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RESEARCH ARTICLE

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A REPRESENTATION MODEL OF BRAZILIAN ENERGY MATRIX

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ABSTRACT

It's known that resources such as water, sunlight, oil and natural gas are scarce, influencing industrial production and, therefore, determining the desirable economic growth of nations. However, for a sustainable production, it's needed to reoriented energy matrices that do not align with a scenario of global energy crisis and worsening living conditions in some parts of the planet for the fossil fuel emissions. In this sense, the objective of the present study is to propose a model that represents the status of the Brazilian energy matrix, based on the use of quantitative variables proposed by the World Bank, using the PCA analysis methodology (Principal Component Analysis) and the Clusters analysis in the definition of groupings, based in common characteristic present in 266 countries. The main contribution of study is the (model under development), that it can be used as an element of preliminary guidance for public policies in the Brazilian energy sector.

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INTRODUCTION

Given the global panorama of facing challenges, mainly represented by climate change observed worldwide, there is a need to refer actions that can respond to the more rational use of non-renewable natural resources, with the explicit intention of preserving the integrity of human life conditions on the planet, particularly threatened by global warming. Nevertheless, such actions hardly guarantee economic stability to nations, and, therefore, difficulties are created in agendas that define protocols with common interests.Many of the environmental threats arise from the simultaneous use of the means necessary for producing energy from more traditional matrices, more specifically those derived from oil refining and, in some cases, even less intensely today, from the use of coal. With the scarcity of these resources, represented by the ownership of a few nations of their extraction or refining sources, alternatives arise for the use of different energy matrices, representing a large part of government efforts in the world to preserve the stability of their economies in the face of an environment of intensified international competition during the last decades.The context of interaction between energy-producing and consuming agents suggests that there is a regulation by a third agent with a regulatory role in this relationship of interaction or resulting interactions, being concerned here not only the economic stability of a system of supply of productive activity but also a concern for the perpetuation of autonomy in wealth management or under other approaches, which is the guarantee of national sovereignty. In this sense, Barros (2010) highlights the critical importance of the energy sector of any nation to achieve and maintain competitive environmental conditions in the international context. As it is an essential sector to maintain the factors of production or as it constitutes an industry in support of numerous other industrial and service sectors. These concerns have already been highlighted by Ramos, Moreira, and Rosa (1993). They advocate that an energy matrix (EM) should, as much as possible, establish relationships between energy-producing and consuming activities, making it possible to evaluate and reduce direct and indirect pressures that change the composition of final demand exerted on the different energy-producing activities, as well as consider the impact on the prices of non-energy products due to variations in energy prices and, supposedly, provide better conditions of economic stability.Given the above, this study is related to a preliminary attempt to establish future trends in the design of a national energy matrix (EM), depending on the use of renewable and non-renewable sources, with reference to quantitative variables that characterize them.

ENERGY MARKETS

It's Traditionally in Brazil, as in many other economies, the State was responsible for structuring the energy generation sector, a role that, given the abundance of water resources and the significant volume of investments necessary for its implementation, determined the hydroelectric matrix as the main source of energy supply for the industrial sector still in the development process during the 1970s, more commonly known as the “Brazilian miracle”. More recently, still within a vision of maximum use of water resources, the construction of the Porto Primavera and Belo Monte hydroelectric power plants is notable during the 1990s, the latter with the highest generating potential among national hydroelectric plants.Besides the large hydroelectric plants that support a large part of the industrial and domestic sector demand, it is also essential to highlight the vital role of SHPs (Small Hydroelectric Plants), which together end up representing approximately 70% of all installed power production capacity in the country.Despite the exponential growth observed in the power generation capacity of the hydroelectric matrix, Brazil still has the immense potential to develop energy matrices considered renewable and not fully exploited, such as wind, natural gas, photovoltaic, biomass, etc.

However, it should be noted that one of the main problems, as can be seen, does not lie in the generation of energy, but results from the regulation and management of the system, given the limitations resulting from the hydroelectric matrix itself (decrease in reservoir levels, large distances necessary for distribution, high and long-term investments, environmental impacts, and dependence on rainfall volumes observed each year).Just as in the 1800s, the main source of energy was constituted by the burning of traditional biomass (wood, crop residues, or charcoal); it must be thought that the definition of an energy matrix must consider the possibility of exhausting the resources placed in the generation of energy and, therefore, think of improvements resulting from its maximum use or interchangeability from the use of other renewable sources or even concomitant gradual replacement, given the predominance within the Brazilian energy matrix of hydroelectric sources. Without, however, ignoring that these alternatives also go through the full understanding of demand to be suppressed and the existing economic relations between the most different economic agents.Currently, there is a diversity of energy sources derived from oil, hydroelectric, mineral coal, solar, wind, nuclear, and biofuels. These have greater or lesser availability but are present in the most different contexts. However, this reality is relatively new, as shown in Figure 1.

Until the 1800s, the main source of energy was the burning of traditional biomass (wood, crop residues, or charcoal). With the Industrial Revolution, this panorama began to change with the extensive use of coal, after oil and gas. And hydropower only appears around the beginning of the 20th century. Subsequently, around the 1960s, nuclear energy began to occupy its space, and the most modern renewable energies (solar and wind) only figured as an option in the 1980s. Nevertheless, this process of energy transitions is slow given the urgency of how a new energy transition that must occur, from fossil fuels to low-carbon energies, constitutes a new challenge very different from those that have occurred so far (SMIL, 2017). Faced with the global trend, especially by European countries, the search for alternative energy sources that are more economical and less polluting. In Brazil, as Corrêa (2021) points out, the Brazilian electrical system for its stability and decision to continue energy production from the hydroelectric matrix generates restrictions on the diversification of the current energy matrix. Lorenzo (2002) points out that one of the most serious limitations of the national electricity sector was and still is the total absence of long-term strategies.

Environmental issues, better use of hydroelectric resources, excessive emphasis on gas-fired thermoelectric plants that depend on the import of equipment for their maintenance, and the gas itself are also excluded. In Figure 2, one observes no apparent trend in investments in renewable energies from 2005 to 2019. Lorenzo (2002) also describes limited investment possibilities in the electricity sector, highlighting the deterioration of the state structure around the 1980s due to the economic crisis. Faced with the state’s inability to invest, institutional reform was proposed based on a model focused on the private initiative. Despite the consensus regarding the establishment of competition in the wholesale market, free access to transmission, the need to strengthen the independent producer, and the de-verticalization of the sector, there were many divergences during the implementation of the alleged reform.

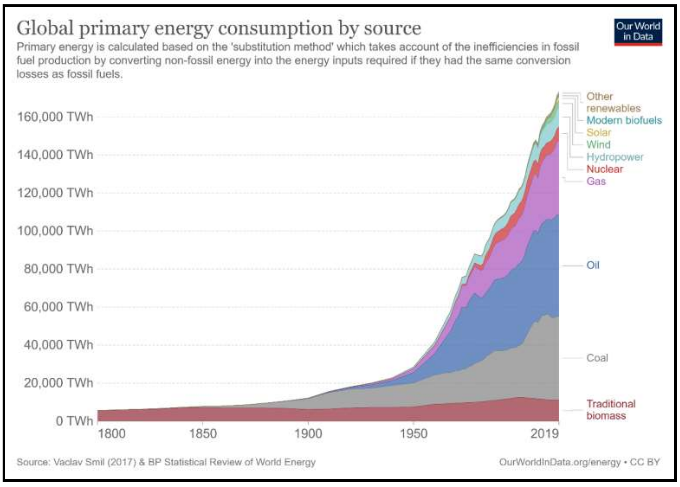

Figure 1. Global consumption of primary energy by source. Adapted from Ritchie and Roser(2020)

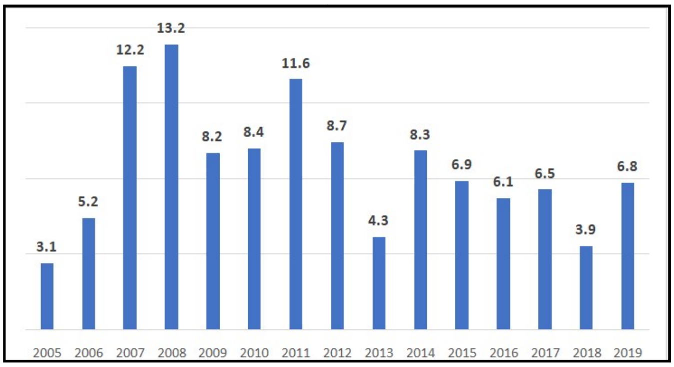

Figure 2. Investments in renewable energy in Brazil (2005/2019) (in billions of US$). Adapted from Corrêa(2021)

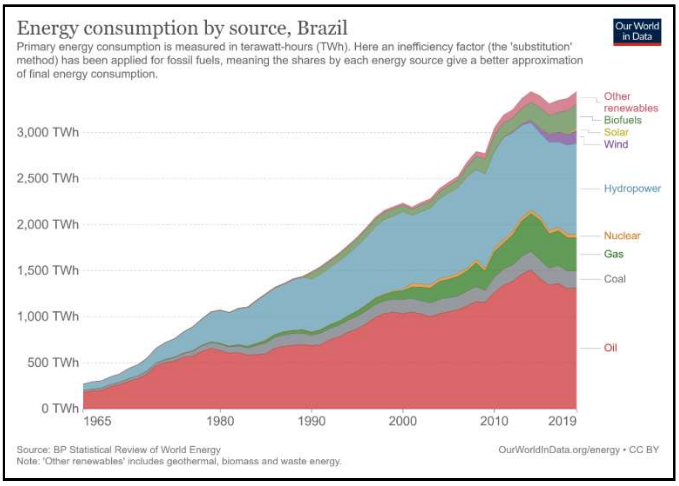

Figure 3. Brazil’s energy consumption by source (1965/2019). Adapted from Ritchie and Roser(2020)

Thus, what was seen was incomplete regulation and not fully implemented.This highlights the lack of clear, objective, and consistent state guidelines over time in order to take advantage of the country’s already privileged position in terms of low-carbon energy sources. However, the reverse path has been observed, as presented in Figure 3. In other words, the country has increased its share of non-renewable sources. According to data from the Energy Research Company – ERC (2021), the Brazilian energy market in 2020 had the hydraulic source responsible for 63,8% of the electricity generated in the country.

Chart 1. Variables initially selected for the proposed model. Prepared by the authors adapted from The World Bank (2020)

No.	Code	Variable	Description
1	ANE	Alternative and nuclear energy (% of total energy use)	Clean energy is non-carbohydrate energy that does not produce carbon dioxide when generated. It includes hydroelectric and nuclear, geothermal, and solar energy, among others.
2	APD	Average precipitation in depth (mm per year)	It is the long-term average in depth (over space and time) of the annual rainfall in the country. It is defined as any type of water that falls from the clouds as a liquid or solid.
3	ATE	Access to electricity (% of population)	It is the percentage of the population with access to electricity. Electrification data are collected from industry, national surveys, and international sources.
4	CPI	Consumer price index (2010 = 100)	The consumer price index reflects changes in the average cost to the consumer of purchasing a basket of goods and services that can be fixed or changed at specified intervals, such as annually. The Laspeyres formula is generally used. Data are period averages.
5	EIN	Energy imports, net (% of energy use)	Net energy imports are estimated as energy use minus production, both measured in oil equivalents. A negative value indicates that the country is a net exporter. Energy use refers to the use of primary energy before transforming to other end-use fuels, which equals indigenous production plus imports and inventory changes, minus exports, and fuels supplied to ships and aircraft engaged in international transport.
6	EPC	Electric power consumption (kWh per capita)	Electricity consumption measures the production of power plants and combined heat and power plants minus transmission, distribution, and transformation losses and own use by heat and power plants.
7	EPFNS	Electricity production from nuclear sources (% of total)	Electricity sources refer to the inputs used to generate electricity. Nuclear energy refers to electricity produced by nuclear power plants.
8	EPFO GCS	Electricity production from oil, gas, and coal sources (% of total)	It refers to the inputs used to generate electricity. Oil refers to crude oil and petroleum derivatives. Gas refers to natural gas but excludes natural gas liquids. Coal refers to all coal and brown, both primary (including hard coal and lignite) and derived fuels (including patented fuel, coke-oven coke, gas coke, coke-oven gas, and blast furnace gas). Peat is also included in this category.
9	EPFOS	Electricity production from oil sources (% of total)	Electricity sources refer to the inputs used to generate electricity. Oil refers to crude oil and petroleum derivatives.
10	EPFRS	Electricity production from renewable sources, excluding hydroelectric (kWh)	Electricity production from renewable sources, excluding hydroelectric power, includes geothermal, solar, tidal, wind, biomass, and biofuels.
11	EPTDL	Electric power transmission and distribution losses (% of output)	They are losses in the transmission and distribution of electricity in the transmission between sources of supply and distribution points and in the distribution to consumers, including theft.
12	EU	Energy use (kg of oil equivalent per capita)	Energy use refers to primary energy before transforming to other end-use fuels, which equals internal production plus imports and inventory changes, minus exports, and fuels supplied to ships and aircraft engaged in international transport.
13	FFEC	Fossil fuel energy consumption (% of total)	Fossil fuel comprises coal, oil, petroleum, and natural gas products.
14	ICP	Inflation, consumer prices (annual %)	As measured by the consumer price index, inflation reflects the annual percentage change in the average cost to the consumer of purchasing a basket of goods and services that can be fixed or changed at specified intervals, such as annually. The Laspeyres formula is generally used.
15	IEWPP	Investment in energy with private participation (current US$)	It refers to commitments to energy infrastructure projects (electricity and natural gas: generation, transmission, and distribution) that have reached financial closure and serve directly or indirectly to the public. Mobile assets and small projects such as windmills are excluded. The types of projects included are management and lease contracts, operations and management contracts with large capital expenditures, greenfield projects (in which a private entity or a public-private joint venture builds and operates a new facility), and divestments. Investment commitments are the sum of investments in facilities and investments in government assets. Investments in facilities are the resources that the project company undertakes to invest during the contract period, either in new facilities or the expansion and modernization of existing facilities. Investments in government assets are the resources that the project company spends on acquiring government assets, such as state-owned companies, rights to provide services in a specific area, or the use of specific radio spectra. The data are presented based on the year of investment. The data is in current US dollars.
16	MEES	Methane emissions in energy sector (thousand metric tons of CO2 equivalent)	Methane emissions from energy processes are emissions from the production, handling, transmission, and combustion of fossil fuels and biofuels.
17	REC	Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.
18	RIFRT	Renewable internal freshwater resources, total (billion cubic meters)	Renewable internal flows of freshwater resources refer to the country's renewable internal resources (internal flows of rivers and groundwater from rainfall).

And photovoltaic energy corresponds to only 1,7% of the total And photovoltaic energy corresponds to only 1,7% of the total generated in the country, expanding worldwide, despite the increase of 61,1% verified in its generation from 2019 to 2020.Calabria and Saraiva (2015) characterized the Brazilian transmission system as interconnected continental with a total installed production capacity of 135 GW (70% from hydroelectric plants). Nonetheless, this system has evolved from vertically integrated systems to more decentralized structures, contributing to fairer competitiveness in the sector. Consequently, it migrated from a strongly regulated system at all levels (generation, transmission, and distribution) to a system still regulated in the fields of transmission and distribution (natural monopolies), and generation and commercialization inserted in a more competitive market. In the field of commercialization, the existing competition depends on the environment where the contracts for the purchase and sale of energy are signed. After some reforms were established: the Regulated Contracting Environment (ACR), in which companies compete through auctions; and the Free Contracting Environment (ACL), in which contracts are freely negotiated between agents (CAMPAGNANI, 2021).

Economic Development Agents: Campos (2016) states that economic theory has rescued the importance of institutions since the economy of institutions and transaction costs have been applied to several areas in the economy. Due to this interest in institutions, the economy has approached other social sciences. This is because it is known that development is more than a process of capital accumulation, that is, it is about changes in the organizations, the culture, and the rules that regulate markets (EVANS, 2005). For North (1991), institutions represent formal and informal restrictions, which aim to structure their social, economic, and political interaction. Two other relevant concepts are the institutional environment and institutional arrangement. The institutional environment is formed by the set of fundamental rules (political, social, and legal nature) that establish the basis for production, exchange, and distribution. On the other hand, an institutional arrangement occurs between economic units, which governs how these units can cooperate and/or compete. Thus, institutional arrangements define how an economic system coordinates a specific set of economic activities in each context (FIANI, 2016; BARROS, 2010). Given these concepts, Ferreira and Salles (2017) emphasize that the state-regulatory environment in Brazil needs to advance beyond projects (in short-term horizons). It needs to establish long-term guidelines and mechanisms to achieve economic, social, and environmental development. In other words, it is necessary to overcome the lack of a "planning culture" and transpose an economic structure, shaping institutions capable of integrating the environmental dimension that equally favors the country's socioeconomic development.A trend that has brought about profound changes in institutions and society is advances in the context of information and communication technologies (ICTs). Businesses, governments, and private-public institutions, faced with the abundance of data and its exponential growth, have aroused a growing interest in developing capacities and methods of extracting knowledge from the data to obtain organizational intelligence or, within the public context, the provision of service to society in a more effective and capillarized way (PROVOST; FAWCETT, 2013). This is because the social trend of openness and sharing are forces of power that are changing the economy and global society (JETZEK; AVITAL; BJORN-ANDERSEN, 2014).

Conditions of an Energy Matrix: It is observed that Brazil has an energy matrix primarily dependent on hydroelectric generation within a sector that is composed of public and private companies and, to a certain extent, characterized as an oligopoly (imperfect market) since there are a small number of companies whose products are differentiable by the price and quantities produced as occurs in the air and road transport sectors, for example (SAUAIA; KALLÁS, 2007). Faced with this difficult and challenging scenario, the country needs to define long-term policies in which the planning and effective construction of an energy matrix contemplate the use of energy (renewable and non-renewable) and strategic potentials at its disposal. For this, it is fundamental to consider variables that naturally condition the energy generation process, considering the economic and energy crisis that the country and other nations go through. To define a more feasible scenario for better use of its resources and considering global trends, a more competitive development model is needed, assuming more economic stability and perpetuating the concern with redesigning the energy matrix. Thus, through secondary data, this study aims to map scenarios that characterize energy production in the world and determine how Brazil positions in this context, thus providing some elementary assumptions of an evolutionary understanding of energy production conditions in the country.In this sense, the study uses an explanatory character as to its objectives, a quantitative approach, and being a documentary study, it is based on the New Institutional Theory from a theoretical point of view Methodological ProceduresFaced with a complex and dynamic panorama and, therefore, adaptations that cross almost all institutional environments, the apparent success of the planning activity needs to contemplate the use of useful and available information, combining the application of techniques that contain a quantitative approach and aided by conceptual structures to enable more qualified interpretations. Provost and Fawcett (2013) state that understanding this process and its stages makes it more systematic and, consequently, less subject to errors and inconsistencies. In this sense, two techniques for effectively analyzing the data are explained: principal component analysis (PCA) and cluster analysis.

The Model Development: Data are collected directly from the World Bank website (2020) in the indicators section (Chart 1). Subsequently, these data are open in the computer environment R and exploratory data analysis and normalization were conducted.The principal component analysis (PCA) conduct to find which variables are most relevant in the context studied and thus simplify the proposed analyses.With the most significant variables, the cluster analysis conducted using the K-means method (unsupervised machine learning algorithm that aims to group the data through similarities between groups). Thus, no previous labels or classifications will be provided for the algorithm, the algorithm searches for patterns in the data set previously presented (JAIN, 2010; KASSAMBARA, 2017), according to the flow shows in Figure 4.

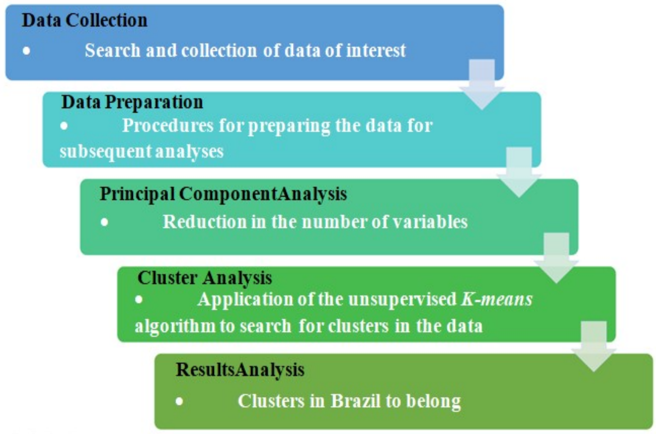

Figure 4. Sequence of activities of Model Development. Prepared by the authors

CONCLUSIONS

The State has assumed an essential role in the direction of the energy sector in Brazil and, within this context, has been establishing guidelines for the management of the supply of energy necessary to foster economic and social development, as well as serving as an agent of intermediation of conflicts of interest among other economic agents. More recently, concern about environmental impacts related to energy matrix choices is a recurring concern of most nations, notably concerning gas emissions and their effects on recently observed climate change. Therefore, the reiterated need for the regulatory action that the State is usually expected to take and, in parallel, as well as the definition of policies specifically aimed at ensuring economic sustainability and national autonomy in the production of wealth is emphasized, assuming previous evidence-based planning.The importance of the development of mapping the conditions of the national energy matrix, taking as reference its position in relation to other nations, provides a preliminary situational panorama of situational understanding over time, considering outcome variables. Nevertheless, it offers insights into the potential definition of the Brazilian energy matrix, that is strategic for maintaining levels of international competitiveness, national security, and the preservation of non-renewable natural resources.

REFERENCES

BARROS, Evandro Vieira de. A Matriz Energética Mundial e a Competitividade das Nações: Bases de uma Nova Geopolítica. Engevista, v. 9, n. 1, 2 fev. 2010. DOI 10.22409/engevista.v9i1.183. Available in: http://periodicos.uff.br/engevista/article/view/8802. Access in:22 dez. 2021.

CALABRIA, Felipe A.; SARAIVA, J. Tomé. Brazilian electricity market: Problems, dilemmas and a new market design aiming to enhance flexibility while ensuring the same level of efficiency and security of supply. *Revista Econômica*, v. 16, n. 2, 8 set. 2015. DOI 10.22409/economica.16i2.p232. Available in:

http://www.revistaeconomica.uff.br/index.php/revistaeconomica/article/view/232. Access in: 31 out. 2021.

CAMPAGNANI, Matheus Carneiro. Análise da Expansão do Mercado Livre de Energia no Brasil Incluindo Mercado Varejista. 2021. 86 f. Monograph (Universidade Federal do Rio de Janeiro - Graduate Degree) , Rio de Janeiro, 2021.

CAMPOS, Marcelo Mallet Siqueira. O Processo de Desenvolvimento Econômico a Partir de Uma Perspectiva Institucionalista: Elementos de Uma Abordagem Heterodoxa. 2016. 335 f. Thesis (Universidade Federal do Rio Grande do Sul - Doctoral Degree, Porto Alegre, 2016. Available in: https://www.lume.ufrgs.br/handle/10183/147358.

CORRÊA, Lucas. Transição energética, políticas de inovação e desenvolvimento econômico. 2021. 173 f. Dissertation (Universidade Federal de Santa Catarina, Master Degree, 2021. Available in: https://repositorio.ufsc.br/handle/123456789/227274.

EMPRESA DE PESQUISA ENERGÉTICA. Anuário Estatístico de Energia Elétrica. Brasília: Empresa de Pesquisa Energética, 2021. Disponível em: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/anuario-estatistico-de-energia-eletrica. Access in: 10 dez. 2021.

EVANS, Peter. The Challenges of the "Institutional Turn": New Interdisciplinary Opportunities in Development Theory. *In*: NEE, Victor; SWEDBERG, Richard (orgs.). The Economic Sociology of Capitalism. [*S. l.*]: Princeton University Press, 2005. p. 90–116. DOI 10.1515/9780691217932-008. Disponível em: https://www.degruyter.com/document/doi/10.1515/9780691217932-008/html. Access in: 22 jan. 2022.

FERREIRA, Marcus Bruno Malaquias; SALLES, Alexandre Ottoni Teatini. Política Ambiental Brasileira: Análise Histórico-Institucionalista das Principais Abordagens Estratégicas. Revista de Economia, v. 42, n. 2, 26 jul. 2017. DOI 10.5380/re.v42i2.54001. Available in: https://revistas.ufpr.br/economia/article/view/54001. Access in: 22 jan. 2022.

FIANI, Ronaldo. Crescimento econômico e liberdades: a economia política de Douglass North. *Economia e Sociedade*, v. 11, n. 1, p. 18, 2016.

JAIN, Anil K. Data clustering: 50 years beyond K-means. Pattern Recognition Letters, v. 31, n. 8, p. 651–666, jun. 2010. https://doi.org/10.1016/j.patrec.2009.09.011.

JETZEK, Thorhildur; AVITAL, Michel; BJORN-ANDERSEN, Niels. Data-Driven Innovation through Open Government Data. *Journal of theoretical and applied electronic commerce research,* v. 9, n. 2, p. 15–16, ago. 2014. https://doi.org/10.4067/S0718-18762014000200008.

KASSAMBARA, Alboukadel. Practical Guide to Cluster Analysis in R: Unsupervised Machine Learning. 1. ed. [*S. l.*]: STHDA, 2017. v. I, (Multivariateanalysis).

LORENZO, Helena Carvalho de. O Setor Elétrico Brasileiro: Passado e Futuro. Perspectivas, v. 24–25, p. 147–170, 2002.

NORTH, Douglass C. Institutions. *Journal of Economic Perspectives,* v. 5, n. 1, p. 97–112, 1 fev. 1991. https://doi.org/10.1257/jep.5.1.97.

PROVOST, Foster; FAWCETT, Tom. Data Science and its Relationship to Big Data and Data-Driven Decision Making. Big Data, v. 1, n. 1, p. 51–59, mar. 2013. https://doi.org/10.1089/big.2013.1508.

RAMOS, Roberto Luís Olinto; MOREIRA, Ajax R B; ROSA, Marco Antonio. Construção de Uma Matriz Energética para o Brasil. Textos para Discussão, n. 315, p. 84, 1993.

RITCHIE, Hannah; ROSER, Max. Energy Mix. 2020. Our World in Data. Available in: https://ourworldindata.org/energy. Accessin: 10 dez. 2021.

SAUAIA, Antonio Carlos Aidar; KALLÁS, David. O dilema cooperação-competição em mercados concorrenciais: o conflito do oligopólio tratado em um jogo de empresas. *Revista de Administração Contemporânea,* v. 11, n. spe1, p. 77–101, 2007. https://doi.org/10.1590/S1415-65552007000500005.

SMIL, Vaclav. Energy and Civilization: A History. Cambridge, Massachusetts: The MIT Press, 2017.

THE WORLD BANK. The World Bank | Data. 2020. Indicators. [Institucional]. Available in: https://data.worldbank.org/ indicator. Access in: 15 out. 2021.

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