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STUDY OF THE INTRINSICAL ENERGETIC SUSTAINABILITY OF NATIONAL STRATEGIC PLANS FOR THE ELECTRIC SECTOR

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Abstract:The objective of the work is to analyze comprehensively the national energy plans in evidence of the electric sector considering the complete costs in such a way that they demonstrate the address for the sustainable development. For this, a multicriteria analysis is developed incorporating the representative dimensions of development and socioeconomic activity as support for a complete energy assessment. It assumes the stratification of selected countries in groups, according to the Gross Domestic Product (GDP) per inhabitant for a complete evaluation within the dimensions of development. The methodological tool of the Integrated Planning of Energy Resources - PIR is applied, defined through the environmental, political, social and technical-economic dimensions, inquiring this way the conditions of the country for the applicability of a planning based on the sustainable development in these four dimensions. The results indicate that, individually, the countries have an official energy planning sometimes within the specific indicators of real sustainable development at the time of the study and this difference points to a potential applicability of a planning that seeks the satisfaction of needs and well-being in synergy with the other dimensions. However, it appears that in the preferential plans of almost all countries there is an aggressive prioritization of the technical-economic aspect. When countries are segregated into groups by GDP per capita, this difference becomes more evident. Despite this, the results indicate that the countries have real conditions to conduct a PIR, at the minimum complete costs in the dimensions considered, in actions consistent with sustainable development.

Keywords: Energy Planning, Electric Sector, PIR, Sustainable Development, Energy.

INTRODUCTION

Historically, strategic planning related to electric energy systems is elaborated with a view primarily to the cost-benefit ratio, relegating the environmental, political and social dimensions to the background, even if these are directly affected by the sector (UDAETA, 1997). Projections show that, in 2050, electricity consumption will grow by 36% in a benchmark scenario, and could reach up to 83% in a scenario of economic growth, both in relation to consumption in 2020 (EIA, 2021). This prognosis points to an enormous growth in impacts, both economic and environmental, social and political, arising from the exploration and use of fuels. In this study, the Integrated Planning of Energy Resources (UDAETA, 2012) and (MARUYAMA, et al, 2018) are used as an analysis tool, of preferential national strategic plans of the electricity sector, and of the economic, environmental, political and social situation, the basic dimensions of sustainable planning, from a heterogeneous sample of countries with different environmental, economic and social realities. Prospecting for supply alternatives for the growing increase in electricity consumption are part of countries' development expansion plans, being their long-term planning instruments, with technology guidelines and energy policies to be applied throughout the planning period called Electric Sector Preferred Plans. Through the preferential plans, it is possible to visualize the transformation of the electricity sector in the medium and long term, the consistency of plans, goals and objectives in meeting consumption and sustainability considerations in its development. The countries selected in this work are part of different social, environmental, political and economic realities and, despite the sample of countries being small, they form a very heterogeneous and comprehensive group. This way, the implications arising from the evaluation developed aim to provide an overview with information on the situation of electrical planning in the world, through the groups of countries evaluated, in the broad context of development, contemplating the environmental, political, social and technical-economic.

PROCEDURE FOR COMPARATIVE ANALYSIS OF ENERGY SYSTEMS

COUNTRY SAMPLING AND STRATIFICATION INTO GROUPS

The countries selected for the study are: Germany, Argentina, Australia, Bolivia, South Korea, Ecuador, Spain, United States, Israel, Japan, Mexico, Mozambique, Paraguay and Venezuela. The objective is to select a heterogeneous sample of the general characteristics of these countries.

In this methodology, of analysis of preferential plans of the electric sector of groupings of countries, three groups are formed, A, B and C. The criterion for the segregation of the groups is the descending order of GDP per capita. It is then defined: Group A: Australia, United States, Japan, Germany and Israel; Group B: Spain, South Korea, Venezuela and Argentina; Group C: Mexico, Ecuador, Paraguay, Bolivia and Mozambique. GDP per capita is considered because it is a relative parameter that reflects the economic situation of countries more accurately than GDP alone. Additionally, the lack of economic flexibility is reflected in the low GDP per capita, and it is a factor that practically makes planning along the lines of the PIR unfeasible, given that such planning generally demands high initial investments in all the methodological dimensions of an integrated planning, both in mitigating environmental and social damages and in

technological investment, among others. (RTC/PIRnaUSP 455, 2014).

MULTI-CRITERIA CRITERIA FOR EVALUATING COUNTRIES

The analyzes of the preferential plans proceed in two ways: Institutional and Non-Institutional analyses. Institutional analysis studies and evaluates the adherence of the institutional energy planning of the electricity sector in a given country to the methodological criteria that underlie the PIR. The Non-Institutional analysis investigates the effective degree to which the country assumes sustainable development as a goal, if it has the conditions or is prepared for the real application of the PIR with more or less difficulty, according to the methodology established in UDAETA, 2012. These two aspects demonstrate whether in the analyzed country, strategic planning is already applied aimed at sustainable development in the global context and the country's real capacity to carry out planning along these lines.

INSTITUTIONAL EVALUATION CRITERIA

The institutional analysis followed a research hierarchy with priority given to official sources, such as those published by the ministries of mines and energy or equivalent. The second position in the hierarchy is for renowned academic and/or research entities. In addition to the hierarchy of sources, a hierarchy of information regarding the quality of the available documentation was established. The first position belongs to the official energy plans of the electricity sector. The second position pertains to a country's overall energy development plans. The next position is occupied by operational plans, such as short-term plans. Still, the next position pertains to development guides and energy laws. The national energy plans have as analysis reference the methodology developed in MARUYAMA (2013) which consists of valuing the data according to the PIR criteria (UDAETA, 2012). The selected indicators, for each dimension, are based on the degree of relevance of the evaluation objective, which can be evidenced in Table 1, below:

The valuation criteria are presented in Table 2:

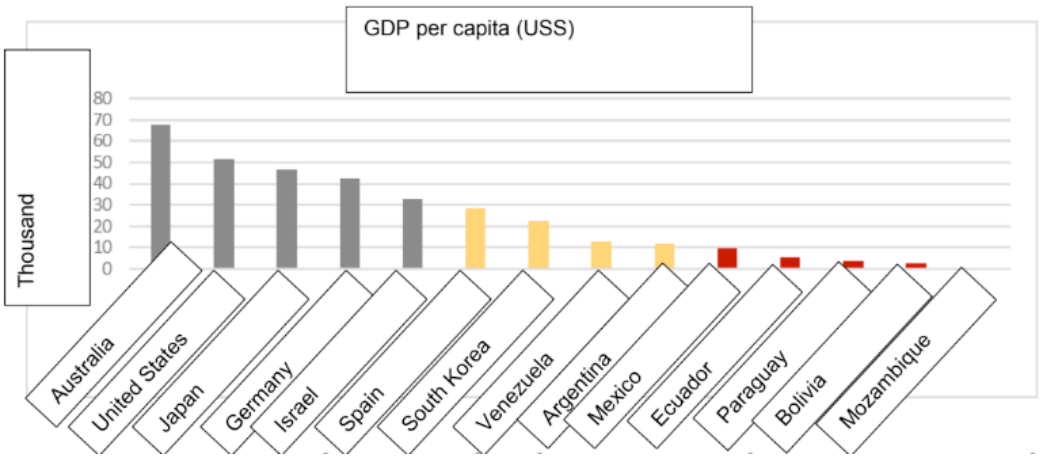
CRITERIA FOR NON-INSTITUTIONAL EVALUATION

The survey and qualification of Non-Institutional information, unlike Institutional data, has a wider and more diversified range of sources in different media. The main sources are based on the approval of recognized international bodies and listings, in addition to information made available by governments when necessary. The treatment and systematization of the collected data lead to the systemic and analytical fulfillment of criteria, which contain the possibility of a qualitative-quantitative valuation, taken to simple scalar notation, as shown in Table 3.

For the non-institutional analysis, data with the indicators in table 3 are evaluated. For valuation purposes, the country that obtained the best performance for a given criterion, when this criterion is comparative, receives numerical valuation 2, and the others receive valuation respectively proportionally.

PERFORMANCE OF THE NATIONS IN THE DIMENSIONS OF ANALYSIS

The analysis is carried out by comparing the results in each dimension represented by graphs in the strands: Institutional and Non-Institutional. It is noteworthy that, among the groups, the absolute numerical value is not relevant, but the relative values.



Dimension	Criterion	Indicator	Valuation
Environmental	1	Consideration of impacts on the air environment of planned resources	0 to 2
	2	Consideration of impacts on the aquatic environment of planned resources	0 to 2
	3	Consideration of impacts on the land environment of planned resources	0 to 2
	4	Consideration of impacts on biodiversity in the region due to planned resources	0 to 2
	5	Analysis and restriction of energy resources aiming at sustainability	0 to 2
Policy	6	Consideration of political support in energy planning: legal aspects, policy instruments	0 to 2
	7	Consideration of the combination of interests between the Involved and Stakeholders	0 to 2
	8	Consideration of the degree of acceptance of energy resources by the Involved and Stakeholders	0 to 2
	9	Consideration of the level of motivation of the Involved and Interested agents	0 to 2
	10	Consideration of Possession, Ownership and Energetic Integration of Resources	0 to 2
Social	11	Consideration of the resource in the environmental imbalance in the social environment	0 to 2
	12	Consideration of the influence of energy resources on improving social indicators	0 to 2
	13	Consideration of the resource in the generation of direct jobs and in quality and safety	0 to 2
	14	Consideration of the impact of spatial occupation of projects	0 to 2
	15	Consideration in changing the perception of comfort: Olfactory, Sound, Thermal or Visual	0 to 2
Technical-Economic	16	Consideration of Reliability and Intermittency of Energy Resources	0 to 2
	17	Consideration of the cost of generation, implementation, O&M, IRR, NPV and Useful Life	0 to 2
	18	Consideration of the technological domain of resources: Design, Logistics, Technology and Equipment	0 to 2
	19	Consideration of the technical ease of deploying resources	0 to 2
	20	Consideration in the power quality of energy resources	0 to 2

Table 1 - Institutional criteria valuation structure

Consideration of preferred plans	Valuation
It is not considered in the elaboration of the preferential plan	0,0
The subject is discussed in the preferential plan	0,5
A specific study in the preferred plan is recommended	1,0
It is analyzed for the preferred plan in question	1,5
It is considered in the elaboration of the preferential plan	2,0

Table 2 - Preferred plan evaluation factors

Dimension	Criterion	Indicator	Value
Environ-mental	1	Signatory or not of the Kyoto Protocol	0 to 2
	2	Existence of a ministry dedicated to the environment	0 to 2
	3	Consideration of the percentage of electricity from renewable sources	0 to 2
	4	CO2 emissions from per capita energy consumption	0 to 2
	5	Consideration of the percentage of installed capacity from renewable sources	0 to 2
Policy	6	Consideration of the existence of electricity trade with other countries	0 to 2
	7	Existence of a regulatory body for electricity in the country	0 to 2
	8	Existence of one or more governing laws of the electrical system	0 to 2
	9	Existence of mention to energy planning in the constitution	0 to 2
	10	Consideration of membership in international associations	0 to 2
Social	11	HDI consideration	0 to 2
	12	Consideration of the percentage of homes/families/people without access to electricity	0 to 2
	13	Consideration of the country's unemployment rate	0 to 2
	14	Consideration of participation in the WTO	0 to 2
	15	Consideration of the percentage of urbanization in the country	0 to 2
Technical Economic	16	Consideration of the country's GDP per capita	0 to 2
	17	External debt consideration	0 to 2
	18	Consideration of per capita energy production	0 to 2
	19	Existence of a ministry dedicated to research and development (or other ministries that, combined, exercise this function)	0 to 2
	20	Inflation rate consideration	0 to 2

Table 3 - Non-institutional criterion valuation structure

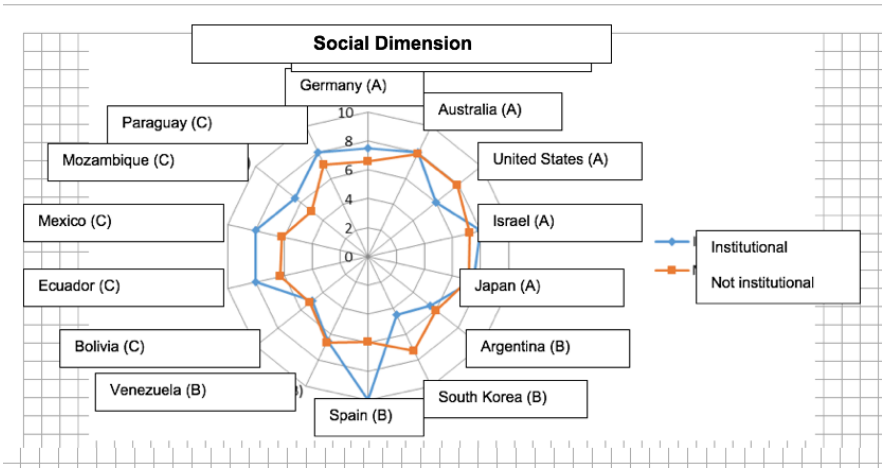


FIGURE 2 – Analysis of countries in the Environmental dimension

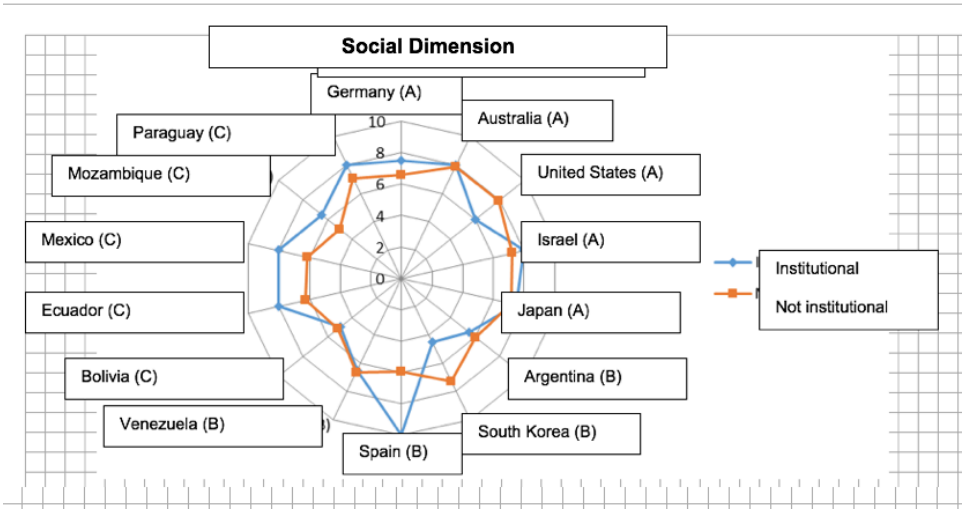


FIGURE 4 – Analysis of groups in the Political dimension

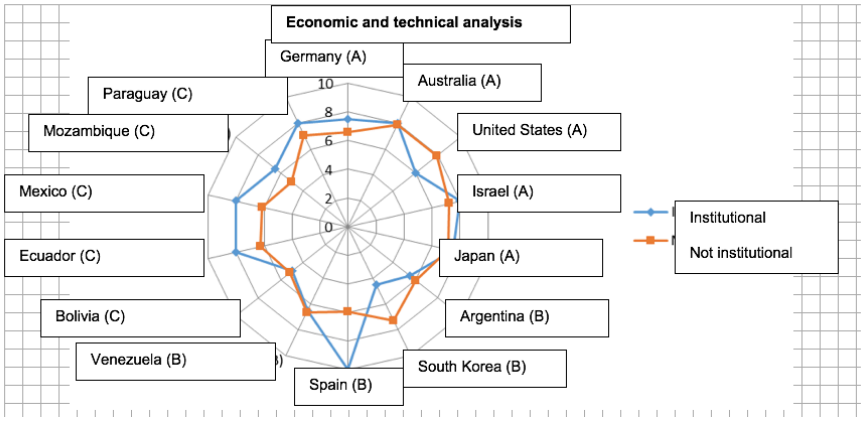


FIGURE 6 – Analysis of groups in the Social dimension

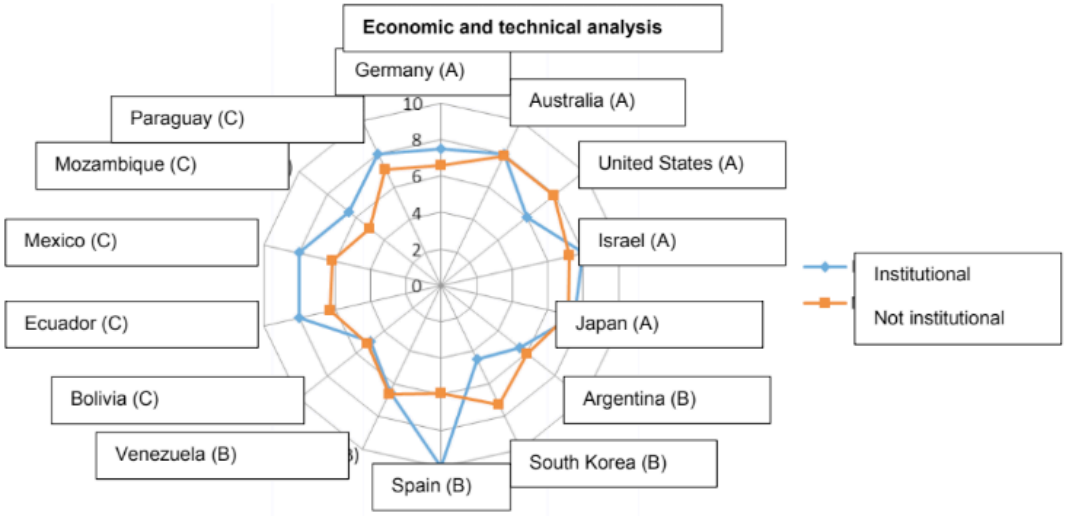


FIGURE 8 – Analysis of countries in the Technical-Economic dimension

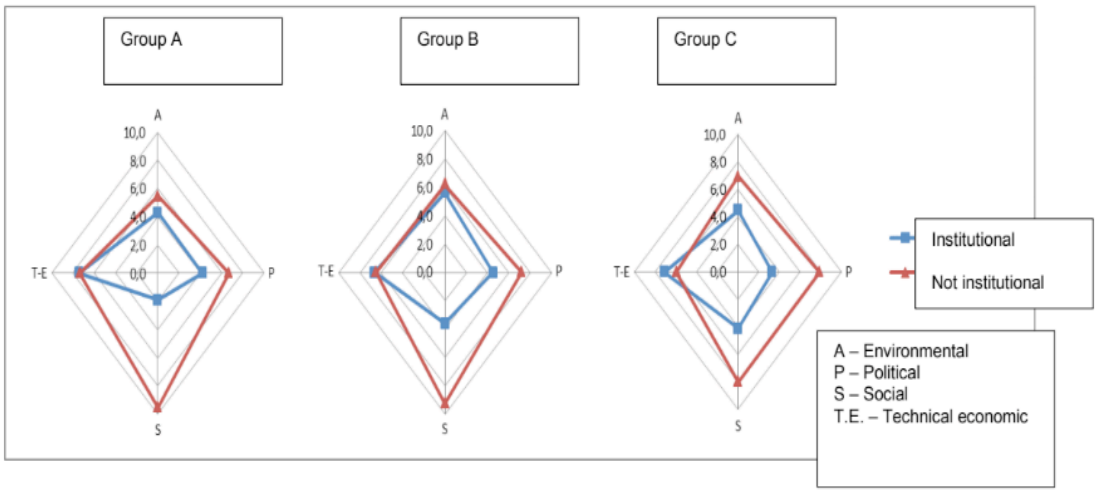


Figure 9 - Worldwide Institutional and Non-Institutional Merit Analysis

ENVIRONMENTAL DIMENSION

There is a diversity of values obtained in the Institutional criteria of the countries, corresponding to preferential plans with different environmental approaches. In the Non-Institutional analysis, the values were very similar to each other, with the exception of Mozambique and Paraguay.

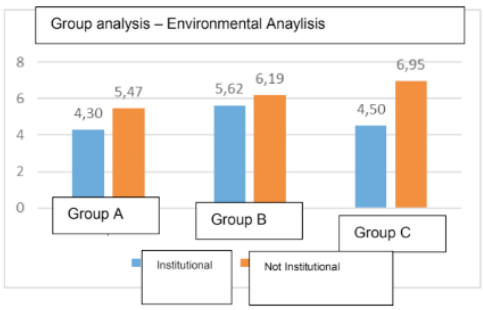


FIGURE 1 – Analysis of groups in the Environmental dimension

It is noted in the diagram, Figure 2, that in the analysis of importance in the Institutional criterion in groups B and C there are great variations.

The Non-Institutional importance given to the environmental dimension by the countries comprising group A and B is quite similar and the average value is practically equal to the world average value. However, the valuation distributions in the non-institutional analysis of Mozambique and Paraguay extrapolate the average due to the percentage of installed capacity from renewable sources, such as hydroelectric plants. In addition, the three countries that obtained the highest values in the institutional criterion, Argentina, Spain and Ecuador, exceeded the average values of the non-institutional criteria in this same dimension. The complementary relationship between Institutional and Non-Institutional valuation is perceived in several of the analyzed countries, but more strongly in the countries: Venezuela, Japan, Mozambique, Paraguay and Argentina, a fact that indicates planning, in the environmental issue, directed to sustainable development and, therefore, in synergy with the PIR guidelines.

POLITICAL DIMENSION

The graphical representation of the results of the analyzes referring to the political dimension can be found in Figures 3 and 4.

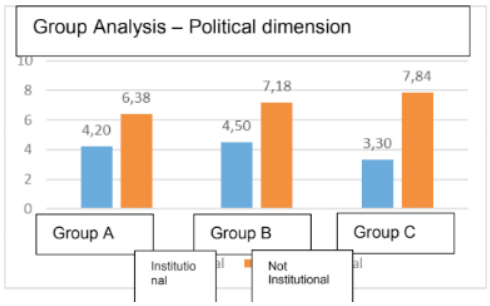


FIGURE 3 – Analysis of groups in the Political dimension

The results of group A have the lowest Non-Institutional valuation, while group C has the highest valuation. This mainly reflects the interventionist power of the State in these countries. The governments of group A countries tend to have smaller states and less influential policies with regard to the electricity-energy sector, a situation opposite to what occurs in group C countries.

It is observed that, in order to maintain these policies, it is necessary, in countries such as those in group A, to establish basic guidelines to be followed by actors independent of the State, the opposite of what occurs in countries such as those in group C, where the establishment of guidelines is not necessary in the Strategic Planning itself, due to the intervention power of the State. Complementarity is demonstrated in all groups in the political dimension, demonstrating planning aimed at sustainable development.

SOCIAL DIMENSION

The graphical representation of the results

referring to the social dimension can be found in Figures 5 and 6. The countries allocated in groups A and B presented very similar and low values for the social dimension in the Institutional analysis.

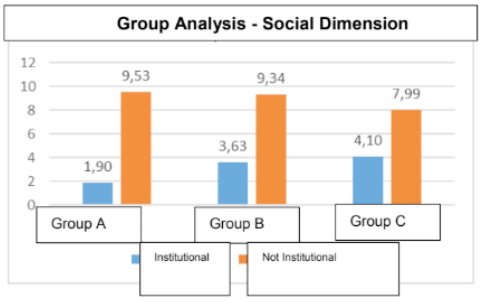


FIGURE 5 – Analysis of groups in the Social dimension

In general, the plans that are reflected in the Institutional analysis, little consider the social scope, the exceptions being Argentina and mainly Ecuador that present comprehensive and detailed considerations of the social dimension in their plans for the electric sector.

However, almost all the analyzed countries consider, through the Non-Institutional analysis, the Preferred Plans as a strong vector of considerations and actions in this social dimension.

TECHNICAL-ECONOMIC DIMENSION

The graphic representation of the analyzes of the technical-economic dimension is shown in Figures 7 and 8.

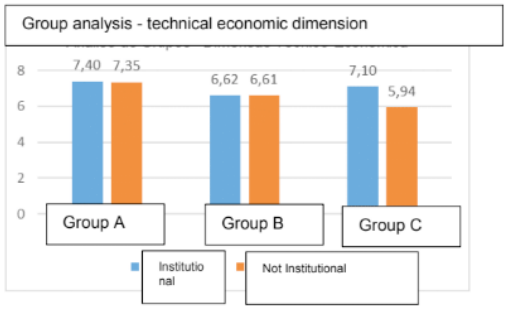


FIGURE 7 – Analysis of groups in the Technical-Economic dimension

Group A presents the highest non-institutional technical-economic indicators and group C the lowest. Still, in groups B and C there is an indicative complementarity of planning directed to sustainable development.

However, emphasis is placed on the technical-economic criterion in institutional planning in most countries, especially in countries belonging to group A, which demonstrates a strong break with the foundations of energy planning aimed at sustainable development. Still, given the more stable economic situation of these countries, there is applicability for the RIP. In relation to complementarity in most of the countries that make up groups B and C, it demonstrates a broader application of the PIR guidelines in these countries.

SYSTEMATIZATION AND DIAGNOSIS WITHIN DEVELOPMENT DIMENSIONS

The merit analyzes in figure 9 present the summary of the worldwide analysis. They show the average values of the analyzes of all dimensions for the three groups of countries.

The three groups emphasize the technical-economic aspect when considering the Institutional analysis, especially in countries in group A and C. Despite being a characteristic of traditional resource planning, the strong technical-economic aspect can be seen as a characteristic of RIP in countries belonging to group B and C.

Institutionally, in most countries, great focus is given to the environmental aspect, although less than to the technical-economic aspect, which, by itself, already indicates planning directed towards sustainable development. Due to the consumption pattern of group A countries and the need for economic growth of group C countries, the applicability of the PIR is reduced in the environmental issue for countries in these groups.

The social dimension presents complementarity in a more pronounced way. Countries belonging to group A have the highest Non-Institutional values and the lowest Institutional values. Group B had intermediate values and group C had the lowest non-institutional value and a similar value to group B for institutional value. The orientation of energy planning towards sustainable development is notable in all three groups.

Similar to what happens in the social dimension, complementarity is quite pronounced in the political dimension, but there is an inversion of what happens in the social dimension. Countries in group A and B have the highest institutional value and the lowest non-institutional value, and group C has the highest non-institutional value and the lowest institutional value. Again, the applicability of the PIR for the political dimension in the three groups is noted.

CONCLUSION

The results indicate that the three groups of countries analyzed in the sample testify, relatively, to the content of the sustainable development of the electricity sector in the world.

It is observed that energy plans largely reflect the economic and social situation of the country from which they come. In general, countries considered to be developed tend to emphasize environmental and technical-economic aspects in their plans, while emerging countries tend to prioritize environmental, technical-economic and social aspects. Thus, for example, a comparison between Germany and Ecuador, in Germany the social dimension is practically not mentioned, and the environmental one, treated in general (however, not with neglect). In Ecuador, social matters were given the greatest importance, demonstrating an active State concerned with the well-being of society, a policy strongly adopted in South American countries. In any case, it must be noted that a developed country has social content already embedded in everyday life, while a developing country really needs to dedicate itself to this aspect by definition of the development of a modern state.

In this sense, it is observed on a world scale, the great effort for the technical, economic and environmental evolution, but in much smaller order for the social and political requirements. Since the strong presence of the environmental parameter already demonstrates the greatest concern with integrated planning (although not in accordance with the PIR), but which leads to the breakdown of the traditional model of energy planning.

These analyzed countries present considerable conditions of sustainable energy planning, that is, they present conditions for the applicability of a methodology that considers the impacts in the diverse dimensions: environmental, social, political and technical-economic, which are the dimensions of support of the integrated planning of energy resources, the RIP. This integrated planning that seeks a minimum complete cost is not related to a single momentary effective cost, as it depends on a series of combinations and decisions. That is, the minimum cost for a company may not be the minimum cost for society, or vice versa. The minimum cost concept will be distributed along the planning horizon, which may cause a momentary minimum cost not necessarily to reflect the lowest absolute cost in the complete process. In this sense, the complete evaluation corresponds to a balanced balance of competing interests, among all those involved and interested in the process, in a long and defined planning horizon.

REFERENCES

EIA. U.S. Energy Information Administration (EIA), **International Energy Outlook (2021)**, https://www.eia.gov/outlooks/ieo/tables_side_pdf.php

MARTINS, F; Felgueiras, C; Smitkova, M; Caetano, N. **Analysis of Fossil Fuel Energy Consumption and Environmental Impacts in European Countries**. Porto, Portugal, 2019; 12(6):964. https://doi.org/10.3390/en12060964

MARUYAMA, F. M. **Arquitetura do Plano Preferencial de Recursos para o setor elétrico no Planejamento Integrado de Recursos Energéticos**. Dissertação de Mestrado. Escola Politécnica da Universidade de São Paulo. São Paulo, SP, 2013.

MARUYAMA, F. M., *et al.* 2018, **Bases for the Preferential Plan from an Integrated Energy Resources Planning.** IOP Conf. Ser.: Earth Environ. Sci. 188 012046

RTC/PIRnaUSP - Nº455. UDAETA, M. E. M. et al. **Avaliação Completa de Planos Preferenciais do Setor Elétrico pelo Mundo dentro da Metodologia do Planejamento Integrado de Recursos Energéticos visando o Desenvolvimento Sustentável**. Relatório Técnico Científico. São Paulo, SP, 2014.

UDAETA, M. E. M. **Novos instrumentos de planejamento energético e o desenvolvimento sustentável - Planejamento Integrado de Recursos energéticos na USP**. Tese de Livre Docência. EPUSP, Universidade de São Paulo, São Paulo, 2012.

UDAETA, M. E. M. **Planejamento Integrado de Recursos Energéticos - PIR para o Setor Elétrico – pensando o desenvolvimento sustentável**. Tese de Doutorado. Escola Politécnica da USP, Universidade de São Paulo, São Paulo, 1997.