governmental and private actors involved with the processes of generation, transmission, distribution, and supply of energy to society. Thus, the authors point out that energy sustainability can be expressed based on four dimensions: access to energy, energy efficiency, diversification of the matrix, and political-institutional articulation, as described below:

Access to Energy: it is related to a fair and equitable availability of basic energy services, to ensure a better quality of life for the population through modern electricity services and non-dependence on traditional energy fuels. This dimension contemplates the goal of the 2030 Agenda, which aims to ensure universal access to modern, reliable, and affordable energy services (UN, 2015; Pan et al., 2023).

Energy Efficiency: it involves all the changes that result in the reduction of energy used for a certain service or activity, which is not necessarily linked to technical changes, because it can also be the result of better management and organization of energy resources and available technologies, or even the incentive to change the habits of the population, in order to contribute to the goal of the 2030 Agenda that seeks to double the global rate of improvement in energy efficiency (UN, 2015; Pan et al., 2023).

Diversification of the Matrix: it consists in the introduction of other sources of energy to meet the basic needs of society. Sources of lower environmental impact allow diversification,

considering environmental dimensions such as GHG emission levels and limitations inherent in fossil fuels. This must happen as a fulfillment of the goal of the 2030 Agenda that foresees the substantial participation of renewable energies in the global energy matrix (UN, 2015; Pan et al., 2023).

Political-Institutional Articulation: it is related to the set of actions necessary for the balance of an energy system, which involves the action of a set of institutions and *stakeholders* to promote the previous dimensions' applicability. This involves the articulation of government agents and the private sector, through development of new technologies to improve the use of energy, making it an accessible asset, encouraging the insertion of sources of lower environmental impact, and monitoring the performance of the energy sector.

Therefore, according to Soares and Cândido (2020), energy sustainability presupposes the balance between access conditions, which can be improved by energy efficiency actions and diversification of the matrix. However, this balance depends on the political-institutional articulation between the agents that make up the energy sector. Sustainability should be identified through tools such as energy indicators and analysis of the different programs that reflect energy policy and planning and actions already underway or under development, and that are also necessary to ensure that society's needs are met in terms of energy services.

Methodological elements of research

As for the objectives, the research carried out can be characterized as exploratory and descriptive. As for technical procedures such as bibliographic and documentary research. Regarding the approach of the main problem, it is characterized as qualitative-quantitative research, since to identify energy indicators a quantitative survey was carried out on the websites of national and international institutions, as well as journals that presented studies on energy indicators and, specifically, indicators that demonstrate relation to energy sustainability.

The indicators were selected from 04 (four) criteria, which are measures capable of promoting access to energy, energy efficiency, diversification of the matrix and political-institutional articulation. At the end of the steps presented, the scoreboard resulted in a set of 20 indicators, as can be seen in Board 1.

Board 1
Energy Sustainability Dimensions

Dimension	Indicators
Access to energy	% of households with access to electricity or dependent on non-commercial energy.
	% of the amount of expenses with fuel and electricity in the household income.
	Energy consumption per capita
	Employment
Energy Efficiency	Energy intensity (per unity of the PIB)
	Energy Efficiency
	Length of the road
	Wind speed
Diversification of the Energy Matrix	Generation of electric energy from non-carbon emitting sources
	Generation of electric energy from non-renewable sources
	Greenhouse gas emissions (GHG)
	Concentration of polluting in the environment and in urban areas
	Air pollution through energy generation
	Logging rate related to the energy generation
Political-Institutional	Accidents in the energy flow
	Local technical capacity
	Crisis Management
	Scientific Information
	Investment
	Transparency

Source: Soares (2020).

After the selection of the final set of indicators, the next step consisted of a documentary survey aiming to analyze whether, in the process of formulation of National Energy Policy and planning, the pre-selected energy sustainability indicators are taken into account from the dimensions: access to energy, energy efficiency, diversification of the matrix and political-institutional articulation.

The sources of documentation consist of statistical records, such as the National Energy Balance and data from the Brazilian Institute of Geography and Statistics (IBGE), and also consist

of written institutional records, such as national balance sheets, electricity sector legislation, auction records, and ten-year plans of energy. All the documents were taken from the National Electric Energy Agency (ANEEL), Energy Research Company (EPE), Ministry of Mines and Energy- (Mme.), Brazilian Institute of Geography and Statistics- (IBGE) and Planalto websites, resulting in a set of 29 documents. The criteria used for the selection of documents were: relation to energy policy and planning, relation to programs focused on electricity generation, and relation to the regulation of the Brazilian electricity sector, as presented in Board 2.

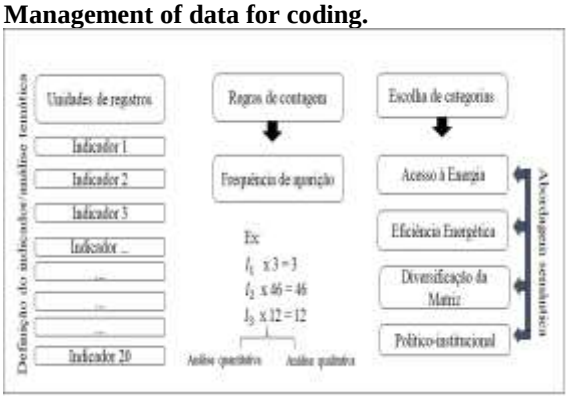
Board 2
Documents Classification

Sequence	Document name
D1	Electric Energy Statistical Yearbook 2017
D2	National Energy Balance 2017
D3	National Energy Plan 2030
D4	Basic Legislation of the Brazilian Electric Sector
D5	Alternative Sources Auction (2007)
D6	Alternative Sources Auction (2015)
D7	Alternative Sources Auction (2007)
D8	Alternative Sources Auction (2007)
D9	Alternative Sources Auction (2010)
D10	Alternative Sources Auction (2015)
D11	Reserve Auction (2010)
D12	Reserve Auction (2010)
D13	Reserve Auction (2010)
D14	Reserve Auction (2009)
D15	Reserve Auction (2009)
D16	Reserve Auction (2009)
D17	Alternative Sources Auction (2010)
D18	Other Sources (National Plan – 2030)
D19	Ten-Year Electric Power Expansion Plan 2006-2015
D20	Ten-Year Electric Power Expansion Plan 2007-2016
D21	Ten-Year Electric Power Expansion Plan 2008-2017
D22	Ten-Year Electric Power Expansion Plan 2019
D23	Ten-Year Electric Power Expansion Plan 2020
D24	Ten-Year Electric Power Expansion Plan 2021
D25	Ten-Year Electric Power Expansion Plan 2022
D26	Ten-Year Electric Power Expansion Plan 2023
D27	Ten-Year Electric Power Expansion Plan 2024
D28	Ten-Year Electric Power Expansion Plan 2026
D29	Energy Demand 2050

Source: Soares (2020).

After a bibliographic and documentary survey, we proceeded with the content analysis, in order to verify which of the pre-selected indicators are included in these documents. To support this process, Atlas t.i software was used to systematize the material and information, through the categorization/definition of record units, which was represented in this process by pre-selected indicators in four dimensions of energy sustainability: access to energy, energy efficiency, diversification of the matrix and political-institutional articulation. As in Figure 1.

Figure 1
Management of data for coding.



Source: Soares (2020).

Once the step of linking the units of records/indicators to the categories/dimensions was completed, the coding process was carried out. The codification was carried out through careful reading of each document and linking quotes to one or more indicators. It is worth noting that the counting rules were used as criteria to link the indicators so that the indicator linked to a document was related to the times it appears in the analyzed documents. The analysis process of the organized and coded data was carried out using the technique of analysis by categories, through semantic criteria and inferential analysis.

Presentation and discussion of results

Access to Energy

The Access to Energy dimension is presented by a subset of four energy indicators that seek to

express measures that promote access to basic electricity services and that contribute to improving the life quality of households and, therefore, society, promoting sustainable development.

In general, 355 quotes were coded for the set of indicators of the Energy Access Dimension. Table 1 shows the absolute frequency of quotes for each indicator. The indicators in this dimension were Energy Consumption - (I-1), Households with Access to Electricity (I-2), Employment Generation (I-3), and Expenses with Electricity and Fuel (I-4).

Table 1
Absolute frequency of quotes for code/ indicator and documents

	Indicators			
	(I-1)	**(I-2)**	**(I-3)**	**(I-4)**
Ocurrence of quotes	116	86	141	12
Percentage	32,68%	24,23%	39,72%	3,38%

Source: Adapted from Soares (2020).

The Employment Generation and Energy Consumption indicators present the highest percentage of quotes, consisting, respectively, in 39.72% and 32.68% of quotes involving all documents analyzed. The set of indicators expresses the frequency that documents related to energy policy and planning address energy sustainability indicators as guiding measures of Brazilian energy sector actions.

On the whole, 116 quotes mentioned, in some way, the concept of energy consumption, corresponding to 32.68% of the quotes coded for the dimension under analysis. The indicator Households with access to electricity presented an amount of 86 quotes, which corresponds to 24.23% of quotes linked to the analyzed documents. It is worth highlighting that these quotes about this indicator were linked to 80% of the documents presented in Board 2. Which means that some documents did not present any link with this indicator, such as documents D4, D18 and D19. However, the D2 document has 90% of the quotes referring to the indicator when compared to the other indicators of the dimension under analysis.

The Employment Generation indicator has the highest number of quotes, 141, present in 75% of the documents analyzed, which corresponds to 39.72% of quotes, when compared to the other indicators. Document D21 presented 80% of quotes in relation to the other indicators. This document discusses the Ten-year electricity expansion plan 2008-2017. The quotes linked to this indicator discuss the job opportunities that can be offered through the productive chain in which energy is inserted, contributing to an increase in other indicators of this dimension. This is the case of Expenses on Electricity and Fuel indicator, which just had 3.38% of quotes in this dimension, and is linked to 54% of the documents presented in Board 2. The document that presented the highest number of quotes was D3, referring to the National Energy Plan 2030, which also discusses the long-term planning of the sector.

Although the Expenses on Electricity and Fuel indicator has a lower representativeness in relation to other indicators of the Energy Access dimension, it is important to mention that the four sets of this dimension present a very close relation. The Employment Generation indicator was the most representative in the set of indicators analyzed, followed by the Energy Consumption, Households with Access to Electricity, and Expenses on Electricity and Fuel indicators. By means of promoting new jobs, people may have access to basic energy services. That is, it means that more households have access to energy, and consequently, the income spent on energy and electricity increases because energy consumption also tends to increase.

The relation identified in these indicators must result in greater access to energy, reduce social inequalities and regional disparities in the country, and must provide those who still depend on traditional sources the benefits that electricity may offer to the well-being of more vulnerable communities. In other words, access to energy is fundamental to promoting sustainable development, and monitoring these indicators can express conditions related to the effectiveness of programs and policies that aim to guarantee access to electricity.

It can be observed that access to electricity still faces challenges, which is clear from the quote stating that firewood is still used in Brazilian households for electricity. In fact, universalization of electricity is a challenge faced by the energy sector in Brazil, and programs and policies have been developed to provide basic electricity

services to the most remote places, such as the Luz para Todos (Light for All) program. The more households have access to electricity services, the more actions in the energy sector are moving towards energy sustainability, in light of the population and communities that will, from then on, have a more dignified and secure quality of life.

Energy efficiency

The Energy efficiency definition covers different approaches and a range of energy consumption indicators. In other words, energy efficiency involves all changes that result in the reduction of energy used for a particular service or activity, which is not linked just to technical changes, given that it can also be the result of better management and organization, or improvement of economic efficiency of the sector. On the whole, 339 quotes were coded in the set of codes/ indicators of the Energetic Efficiency dimension, according to Table 2. The indicators approached in this dimension were: Road Length (I-5); Energy Efficiency (I-6); Energy Intensity (I-7) and Wind Speed (I-8).

Table 2
Absolute frequency of quotes for code/ indicator and documents

	Indicators			
	(I-5)	**(I-6)**	**(I-7)**	**(I-8)**
Occurrence of quotes	3	252	73	11
Percentage	0,88%	74.34%	21,53%	3,24%

Source: Adapted from Soares (2020).

From the analysis of the relative frequency of quotes for each code/indicator regarding 29 documents, in Table 2, the codes/indicators Energy Efficiency and Energy Intensity presented the highest percentage of quotes, respectively: 74.34%% and 21.53% of quotes involving all documents analyzed. The Road Length and Wind Speed indicators were less representative in the set of quotes linked to this dimension. Such indicators, in general, aim to promote a better use of energy, in the sense of facilitating and allowing various forms of generation, through sources of distribution and transmission of energy with lower environmental impact.

From the four indicators of this dimension, among all the 339 quotes linked to 29 documents, 252 were linked to the Energy Efficiency indicator, covering 92% of the documents analyzed. Almost all the documents in which this indicator was quoted presented a percentage of quotes above 60%, and only document D18 and D20 presented a percentage of 32% and 14%.

Regarding the documents that obtained the highest number of quotes linked to the Energy Efficiency indicator, documents D3, D23 and D29 stand out with 95%, 77% and 65% of quotes, when compared to the other indicators of this dimension.

The Energy Intensity indicator had a total of 73 quotes linked to this indicator, with 100% of quotes in the documents analyzed. Such quotations refer to the amount of energy used per unit of Gross Domestic Product (GDP), which can also refer to the amount of energy needed to move the agricultural, industrial, residential and transport sectors. Thus, the quotes linked to this indicator express the energy intensity in different economic sectors in the country.

The other indicators of this dimension, such as Road Length and Wind Speed, complement the Energy Efficiency indicator. Its representativeness was not significant in terms of quotes, only three, regarding the set of quotes linked to the documents shown in Table 2, which represents less than 1% of the entire set of quotes in this dimension. This result points to the fact that this indicator may not be a reference measure to evaluate or promote the energy efficiency of the sector.

The last indicator that is part of the Energy Efficiency dimension is Wind Speed, which refers to a measure of multiple uses of energy resources, in the sense that, energy of lower environmental impact can be generated with wind. It is related to a more specific use of energy, as a way of promoting the best use of available resources. In total, 11 quotes were linked to this indicator in the set of documents analyzed, which represents 3.24% of quotes in this dimension. Regarding the other indicators, document D18 presents 38% of quotes linked to this indicator and refers to the use of wind as a source of energy generation. Such indicator was inserted in this dimension as a way to point to the generation of energy by sources of lower environmental impact as one of the measures of energy efficiency, presented by programs and policies in the Brazilian sector, such as the Emergency Wind Energy Program (PROEÓLIC) and Incentive Program for Alternative Sources of

Electric Energy - (PROINFA).

The aim is to demonstrate possible relations between these indicators, which go beyond equipment exchange programs and behavior changes related to energy use and consumption. Energy efficiency can be promoted from analysis of measures that consider economic and environmental impacts to promote energy generation by various sources.

The diversification of the energy matrix

The diversification of the energy matrix is related to the introduction of other energy sources to meet the electricity and fuel needs. This process of diversification lowers the chances of an energetic crisis, seeing that the participation of other sources may function in a complementary way between the different types of sources available. In the case of Brazil, the necessity of complementation is a reality faced by the electricity sector, mainly in times of drought, when the main source of energy matrix, the hydraulic, becomes scarce, lowering the reservoir levels.

In all, there were 462 coded citations to the set of codes/indicators of dimension for the diversification of the energy matrix. In Chart 3 there are the absolute and relative frequencies of the citations to each indicator. The indicator considered in this dimension were: Soil Acidity (I-9), Pollutant concentration in urban areas (I-10), Outflow of contaminants and liquid effluents (I-11), Deforestation in the energy chain (I-12), GGE emission (I-13) and Generation from renewable sources (I-14).

Chart 3
Absolute and relative frequencies of the Citations

	Indicators					
	(I-9)	**(I-10)**	**(I-11)**	**(I-12)**	**(I-13)**	**(I-14)**
Citation occurrences	24	49	2	15	89	283
Percentage	5.2%	11%	0.5%	3.24%	20%	60%

Source: Adapted from Soares (2020).

According to the data in Chart 3, in percentage presentation terms, the Soil acidity indicator was shown in 5.2% of the citations. This indicator refers to the possible impacts that the different types of sources may have, such as the case of soil acidity, which is done through landscaping processes, glade opening, large undertakings to generate energy and so on. In the same way, Pollutant concentration in urban areas was shown in 11% from the total of citations.

The Outflow of contaminants in liquid effluents indicator was shown in 0,5% of citations, in which 50% were linked to document D18, and the other 50% linked to document D27. Although D18 is about the national planning for 2030, D27 refers to the decennial plan of energy expansion for 2024, that incorporates an integrated vision for the increase of supply and demand of many energy sources in the period of 2015 to 2024.

The Deforestation in the energy chain indicator refers to the process of road openings and the removal of vegetation to give space to large projects for energy generation. The citations linked to this indicator are distributed along four documents, D18, D19, D20 and D22, with a percentage of 13.66% of citations in each one. The documents D19, D20 and D22 are decennial plans for energy expansion in the years of 2015, 2016 and 2019, they refer to important instructions to orient the actions and decisions related to the equalizing of the projections of economic growth in the country, their reflexes in the electric energy needs and in the necessity of increase, in a technical, economic and environmentally sustainable basis. This way, in looking at the energy supply under a sustainable perspective, this indicator is relatively approached as a guiding measure for the actions of the electricity sector.

The greenhouse gases emission indicator is shown in 60% of the documents, with more occurrences in D18, D20 and D28, with 13%, 12% and 10% of citations, when compared to all 29 documents. The documents D20 and D28 are decennial plans, while D18 refers to a national plan. Specifically, D28, together with the other decennial plans shown in this study, serves as a guide of investment for state-owned companies to the opening for participation of the private sector. This document presents an integrated vision for the increase of supply and demand of many energy sources, even more so after the National Climate Change Measure, in which Brazil contributes according to the Paris Agreement, imposing new conditions to the sectors action planning.

Lastly, the energy generation by renewable sources was shown in 94% of the documents,

together with 60% of citations, with more frequency in the documents D2, D18, D26, D27 and D28, with a percentage of 14.49%, 11.31%, 10.60%, 12.72%, respectively. Document D2 talks about the National Energy Balance for the year of 2017, with information about the related accounting of demand and the energy consumption in Brazil, as well as the process of conversion of energy products and foreign trade. The National Energy Balance (Balanço Energético Nacional - BEN) gathers in a single document the records of these operations, together with the information on the reserves, installed capacities and important state data.

All the documents that have linked citations to the energy generation by renewable sources indicator show the balance in regards to the supply of energy from those sources, as well as projections to the following decades. The 29 documents present actions of a determinative character to the Estate, whereas to the private sector they have an indicative character. The objective is to promote an equilibrium between the many political-institutional actors that take part in the Brazilian electricity sector, in the sense of guaranteeing the energy supply, the access to it and its best use.

Political-institutional articulation

The capacity for development of plans that guide the acting of the Brazilian electricity sector in a more sustainable scenario is a challenge faced by the public and private institutions that generate, transmit and distribute energy in the country. The integrated management of sources, in a way that promotes the secure and fair access to basic energy services, together with environment preservation, have been a question to be considered by the government and the institutions that compose this sector.

The political-institutional dimension seeks to analyze the actions of public and private institutions that are part of the Brazilian electricity sector, through the identification of energy sustainability indicators, expressing actions of secure supply promotion, fair access, efficient and environmentally sustainable use of energy.

In Brazil's case, the institutions that form this political-institutional scenario are the businesses that generate, transmit and distribute energy together with government bodies, who are responsible for the regulation and running of the National Interconnected System (Sistema Interligado Nacional - SIN), such as the National Counsel of Energy Measures (Conselho Nacional de Política Energética - CNPE), the Ministry of Mines and Energy (Ministério de Minas e Energia - MME), the National Agency of Electric Energy (Agência Nacional de Energia Elétrica - ANEEL), the Company of Energy Research (Empresa de Pesquisa Energética - EPE), the National System Operator (Operador Nacional do Sistema - ONS) and the Assembly of Commercialization of Electric Energy (Câmara de Comercialização de Energia Elétrica - CCEE). This way, the process of identification of the political-institutional indicators had as its objective to evaluate the energy measures and planning in Brazil through the acting of these institutions to the integrated and harmonic functioning of the sector.

The political-institutional dimension is show as a subset of five energy indicators that look to express measures that assess the acting of public and private institutions that form the Brazilian electricity sector.

The total of citations linked to these indicators were 269 In Chart 4 there are the absolute and relative frequencies of the citations to each indicator related to the analyzed documents. The indicators that address this dimension are Local technical capacity (I-15), Crisis management (I-16), Scientific Information (I-17), Investment (I-18) and Transparency (I-19).

Chart 3
Absolute and relative frequencies of the Citations

	Indicators				
	(I-15)	**(I-16)**	**(I-17)**	**(I-18)**	**(I-19)**
Citation occurrences	4	14	13	232	6
Percentage	1.5%	5.2%	4.8%	86.2%	2.23%

Source: Adapted from Soares (2020).

In the data from the chart below its possible to observe that the Investment indicator was shown in 86.25% of the citations linked to the analyzed documents, which suggests that this indicator is the most representative in the Political-institutional dimension. The Crisis management and Scientific information indicators were shown in 5.2% and 4.85% of the citations, respectively, and the Local technical capacity and Transparency indicators had

a percentage of citations of 1.49% and 2.23%, respectively. Such indicators aim to consider the role institutions have in the Brazilian electricity sector, in the sense that it promotes measures that guarantee the provisions and the sustainable and secure access to energy services from the coordination of the actions of these institutions.

The Investment indicator appeared in a bigger number of citations linked to the analyzed documents. From the 269 citations in the 29 documents, 232 were linked to the Investment indicator, present in all documents from the chart above. Almost all the documents in which this indicator was mentioned showed a percentage of citations of 100%, such as in the documents D20, D22, D23, D24, D25, D26. Those documents refer to decennial plans for a time period that goes from 2019 until 2026, so they are related to the long-term planning in the energy sector of the country for the following decades.

The document that had citations linked to all the indicators in this dimension was D4, being the Investment and Crisis management the ones who presented a greater percentage of linked citations, 42.86% and 28.57%, respectively. Document D4 refers to the norms that compose the regulatory basic boundary of the Brazilian electricity sector, representing the set of laws and decrees that go from the creation of the water code to the regulation of the social electric energy tax.

The Local technical capacity and Transparency indicators were the ones with the least amount of citations linked. In the case of the indicator of Local technical capacity, only four citations were linked and only in the document D4; the Transparency indicator had six citations linked in the documents D3, D4, D28 and D29. Document D3 is about the national planning for 2030, and the documents D28 and D29 refer to the decennial plan of energy expansion for 2026 and the demand of energy to 2030, in that order. The documents who have the greater number of citations were D3, D4, D22, D25, D27 and D28, all referring to the long-term planning in the Brazilian electricity sector. In regards to the indicators in this dimension, the first one, Local technical capacity, was mentioned in 6.66% of the analyzed documents, which corresponds only to document D4 and the 1.49% of citations when compared to the full set. Concerning the other indicators, it is suggested that the actions related to the existence or formation of a local technical capacity for the sector with the aim to generate local benefits, were scarcely mentioned in the analyzed documents, or the institutional acting still does not develop measures in this sense.

The Crisis management indicator was shown in 40% of the analyzed documents, with citations distributed along the documents D3, D4, D18, D19, D21 and D27, that represents 5.2% of the linked citations in all the documents. This may indicate that in 40% of the documents that had citations referring to this dimension, there are actions mentioned for the managing of situations that may compromise the system's capacity to meet the demands of the society for energy. For example, one can mention the Thermoelectric Emergency Program and the Assembly of Crisis Management, in 2021, created to deal with the blackout crisis.

The Scientific information indicator was mentioned in 26.6% of the analyzed documents, with 13 citations distributed along the documents D3, D4, D28 and D29, that is equivalent to 4.83% of the coded citations in this dimension. This set of citations indicates that the energy measures and planning makes available or promotes information related to the sector, to guide the actions of enterprises in the energy sector, taking as example the information about risk areas, contamination processes because of energy generation or polluting and GGE emission.

The Investment indicator was shown in citations along all the documents analyzed in the chart above, represented in 232 citations, which corresponds to 86.25% when compared to the other indicators, as mentioned before. The investment in the energy sector is fundamental to the maintenance and its own development, which means that the actions and energy planning, through the different institutions that compose this sector, have been promoting investments to the improvement of the processes of generation and a more sustainable energy services provision.

Finally, the Transparency indicator was shown in citations linked to 26.6% of the documents, with six citations distributed along the documents D3, D4, D29 and D29, which represents 2.23% of the citations linked to the Political-institutional dimension. So, as the Local technical capacity indicator, its activity was relatively small which may mean that there are

deficiencies in the processes of disclosure and participation in society and institutions in the actions surrounding the energy sector. However, it is important to make this analysis from the citations linked to each indicator.

Although the Local technical capacity and Transparency indicators have less frequency in being mentioned in the analyzed documents related to the other indicators in this dimension, it is important to point that the five indicators make the *corpus* of the integrated acting between the many institutions that form the electricity sector The Investment indicator was the one with most representation in the set of analyzed indicators, followed by Crisis management, Scientific information, Transparency and Local technical capacity. All those indicators represent important and necessary actions so that the energy sector may achieve the goal of secure and fair service providing of the basic societal energy services.

From this analysis, a framework was developed from the correlation between indicators and dimensions.

The relationship between the Dimensions of Energetic Sustainability

The analysis and discussion of the four sustainability dimensions allowed for the indication of the relations between them and each dimension, and the contributions for every other dimension. The Political-institutional dimension, when relating the institutional roles in the articulation of actions of planning and execution of the energy policy from the acting of the many sector agents, can contribute to the other dimensions, seeing that it evaluates the efficacy and plans, strategies and policies adequation (IAEA, 2005), as observed in Figure 1.

This way, Figure 2 shows the relation between the four dimensions of energy sustainability through the indicators that represent best each one, using chain relations, in a way that the developed actions in a dimension influence the other, highlighting the articulated dimension political-institutional as the one who directs fundamental actions of planning and energy policies who will support the actions of the remaining dimensions.

The relations between the indicators of the Political-institutional dimension establish themselves through a process of concatenation between themselves. The investment in the energy sector assumes the development of policies and programs to the performance and balance of the agent's many actions. This investment may be reflected in the formation and training of individuals to act in the many energy sectors, for example, the specialized engineers in renewable energy, or even research to improve the energetic efficiency related to said uses of energy or betterment and introduction of technologies in the sector.

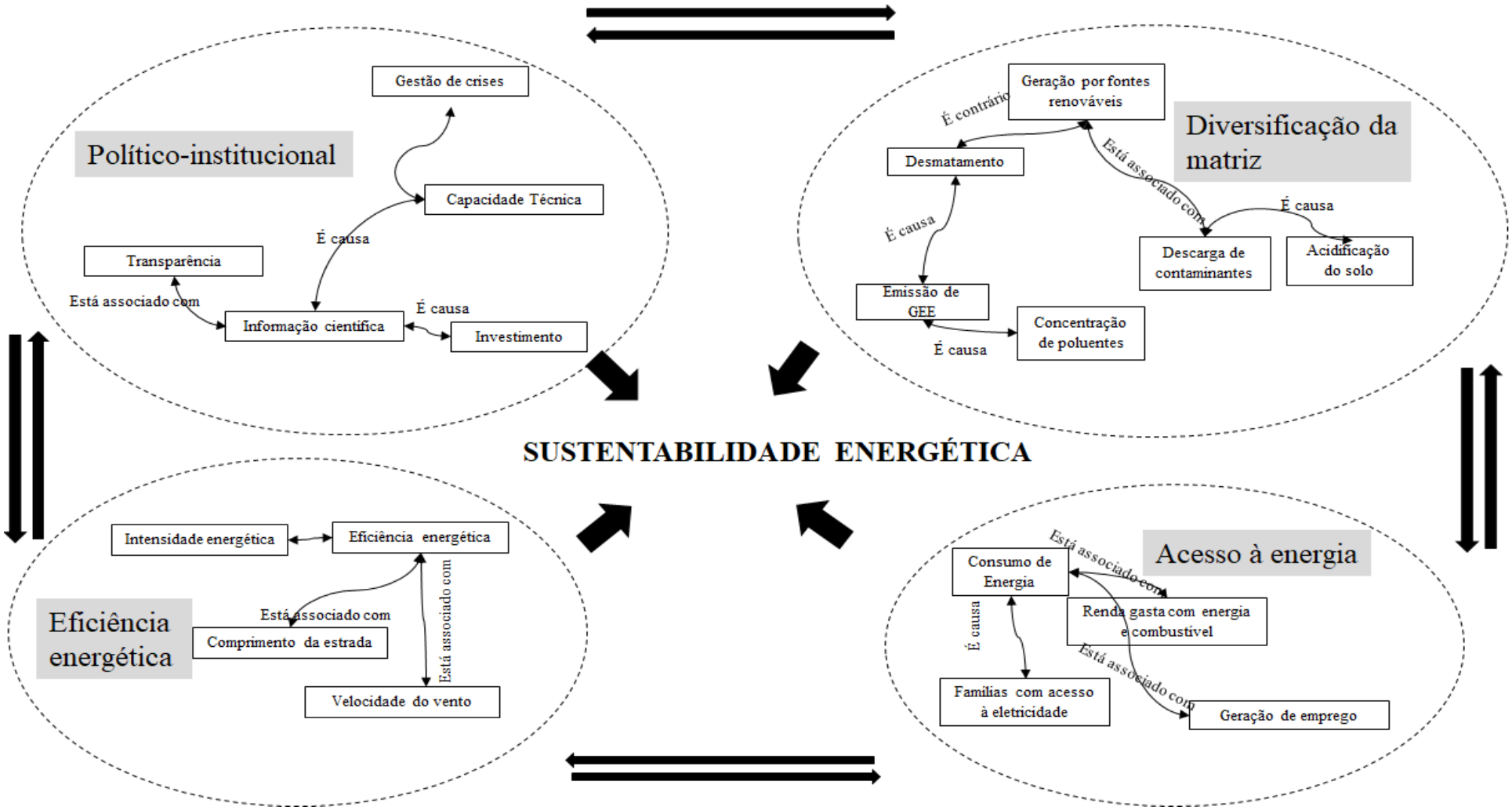
The investments creates more assertive information to decision making by the different actors and influences directly in the process of transparency in the sector, as those information are supported in studies and researches. Lastly, the transparency of these information allows the political decision makers of the sector an information dock that support plan making to avoid energetic crisis or even contingency plans to deal with them.

The role that the institutions, public and private, have in the performance and balance between supply and energy demand, in the Brazilian context, can be seen through the policies of energy efficiency that may directly influence the consumption of energy; therefore, creating a fairer access to the services, at least the basic ones. In the same way, the articulated actions of these actors may imply in the less polluting generation of energy, which means matrix diversification, which has a direct relation with the level of investment in programs that prioritize renewable energies with less environmental impact instead of carbon-based energy generation.

In what concerns the relationship between the Political-institutional and Energy efficiency dimensions, the Investment indicator shows a more direct link. The increase of investment in research and programs of energy efficiency are reflected directly in the better use of energy and in the developing of technologies that enables this more rational use, as well as contributes to the conservation of energy.

Figure 2

Relations between the indicators of the different dimensions



Source: Soares (2020).

Between the indicators of this dimension, such as the increase of energy efficiency, they contribute directly in the results of the Energy intensity indicator, so, in improving the use of energy, it is possible to guarantee the same level of service providing and production with less energy. That is important, above all, in sectors that are energy intensive and, in the ones, responsible for an elevated emission of pollutants.

As part of this dimension, the indicators of Road length and Wind speed are indicators who show an association with energy efficiency in a structural sense. They refer to the infrastructure conditions that can favor a better use of energy and less use of it. This way, in the Energy efficiency dimension it is also possible to point out a indicator interdependency, but in a more significant way, between the Energy efficiency and Energy intensity indicators.

The developments in energy efficiency influence in the policies and programs that have the goal to put different sources in the matrix and contribute to the transition between a carbon-based matrix to a more sustainable one. The development of technologies allows for the generation of sources of less environmental impact, even more so the ones who have limitations in regards to their elevated deployment cost.

Still, it is possible to observe that those limitations have been diminished, which can be seen from the expansion in the wind industry sector, that initially found hindrances in the industry of components and equipment, but that has been surpassed through incentive policies to the creation of enterprises that give support to the productive chain that generate this type of energy.

All the measures that look to contribute to the promoting of a better use of energy, and of energies of less environmental impact, are important to the diversification of the matrix. So, the dimension Matrix diversification is influenced by the policies and programs of energy efficiency, as well as the level of investment in the sector in the insertion of less environmental impact sources and in measurements that look to reduce the impact that fossil sources have in the environment. This way, the indicators in this dimension reflect the actions that minimize the negative impact from the use of pollutant energy and measurements that boost the insertion of renewable sources with less environmental impact.

The greater participation of those sources contribute greatly to the results of other indicators in this dimension, as is the case with Deforesting and Use of fossil fuels, related to the level of emission of greenhouse gases and the concentration of pollutants in urban areas. This relation is shown in a chain, seeing that, in reducing the deforestation index, the level of emissions reduces considerably because one of the biggest causes of emissions in Brazil is associated with deforestation.

In the same way, in inserting less environmental impact sources in the matrix there is also a decrease in the outflow of contaminants in liquid effluents, such as the ones caused by the leaching of mineral coal to the generation of energy in thermoelectric power plants. In turn, this decrease in the level of outflow of contaminants contributes to reduce the soil pollution index caused by acidity form the liquid contaminants as well as the modification in the use of this soil to the installing of large energy enterprises, or even deforesting.

An important point in investing and encouraging renewable sources in the matrix is the possibility of offering more competitive prices to the commercialization of energy. The auction system for that commercialization, introduced from the electricity sector's new model, in 2004 in Brazil, allowed the commercialization of contracts based in the smaller megawatt-MW per hour, which may influence in the energy rate value in the tip of consumption and contribute to the tariff reasonableness and propel a greater access to the energy services.

Furthermore, one of the biggest bottlenecks faced by the sector is related to the

energy complementation (Tolmasquim, Guerreiro & Gorini, 2007; De Miranda, Martins & Lopes, 2019) that in the country still has a predominance of fossil originated sources (Pires, 2000; Sampaio & Perira, 2018). This way, it is possible to say that the insertion of renewable sources in the matrix is a key indicator to the sustainability of the energy sector and the search for balance between supply and energy demand. It can also be considered, in addition, as a preventive measure for energy crisis, as long as the management of the many renewable sources in the country is done in an integrated way with the many regions, considering the different times of year that change the potential of generation of specific sources of energy.

The access to energy resulting from the matrix diversification is made by the possibility of fairer prices through the competition system between the many sources commercialized in the auctions. The policies and programs of energy efficiency contribute through the developing of technologies and more efficient equipment that also influence the energy fare price in creating the possibility to cheapen, for example, the prices of components and equipment to electricity generation, that before were considered of a higher cost.

The indicators that compose the Energy access dimension are also related. The job creation in the energy sector can be the result of investments and incentives to the insertion of less environmental impact sources, that materializes in new enterprises and new jobs. As the new job offers appear, the bigger is the impact in the purchasing power and the development of said regions, so the Job creation indicator has a direct relation with Income generation. This chain of relations results, in the end, in a greater access to energy services, seeing that the increase of purchasing power also increases the use of home appliances and equipment, and in doing so, raising the energy consumption.

The Families with access to electricity indicator also has influence in these indicators, mainly in the population's income increase, because it allows for a greater number of people to use electricity, that in turn influences the consumption of energy. This way, the access to energy and the indicators that are part of this dimension are related to the country's social and economic welfare. They are reflected in ways that contribute to better the quality of life in the society and also in the development of locations.

Final Considerations

From this analysis, the construction of a framework of the four dimensions of energy sustainability was proposed, from the correlation between indicators and dimensions. The construction of this framework was the result of the content analysis, that allowed for the identification of which indicators had a direct, inverse or competing relation with other indicators. So, it was concluded that the dimensions influence each other and that the Political-institutional dimension has an important role, seeing that the actions that are capable of promoting access, diversification and efficiency in the use of energy need an effective articulation between the agents that are part of the electricity sector, that are responsible for the political formulation and energy planning process.

The relations between the indicators show the directing of the Energy policy in Brazil and expose the weaknesses in the measures that need a more thorough care, in the guidance sense the government's efforts and the sector's agents have in searching for a fairer, less pollutant and inclusive energy offering.

This way, the discussion goes back again to the role of the Political-institutional dimension in developing policies focused in the sustainable generation of energy. However, this sustainability should now be limited to the environmental dimension, but be reflected in the social and economic welfare of the country. In other words, the performance of the Energy efficiency, Energy matrix

diversification and Energy access dimensions are dependent on the Political-institutional dimension, although the analysis of the documents and the citation linking to this dimension have not shown any significant results.

The energy sustainability dimensions expose the one-off orientation of the energy policy in Brazil, or even the continuity of policies and programs already being executed. This orientation is important to the sector's planning, looking at the necessity of using the energy resources rationally and the non-waste of effort and of investments that do not have the desired effects.

Other important observation is that the Brazilian energy policy exposed above shows orientations in the way of ongoing actions that bring positive results to the energy sector. Exemplifying, we have the programs of Energy efficiency and Alternate sources incentive, that have shown significant changes in the sector's performance and have contributed to the better use of energy and environment preservation. Moreover, they open the possibility for the energy supply to have a more inclusive and fair character in allowing the sector to be more competitive and efficient, from the matrix' diversification.

One way to better direct those efforts hitherto in force, is to make a regional planning and the process of integrated management of the available energy resources in each region, which would allow for the better use of the investments directed to encourage the installation of energy enterprises, avoiding that resources are wasted, be they energetic or financial. The other important point of the regional projects is the possibility to promote development through each region's potentialities, that being the size of a continent, has many physical and climate characteristics from region to region, so it is required a careful analysis to direct the efforts in energy investments.

That means that programs such as PROINFA may not be adequate to all of the country's regions, that can be observed by the distribution of the many types of energy generation in each region. It is possible do observe that the Northeast is the best region for the program and that regions such as the Midwest, for example, do not benefit in the same way because of the absence of the energy resources covered in the program.

Thus, after considering the size of Brazil, the policy formulation for it to have an "universal" reach is complex, precisely because the necessities of each region are different in energy services terms. Another example to be analyzed is the Light for All Program, that has the objective to universalize the access to energy, still in vigor in the country. Its goal of universal provision did not guarantee that all the Brazilians had access to enegy services, and that happens because the program deals with the different necessities of each region as if they are the same, making it difficult to achieve efficient results, although it has helped increase the number of people that have access to energy since it was implemented.

In the same way, the investment policies also need to be directed to fulfill the specific needs of each region, in other words, to incentive the regional programs. The energy efficiency programs will not achieve effective results if they are not directed to specificities and necessities of each of the country's locations.

In any case, the Brazilian energy policy has advanced to the search for sustainability in the sector and has contributed to the development of the Brazilian society. However, the lack of directing in some actions may make some of the expected results to not be effectively achieved, because all the many energy crisis the country faced, and that will still face, are a reflex of a broad planning that lacks specificity.

The analysis here made from the indicators of energy sustainability is a good starting point for the sector's planning, seeing that it highlights specific conditions that must be considered in the diagnosis of energy sustainability and in the development of more

sustainable energy policies. These indicators are tools that can help the political decision makers to better determine the actions to be implemented in the sector, focusing in the specific necessities that need to be met more urgently.

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