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Assessment of environmental sustainability indexes of water supply and sewage treatment companies listed on the BM&FBOVESPA

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Avaliação de variáveis de sustentabilidade ambiental nas empresas de abastecimento de água e saneamento listadas na BM&FBOVESPA

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Abstract: The critical level of the water reservoirs of the Brazilian hydroelectric power plants represents a breach of the first condition of sustainability. The algebraic sum of the volumes of affluence and diffluence shows an unfavorable result of 6418 m^3 of water per second to the national system. In this study, we present an environmental accounting methodology that measures the use of resources per solar eMergy common unit aiming to assess the interaction of environmental sustainability indexes in water supply and sanitation companies listed on the BM&FBOVESPA in 2014. The measurement was performed by defining the boundaries of the system of each company with the sources of energy and materials that feed it. A system energy diagram was constructed and the flows were summarized in an aggregate diagram of the energy flows. From the inventory of energy and material inputs of the companies in 2013, the resources R, N, and F were inventoried in units, transformations, and eMergy/unit. It has been found that consumers are paying, in seJ/J or seJ/R$, for the resources received from natural ecosystems when they buy products and services in cash. The calculation of accounting indicators in eMergy (EYR, ELR, and SI) and the ternary diagram in eMergy and their sustainability lines indicated the companies' positions in relation to environmental sustainability indicators. Investors of the BM&FBOVESPA acknowledge and perceive positive value in companies labeled as sustainable. Between 2006 and 2015, the ESI obtained a performance index 131% higher than the Ibovespa index. Clients of the companies CASAN, COPASA, SABESP, and SANEPAR pay in their water and sewage treatment bills (average values in R$) for 72.5% of the total eMergy they receive. There is a disadvantageous relation between the biosphere and the water and sewage treatment systems operated by the assessed companies.

Keywords: Environmental sustainability; Water supply companies; BM&FBOVESPA; eMergy.

Resumo: *O nível crítico das águas dos reservatórios e das hidrelétricas brasileiras representa o rompimento da 1ª condição da sustentabilidade. A soma do volume de afluência menos a soma do volume de defluência, resulta em 6.418 m^3 de água por segundo desfavorável, ao sistema nacional. Neste estudo, apresentamos uma metodologia de contabilidade ambiental que mensura o uso de recursos por unidade comum de eMergia solar, com objetivo de avaliar a interação de variáveis de sustentabilidade ambiental nas empresas de abastecimento de água e saneamento listadas na BM&FBOVESPA em 2014. A mensuração foi realizada mediante definição das fronteiras do sistema de cada empresa com as fontes de energia e materiais que a alimentam. Um diagrama de energia do sistema foi construído e resumido em um diagrama agregado dos fluxos de energia. A partir do inventário das entradas de energia e materiais das empresas no exercício de 2013, foram inventariados os recursos R, N e F, em unidades, transformidades e eMergia/unidade. Foi verificado se os consumidores estão pagando, em seJ/J ou seJ/R$, os recursos recebidos dos ecossistemas naturais quando compram produtos e serviços pagos em dinheiro. O cálculo dos indicadores da contabilidade em eMergia (EYR, ELR e SI) e o diagrama ternário em eMergia e suas linhas de sustentabilidade indicaram posições das empresas em relação aos indicadores de sustentabilidade ambiental. Os investidores na BM&FBOVESPA reconhecem e percebem valor positivo das empresas rotuladas como sustentáveis ambientalmente. No período de 2006 a 2015 o ISE obteve uma performance de +131% em relação ao Ibovespa. Os clientes das empresas CASAN, COPASA, SABESP e SANEPAR pagaram nas tarifas de água e tratamento de esgotos, em R$ médios, 72,5% da eMergia total recebida. Há uma relação de desvantagem entre a biosfera e o sistema de tratamento de água e esgotamento sanitário operado pelas empresas avaliadas.*

Palavras-chave: *Sustentabilidade ambiental; Empresas de abastecimento de água; BM&FBOVESPA; eMergia.*

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1 Introduction

Assessing environmental sustainability indexes in the companies is a task of extreme complexity. Scientific knowledge about the business activities interference in the biosphere is still incipient. In this paper, we present an environmental accounting methodology which measures the use of resources and is based on the use of common solar eMergy unit - the amount of power needed directly and/or indirectly - to obtain a particular good, product or service in a process.

According to UN Water report, from the United Nations (UN), our planet is the scene of an offensive, sometimes even warlike, for water. Supply difficulties for the population who needs at least 50 liters of water per day/inhabitant to meet its needs can lead 4 billion people to suffer from water shortages by 2030 (WWAP, 2014).

In Greater São Paulo Region, due to supply shortage through rainfall volume below the historical minimum in 84 years, mainly in Cantareira (It is the largest of the systems managed by SABESP and one of the largest in the world, designed to capture and treat water for Greater São Paulo. It consists of six dams interconnected by a complex system of tunnels, channels, in addition to a high-tech pumping station to overcome the physical barrier of Serra da Cantareira) system, the population of most cities within the metropolitan area supplied by Companhia de Saneamento Básico de São Paulo (SABESP), began receiving in 2014 a 30% discount on the price of used water, subject to a minimum saving of 20% in volume (Sistema Cantareira, 2014).

According to Molinos-Senante et al. (2016), water shortage is one of the main problems faced by many regions in the world in the 21st century and has become one of the most critical factors in the management process of some companies, due to factors such as: climate change, urbanization rate increase and income and industrial production growth.

For Campos et al. (2013), based on a long historical process of human awareness maturation in face of economic development, environmental management began to incorporate several governmental and business initiatives that sought more appropriate management forms to guarantee a better future for society on the planet.

More and more companies have sought to integrate economic indexes with environmental ones. The use of metrics that measure the use of natural resources and the impacts of productive activities broaden the traditional meanings of accounting assets and liabilities, relating them to biosphere preservation, according to balance and accountability (One of the pillars of corporate governance: responsible accountability, ethical reasoning and good accounting and auditing practices) concepts (Kassai et al., 2012).

Among the different investment choices, the actions' and companies' value perception is very important for investor's decision-making, influenced by factors such as liquidity, return and risk, measured with objective and subjective information, coming from the stock exchange and other sources.

The companies' value perception by investors is influenced by several factors, among them by reasons of environmental nature. Increased use of renewable resources (R) such as water, minimization of the use of non-renewable resources (N) and generated waste, and it could interfere with companies' profitability and survival (Bertolini et al., 2012).

According to Giannetti (2009 apud Di Agustini, 2009), the stock exchange is the space in which companies can obtain resources, stimulating business activities and generating capital accumulation. Figure 1 shows the investment system key components through a stock exchange.

The main flows of a productive system are shown in Figure 1, where the resources and products flow are parallel to money flows in the opposite direction. The two flows are interdependent: without resources and products, it is not possible to promote money flow, and, in turn, without capital, resource and product flows do not occur. The transaction takes place under control of the price that is the result of the market value, observing ideal conditions to the economic principle of balance between supply and demand.

In 2014, four companies in water supply and sanitation segment were listed on the Stock Exchange, Commodities and Futures: Companhia Catarinense

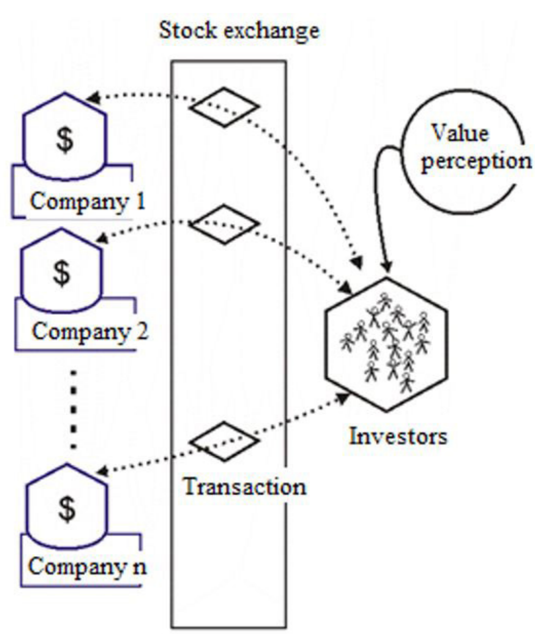

Figure 1. Representation of capital flows through the stock exchange. Source: Giannetti et al. (2009 apud Di Agustini, 2009, p. 16).

de Águas e Saneamento (CASAN), Companhia de Saneamento de Minas Gerais (COPASA), SABESP and Companhia de Saneamento do Paraná (SANEPAR) (BM&FBOVESPA, 2014a).

For Pontes & Schramm (2004), water supply and sanitation companies are of public utility due to their individual and collective size, as they manage scarce and finite natural resources. They are concessionaires of essential services to population with majority share control of federation units, as presented in Table 1 (Brasil, 2006)

The presence of the state as controller of the water supply activity is marked by a long process that is confused with the history of Brazil.

> Here reside six of ours: Four Fathers and two brothers. The Church is not very big. It has fence full of earthy fruits and quinces; and in the cloister a well of good water. José de Anchieta, in a letter of 1585 (Anchieta, 1595).

R resources are withdrawn from the environment and have faster temporal and spatial renewal capacity than their consumption/use. Within this class are solar energy, winds, rain, etc. N resources are stored in nature, but their consumption is faster than their capacity for renewal. Within this class are sources of resources such as coal, oil, forests, drinking water, etc.

The overall goal of this work is to assess the interaction of environmental sustainability indexes in water supply and sanitation companies listed on BM&FBOVESPA in 2014, in accordance with the determinations of BM&FBOVESPA Corporate Sustainability Index (ISE) Advisory Board, which starting in 2008 began to classify as critical environmental aspect the companies that intensively use N resources and few R resources.

In order to reach the goal, the system boundaries of each company were defined with the energy and material sources that feed it, a system energy diagram (Odum, 1996) was constructed and the flows were summarized in an aggregate diagram of the energy flows. The energy and material inputs of the assessed companies were transformed into specific transformation or eMergy to inventory R, N and F resources in units, transformations and eMergy/unit.

The verification results whether consumers are paying, in seJ/J or seJ/R$, the resources received from natural ecosystems, calculations of accounting indicators in eMergy (EYR, ELR and SI) and ternary diagram in eMergy and its lines of sustainability are shown in Tables 2 and 3 and Figure 2.

Table 1. Water supply companies on BM&FBOVESPA in 2015.

Company	Majority shareholder	Total capital %
CASAN	State of Santa Catarina*	67.34%
COPASA	State of Minas Gerais	51.13%
SABESP	State of São Paulo	50.25%
SANEPAR	State of Paraná	58.73%

*Including participation of Centrais Elétricas de Santa Catarina (CELESC). Source: BM&FBOVESPA (2015).

Table 2. Inventory of resources received and paid by companies' clients.

Consumer advantage/disadvantage Sej/year (%)				
SABESP	**COPASA**	**SANEPAR**	**CASAN**	
7.04E+22	2.31E+22	1.47E+22	4.01E+21	Emergy paid by clients
7.97E+22	3.59E+22	1.84E+22	7.09E+21	Emergy received by clients (F+R)
88%	**64%**	**80%**	**58%**	**Paid/received (F+R)**
1.13	**1.56**	**1.25**	**1.73**	**Received (F+R)/paid by clients**

>1 = consumer advantage; <1 = company advantage. Source: Elaborated by the authors (2014).

Table 3. Companies' eMergy accounting indicators.

	Sej/year (%)			
	SABESP	**COPASA**	**SANEPAR**	**CASAN**
R	5.66E+22	2.52E+22	1.30E+22	4.82E+21
N	1.83E+22	8.63E+21	4.22E+21	1.77E+21
F	4.78E+21	2.16E+21	1.10E+21	4.96E+20
ELR	0.41	0.43	0.41	0.47
EYR	16.67	16.67	16.67	14.29
SI	40.80	38.89	40.80	30.36

Source: Elaborated by the authors (2014).

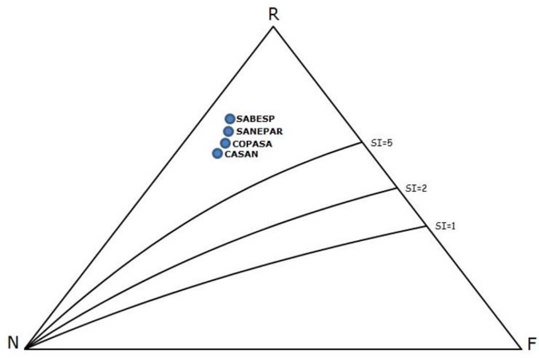

Figure 2. Companies positioning in the ternary diagram in eMergy. Source: Elaborated by the authors (2014).

2 Theoretical reference

The environmental degradation intensified since the Industrial Revolution led to actions and initiatives involving various segments of society aiming at raising awareness of population and, consequently, the change of posture of the individuals and companies. The actions and initiatives are numerous, among them: Biosphere Conference (Paris, 1968); United Nations Conference on Environment (Stockholm, 1972); Eco 92 or Rio 92 (Rio de Janeiro, 1992); World Summit on Sustainable Development or Rio + 10 (Johanesburgo, 2002); Intergovernmental Panel on Climate Changes (Paris, 2007), Rio + 20 (Rio de Janeiro, 2012) and Integrated Report promoted by International Integrated Reporting Council (IIRC), an organization that promotes the integration among the financial, sustainability and governance information into corporate reports, launched worlwide on April 16th, 2013, in Brazil by BM&FBOVESPA (Alves & Barbosa, 2013).

2.1 Sustainability

The issues concerning the environment and the biosphere sustainability are not recent. According to Swearer (2004, p. 21), in the fifth century b.C., there are textual records that Buddha warned about the importance of forests under an environmentalist perspective.

The discussions about sustainability-related themes have a multidisciplinary dimension and a diffuse and complex concept. Sustainability is the word of order that has become common in most diverse environments, being appropriated by corporate executives, investors, politicians, social activists, academics, workers and others. According to Ferreira (2001), sustainability is a feminine noun meaning sustainable quality. Sustainable, in turn, is also an adjective, which can be sustained, and sustain, direct transitive verb, is to conserve, maintain, prevent ruin, protect, defend, hold the same position, stand or balance. Sustainability comes from the Latin sustentare which means to suster, sustain, support, preserve or maintain.

The scientific work related to sustainability theme mainly addresses the relevance of environmental issues within the scope of questioning the predatory nature of production systems to meet humanity's consumption needs. In the early 1980s, the UN resumed the debate on environmental issues, when Norway's Prime Minister, Grö Harlem Brundtland, headed the World Commission on Environment and Development to study the matter. The final document of these studies was called Our Common Future or Brundtland Report. Presented in 1987, it proposes sustainable development, that is, "[…] one that meets the needs of the present without compromising the possibility of future generations to meet their needs" (Comissão Mundial sobre o Meio Ambiente e Desenvolvimento, 1991, p. 114).

Munck & Souza (2013) argue that the concept of sustainable development is fragile by the economic logic that favors the will of the market and that transfers to the environment the misconception of global and uninterrupted economic growth.

According to Miranda (2009), there is no man-nature relation. Being man a social being, there are relations between men through nature - nature is always object of social relationships, not their purpose. With the increase of population on the planet, growth of economic and technological power to meet the consumption needs of mankind, the ecosystems, watersheds, forests, oceans, continents, soil, air and water started to be reached.

Daly (1996), one of the ideologists of the Theory of Sustainability and Ecological Economy, suggested three conditions for defining the sustainable limits that can be applied to business activities.

1st **Sustainability Condition:** R resource source use speed should not exceed the regeneration speed of these resources. For example, fishing becomes unsustainable when fishes are caught in an amount greater than their reproductive capacity.

To further examine this issue, according to Barret & Odum (2007), regeneration is the ratio between the processing rate and the content. The regeneration can be expressed as a fraction of the total amount of a substance in a compartment, which is released (or enters) in a given period of time; the regeneration time is its reciprocal, i.e. the time required to replace the amount of substance equal to its quantity in the compartment. For example, if 1,000 units are present in the compartment and 10 exit or enter per hour, the regeneration rate is 10/1,000 (0.01) or 1% per hour. The regeneration time would then be 1,000/10 or one hundred hours. While a pond may have a rate of 1 day to renovate its tiny plants, longer-living land plants of a pasture may take 100 days and the trees of a forest 100 years.

The withdrawal of water from Cantareira system is an example of non-compliance with the first sustainability condition. The withdrawal speed by increasing use of R finite resource (water) of the reservoirs exceeds the capacity of the ecosystem to regenerate the reservoir (ANA, 2014).

The phenomenon covers the entire national territory. The critical level of Brazilian hydropower plant reservoir waters represents the breaking of the first sustainability condition. According to National Electric System Operator (ONS), the sum of the afluence volume minus the sum of the defluence volume results in 6,418 m^3 of water per second unfavorable to the national system, as shown in Table 4 (ONS, 2014).

2nd **Sustainability Condition:** N resource source use speed should not exceed the development speed of the substitute R. For example, an oil field could be used sustainably if a portion of the financial resources of its exploração were invested in R source power generation and tree planting, so that when oil was exhausted, a sufficient R source of energy would still be available for production activities and consumption.

According to McKelvey (1982), N resources cannot be replenished and their reserves can be exhausted by the extraction of productive systems, i.e. what is available and extracted today will no longer be available tomorrow. Thus, if the technological

Table 4. Position of Brazilian reservoirs in September 2015.

Basin	Reservoir	Level*	Afluence** (A)	Defluence** (D)	A-D
Southeast Region					
Grande	Furnas	23.12	138	518	-380
	M. Moraes	47.22	566	858	-292
	Marimbondo	15.84	966	1,010	-44
	Água Vermelha	20.81	1,520	849	671
Paranaíba	Emborcação	29.43	218	603	-385
	Nova Ponte	18.01	33	194	-161
	Itumbiara	17.92	1,362	1,406	-44
	São Simão	21.32	1,790	1,844	-54
Paraná	Ilha Solteira	0	3,049	2,850	199
	Jupiá	92.38	4,490	4,031	459
	Itaipu	79.75	9,831	9,831	0
Tiete	Barra Bonita	63.19	193	222	-29
	Promissão	29.63	419	252	167
	Três Irmãos	0	165	448	-283
Paranapanema	Jurumirim	25.08	276	235	41
	Chavantes	31.03	406	368	38
	Capivara	57.35	1,220	1,275	-55
South Region					
Iguaçu	G. B. Munhoz	47.13	786	1,006	-220
	Salto Santiago	97.78	1,541	1,421	120
Uruguai	Machadinho	33.64	988	1,226	-238
	Itá	58.43	1,509	1,199	310
	Passo Fundo	94.93	79	62	17
Jacuí	Passo Real	84.25	249	415	-166
Notheast Region					
São Francisco	Três Marias	5.55	66	163	-97
	Sobradinho	31.09	330	1,129	-799
	Luiz Gonzaga	20.12	990	982	8
North Region					
Tocantins	Serra da Mesa	34.71	81	843	-762
	Tucuruí	37.93	2,312	6,751	-4,439

*In ideal capacity %; **Flow in m^3/second. Source: ONS (2014).

development of R substitute materials to N ore is less than the extraction rate, the ore reserves may be exhausted. However, as mentioned in the 1st sustainability condition, R substitute material of N ore must observe the regeneration rate (processing rate and content) and the time required to replace the quantity of substance equal to its quantity in stock (Barret & Odum, 2007).

The existing relationship between N and R resources of biosphere with the production systems is complex. In the process of producing goods and services, not all N resources can be replaced by R resources by the companies. N resources, whose reserves are in extinction, may be replaced by other N resources with larger reserves, such as Ford's replacement of steel by aluminum in manufacturing pickup trucks (Ramsey, 2012).

3rd **Sustainability Condition:** The emission of pollutants (or waste) should not exceed the absorption capacity of the biosphere. For exemple, sewage cannot flow into a river, lake or underground reservoir faster than bacteria and other organisms can absorb their nutrients without themselves pressing and destabilizing the aquatic ecosystem.

For Brown (2009), when analyzing Earth situation against the intense use of natural resources and the economy flows which depend on the ecosystems/environment, he argues that if there is no environment, if everything is destroyed, there is no economy. Thus, the fundamental issue involving corporate sustainability is directly associated with environmental sustainability (extraction and use of N and R resources in productive systems, waste generation and impacts on ecosystems and people) and the daily activities of human beings (life style and consumption).

2.2 BM&FBOVESPA ISE

Created in 2005, ISE is the fourth indicator in the world and a pioneer initiative in Latin America, and is the result of the efforts of several institutions to make it a benchmark for sustainable investments. It is a tool for comparative performance analysis of companies listed on BM&FBOVESPA, whose purpose is to create an investment environment compatible with the demands of sustainability development of society and stimulate more sustainable practices in companies (Bassetto, 2010).

ISE is a reference shares index for environmentally responsible investments, composed of companies that stand out in sustainability. The Advisory Board is composed of members of the following institutions: Associação Brasileira das Entidades Fechadas de Previdência Complementar (ABRAPP); Associação Nacional de Bancos de Investimentos (ANBID); Associação dos Analistas e Profissionais de Investimentos do Mercado de Capitais (APIMEC); BM&FBOVESPA; Instituto Ethos de Empresas e Responsabilidade Social (ETHOS); Instituto Brasileiro de Governança Corporativa (IBGC); International Finance Corporation - Banco Mundial (IFC); Ministério do Meio Ambiente (MMA) and Programa das Nações Unidas para o Meio Ambiente (PNUMA). Fundação Getulio Vargas (FGV) is the institution responsible for ISE research and methodology, whose portfolio from January 6, 2014 to January 2, 2015 was composed of 40 companies (BM&FBOVESPA, 2014b).

From its creation in December 2005 to December 2015, ISE recorded an accumulated growth rate higher than that of Ibovespa (Indicator of average performance of greater tradability and representativeness shares' quotations in the Brazilian stock market), according to Table 5.

Table 5 shows that investors seek to invest in stocks and shares of companies commited to sustainable management practices. From 2006 to 2015 ISE achieved a performance of +222% in relation to Ibovespa, proving the positive perception of value by the investors in relation to companies labeled as sustainable.

Out of the four companies assessed, SABESP and COPASA are part of ISE from January 2014 to January 2, 2015 (BM&FBOVESPA, 2014b).

The integration of economic indexes with environmental ones and the use of metrics that measure the use of natural resources for companies listed in ISE are aspects of Agency Theory that contribute to the expansion of the traditional meanings of accounting assets and liabilities, relating them to preservation

Table 5. ISE and Ibovespa growth rates.

Growth rate (%)		**Ibovespa**
Year	**ISE**	
2006	+37.8	+32.9
2007	+40.4	+43.6
2008	-41.1	-41.2
2009	+66.4	+82.7
2010	+5.8	+1.0
2011	-3.3	-18.1
2012	+20.5	+7.4
2013	+1.9	-15.5
2014	-1.9	-2.9
2015	-10.9	-10.6
Accumulated	108.2	33.6
Annual average	7.6	2.9
Monthly average	0.61	0.24

Source: BM&FBOVESPA (2016).

of all biosphere, according to corporate governance concepts (Sant'Ana et al., 2016).

The modeling of systems that assess the sustainability of water supply and sanitation companies is addressed as a crucial aspect of corporate governance related to transparency and respect for the various stakeholders in the decision process (Marques et al., 2015).

2.3 Environmental sustainability indexes

For Collen et al. (2008), on the measurement of complex indexes, such as environmental and corporate sustainability, the construction of metrics and indicators ends up presenting operational difficulties. They quote, for example, the difficulty to measure the planet's ecosystems, being necessary attribution of estimates and analogies. The estimates, by nature, are susceptible to controversy and contestation, because they may have an associated degree of subjectivity.

There is a large amount of metrics, indicators and tools for measuring sustainability. According to Kerk & Manuel (2008), there are no metrics that provide a complete insight into all relevant aspects of sustainability in a transparent, simple and easily understood way, although sustainability indicators are increasingly recognized as useful tools in making investment decisions.

According to Pulselli et al. (2008), in analyzing sustainability measurement, given the complexity of the process and the large number of existing indicators, according to UN Commission on Sustainable Development (CSD) (Created on January 29th, 1993, by the UN General Assembly, through Resolution A/RES/47/191 (UN, 1993)) and UN Resolution A/RES/47/191 (Resolution 47/191, of December 22nd, 1992, Institutional arrangements to follow up United Nations Conference on Environment and Development, A/RES/47/191, 29 January 1993 (UN, 1993)), a sustainability indicator should include the following requirements:

- ✓ based on a solid scientific base recognized by the international community;
- ✓ relevant to encompass the crucial factors of sustainable development, including local and global aspects;
- ✓ transparent so that it is understood by an audience non-specialized on the theme;
- ✓ quantifiable and anchored by data available or easy to obtain and update; and
- ✓ limited in quantity, depending on the purpose of use.

2.4 R and N resources

From 2008, ISE started to contemplate in the methodology environmental aspects deemed critical by ISE's Advisory Board: N and R natural resources (Denomination applied to all raw materials (R and N), obtained directly from nature and used by man. They are classified as R or N resources due to the time needed for their replacement. N resources include substances that cannot be recovered in a short period of time, such as, for example, oil and ores in general. R resources are those that can renew themselves or can be recovered with human interference, such as forests, sun light, wind and water. Equation 1 shows the formula) ISE considers as critical, the environmental impact that, due to technical (severity, reversibility, magnitude, spatial range), social or legal criteria, demands specific actions of prevention, control and monitoring by companies.

The decision of ISE's Advisory Board to classify as a critical environmental aspect, companies that intensively use N resources and use few R resources are in compliance with the terms and conditions for definition of sustainable limits of a production system (Daly, 1996; Barret & Odum, 2007; McKelvey, 1982; Brown, 2009; Giannetti 2009 apud Di Agustini, 2009).

2.5 Assessment in eMergy

The conceptual basis and application on eMergy was developed by Odum (1996), when proposing a consistent methodology, capable of measuring the use of resources of a given system, called environmental accounting. Such accounting is based on the use of the solar eMergy common unit, which is the quantity of energy required, directly and/or indirectly, to obtain a particular good, product or service, in a process.

Odum (1996) proposes the construction of flow diagrams for a better visualization of the resources, which travel between the boundaries of the economic (F) and natural ecosystems (R and N resources) environments, using a symbology, that represents the flow of energy in the processes. All the resources used in the processes, natural R and N and those from the economic environment F, are counted by Joule of solar energy (seJ) - standard and common metric in the methodology.

Accounting through assessment methodology in eMergy scientifically measures the interference of a production system in the biosphere, segregating and inventorying N and R resources (Figure 3), in compliance with the measures adopted by ISE's Advisory Board from 2008.

Figure 3 illustrates that the assessment in eMergy is a methodology with scope of the interference of production systems with natural ecosystems, considering the inventories of R and N resources of the biosphere, F resources of the economy with

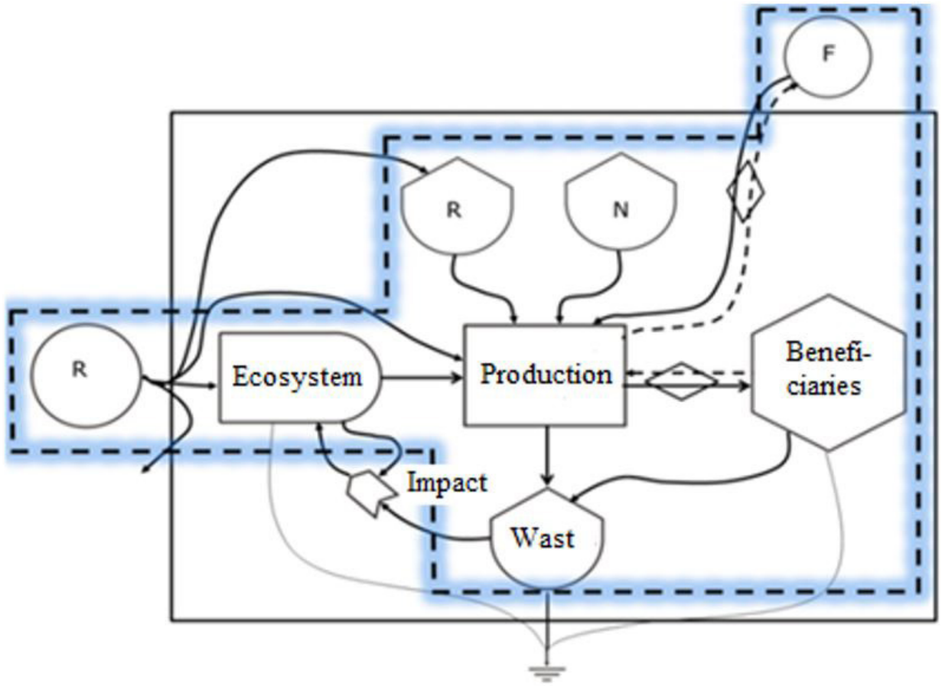

Figure 3. Limitations of the assessment methodology in eMergy. Source: Elaborated by the authors (2014).

clients (beneficiaries) and the generation of waste and impacts.

The great innovation proposed by Odum (1996) was to structure a methodology that makes it possible to account for and measure different resources and processes, usually measured by different methods and units, using a common metric (solar energy joule - seJ). For that, Odum (1996) conceived the concept of solar transformity - amount of solar energy used, directly and/or indirectly - in obtaining a joule of a given product/process (seJ/J). In determining transformity of the system under study, it is possible to calculate cumulatively, from the use of the first resources in the system, the indirect solar power required to obtain another product/process (Odum, 1996). Assessment in eMergy allows the measurement of biosphere resources use by corporate production systems using a standard metric - seJ.

From the inventory of all the resources used in the processes, natural R and N and those from F economic environment, accounted for in seJ, it is possible to calculate the following indicators in eMergy.

2.5.1 Environmental sustainability indicator (SI)

According to Brown & Ulgiati (1997), SI represents the ratio between resources use (EYR) and environmental impact (ELR). The better the resource use and the lower the environmental impact, the greater the sustainability index, that is, the greater the contribution of the systems to the biosphere sustainability.

$$SI = EYR \div ELR \tag{1}$$

The SI assumes that for the purposes of environmental sustainability, the higher this index, the more sustainable is the assessed system, because it minimizes the environmental load, that is, it maximizes the ratio between the use of the resources employed (EYR) in relation to the environmental impact (ELR) (Brown & Ulgiati, 1997).

The concept of sustainability, considering the environmental dimension (biosphere), is associated to the maximization of EYR and the minimization of ELR, that is, a sector, a company or product/service should have the maximum use of the investment with a minimum of consumption of the environmental resources.

SI values below 1 are indicative of unsustainable systems (Brown & Ulgiati, 1997). Systems with values greater than 1 indicate sustainable contributions to the environment. Medium-term sustainability can be characterized by a SI between 1 and 5, while long-term sustainability has a SI greater than 5.

2.5.2 eMergy Yield (EYR)

EYR (emergy *yield ratio*) is an eMergy of output flow Y (product, process, system or service) divided by the sum of eMergies from the economy F. Equation 2 shows the formula.

$$EYR = (R + N + F) \div F \quad (2)$$

EYR measures the ratio between the total output eMergy of the system assessed and the economy's/paid resources not provided, free of charge, by the biosphere (F). It represents the influence of F resources in the assessed system or the use of R and N resources in the process.

2.5.3 Environmental load indicator (ELR)

ELR (environmental *loading ratio)* shows the ratio between the economic investment flows F, N resources and eMergy associated to the R resources flow. Equation 3 shows the formula.

$$ELR = (N + F) \div R \quad (3)$$

ELR assesses the stress of the ecosystems resulting from the activities of the assessed system. High ELR value may indicate a stress of R resources use (Odum, 1996).

Brown & Ulgiati (2002) developed a method to assess the accounting in eMergy with the use of SI, in which the reserves used to obtain the products and the components of the productive system, constitute relations, which are assessed through this index, considering the available local inputs, those imported from outside the system and the fraction of renewable and non-renewable inputs.

Barrella et al. (2005) and Giannetti et al. (2007a) proposed a graphical tool called ternary diagram in eMergy, in which, through an equilateral triangular diagram, the three indexes (R, N and F) used in the object of study are associated with (I was in doubt) percentages of each resource, that is, the sum of R, N and F resources will always be 100%. Thus, it is possible to represent the three indexes in two dimensions, allowing better visualization and understanding of the contribution of environmental (R and N) and economic/paid (F) resources in a system.

R and N resources flows are provided by the biosphere and have no economic value measured by traditional accounting metrics, while R resources can be replenished by the environment at least at the same rate at which they are consumed, N resources can be exploited without time for recovery by the environment. F resources come from the market and have value in currency (Giannetti et al., 2007a).

The ternary diagram in eMergy enables:

- ✓ identify trends and differences regarding the sustainability of the systems assessed;
- ✓ verify indexes that can be changed and/or rearranged to improve the environmental performance of a system;
- ✓ measure the efficiency of the system for the use of reserves and environmental support capacity, required for its activities; and
- ✓ compare and monitor the performance of the system assessed over time (Giannetti et al., 2007b).

The ternary diagram in eMergy complements Odum's environmental accounting and extends the methodology to the extent that it allows the establishment and easy viewing of the sustainability lines, comparing processes and identifying more environmental-friendly production systems (Figure 4).

The assessment in eMergy scientifically measures the interference of water and sanitation sector companies listed on BM&FBOVESPA (CASAN, COPASA, SABESP and SANEPAR) in the biosphere, segregating and inventorying N and R resources (Figures 3 and 4), in compliance with the determinations of ISE's Advisory Board.

3 Methodology

To achieve the goal proposed herein:

The boundaries of the system of each company were defined with the energy sources and materials that feed it, building a system energy diagram, using its own symbology to represent the different components of each company (Odum, 1996), flows were summarized in an aggregate diagram of energy flows.

From the systems energy diagram, a table was built with all the energy and materials inputs of the assessed company, selecting the transformity or specific eMergy for each of these inputs to calculate the eMergy, according to Tables 6 and 7.

The inputs to calculate the eMergy of each company were obtained from the annual financial statements (balance sheets), for the financial year of 2013, published by the assessed companies.

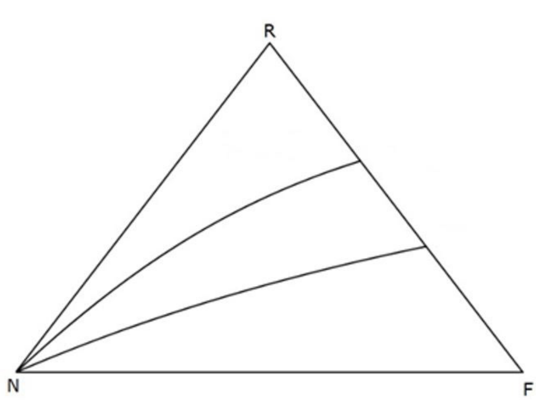

Figure 4. Ternary diagram in eMergy and sustainability lines. Source: Giannetti et al. (2007b, p. 12).

Table 6. Input of energy and materials used by the companies in 2013.

R$ Brazil transformity	Unit	Quantity				eMergy	Unit	Source
2013		SABESP	COPASA	SANEPAR	CASAN	sej/unid.		
R resources R[a]	m^3	**4,686,347,400**	**1,478,868,607**	**1,185,347,038**	**271,340,745**	2.92E+11	Sej/m^3	Buenfil (average)
Paid resources (F) - flow								
Costs abd expenses	R$	8,399,283,000	3,148,360,000	1,826,049,000	556,643,000	6.22E+12	EmR$/year	[c]
Taxes[b]	R$	732,040,000	146,363,000	141,226,000	25,037,000	6.22E+12	EmR$/year	[c]
Use of assets (F) - inventories								
Current assets	R$	3,254,087,000	1,079,708,000	601,122,000	345,860,000	6.22E+12	EmR$/year	[c]
Long-term assets	R$	896,781,000	1,270,102,000	577,633,000	187,462,000	6.22E+12	EmR$/year	[c]
Permanent assets								
Investments	R$	77,699,000	260,000	2,937,000	304,000	6.22E+12	EmR$/year	[c]
Fixed assets	R$	199,496,000	5,334,365,000	5,314,728,000	290,998,000	6.22E+12	EmR$/year	[c]
Intangible assets	R$	23,846,231,000	8,672,619,000	251,607	1,504,284,000	6.22E+12	EmR$/year	[c]
Total used (F)	R$	**13,559,386,000**	**19,651,777,000**	**8,463,946,607**	**2,910,588,000**			
Total used (Buenfil average)	Sej/m^3					2.27E+12		Buenfil (average)
Drinking water production	m^3	2,149,100,000	685,476,240	578,751,800	177,627,190	3.20E+11	Sej/m^3	Buenfil (2001)
Treated sewage production	m^3	1,579,100,000	455,626,080	372,570,060	31,096,460	1.05E+11	Sej/m^3	Arias & Brown (2009)
Total Y	m^3	**3,728,200,000**	**1,141,102,320**	**951,321,860**	**208,723,650**	2.26E+12	Sej/m^3	Buenfil (Tampa Bay)
Received from customers	R$	11,315,567,000	3,714,818,000	2,370,179,000	659,952,000	6.22E+12	EmR$/year	[c]
Average rate drink water	$R\$/m^3$	5.27	5.42	4.10	3.72			

[a]Includes losses in process; [b]Income tax and social contribution; [c]University of Florida (2014). Source: Elaborated by the authors (2014).

Considering that in 2013 the companies did not use the totality of the resources available, because items of a permanent nature benefit several fiscal years, the inventory of resources in each year contemplated the percentage of use of these items in compliance with the Laws in effect (Brasil, 1976, 1999).

From the inventory of energy and material inputs of companies in fiscal year 2013, R, N and F resources were inventoried in units, transformities and eMergy/unit, according to Table 8.

Figure 5 presents R, N and F summarized resources of the companies SABESP, COPASA, SANEPAR and CASAN inventoried, considering the energy and material inputs, from the data published in the annual financial statements (balance sheets), of the year 2013.

Considering the flow of exchanges between the environment and production/consumption systems, in order to verify if consumers are paying, in seJ/J or seJ/R$, the resources received from natural ecosystems when they buy products and services paid in cash (Odum, 1996), the relationship of resources received by clients *versus* resources paid in eMergy, from the companies' resource inventory is presented (Table 2).

The accounting indicators in eMergy (EYR, ELR and SI, Table 3) were calculated and the ternary diagram in eMergy and its sustainability lines were constructed to better visualize the companies' position regarding the environmental sustainability indicators (Figure 2).

4 Results and discussion

4.1 Flow of exchanges between the environment and the companies, in seJ/J or seJ/R$

The relationship resources received by clients *versus* resources paid in eMergy, from the inventory of companies resources, considering the flow of exchanges between the environment and production/consumption systems (Odum, 1996), is presented in Table 2.

Table 7. Energy and materials inputs used by the companies in 2013 in Sej/year.

R$ Brazil transformity 2013	Unit	Economic life[c]	Sej/year			
			SABESP	COPASA	SANEPAR	CASAN
R resources R[a]	m^3		**1.37E+21**	**4.32E+20**	**3.46E+20**	**7.93E+19**
Paid resources (F) - flow						
Costs abd expenses	R$	1	5.22E+22	1.96E+22	1.14E+22	3.46E+21
Taxes[b]	R$	1	4.55E+21	9.10E+20	8.78E+20	1.56E+20
Use of assets (F) - inventories						
Current assets	R$	1	2.02E+22	6.72E+21	3.74E+21	2.15E+21
Long-term assets	R$	5	1.12E+21	1.58E+21	7.19E+20	2.33E+20
Permanent assets						
Investments	R$	25	1.93E+19	6.47E+16	7.31E+17	7.56E+16
Fixed assets	R$	25	4.96E+19	1.33E+21	1.32E+21	7.24E+19
Intangible assets	R$	10	1.24E+20	5.39E+21	1.56E+17	9.36E+20
Total used (F)	R$		**7.97E+22**	**3.59E+22**	**1.84E+22**	**7.09E+21**
Total used (Buenfil average)	Sej/m^3		8.48E+21	2.60E+21	2.16E+21	4.75E+20
Drinking water production	m^3	1	6.88E+20	2.19E+20	1.85E+20	5.68E+19
Treated sewage production	m^3	1	1.66E+20	4.78E+19	3.91E+19	3.27E+18
Total Y	m^3		**8.54E+20**	**2.67E+20**	**2.24E+20**	**6.01E+19**
Received from customers	R$	1	**7.04E+22**	**2.31E+22**	**1.47E+22**	**4.10E+21**
Average rate drink water	R$/$m^3$		102.34	105.34	79.60	72.22

[a]Includes losses in process; [b]Income tax and social contribution; [c]Brazil: Federak Revenue Normative Instruction/98 and Law 6.404/76 (Brasil, 1976, 1999). Source: Elaborated by the authors (2014).

Table 8. Inventory of R, N and F resources of the companies.

	Sej/year (%)			
	SABESP	COPASA	SANEPAR	CASAN
R	71%	70%	71%	68%
N	23%	24%	23%	25%
F	6%	6%	6%	7%

Source: Elaborated by the authors (2014).

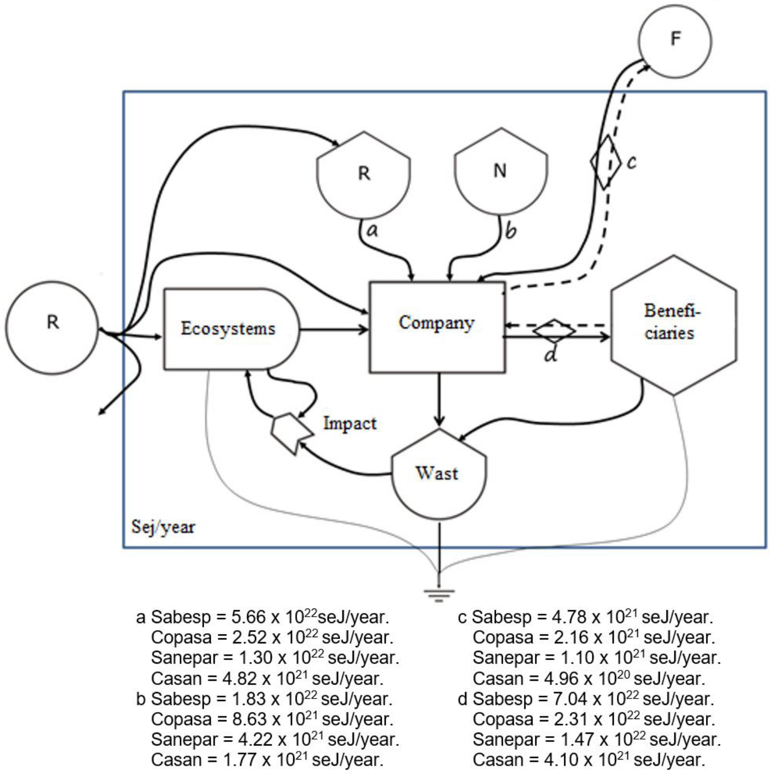

Figure 5. Summarized resource flows of the companies in 2013. Source: Elaborated by the authors (2014).

Table 2 reveals that the average ratio of the amount of resources in eMergy received by clients of the companies for eMergy paid is 1.42. The clients received in 2013 an average of 42% more resources in eMergy than they paid in seJ.

Consumers in the state of Santa Catarina (CASAN) are the ones that pay less for water and sewage treatment services. They pay 58% of the eMergy received or receive 73% more in resources in eMergy, indicating a significant advantage for consumers. On the other hand, consumers in the state of São Paulo (SABESP) are the ones that pay the most for water and sewage treatment services. They pay 88% of the eMergy received or receive 13% more in eMergy, also indicating an advantage for consumers.

Companies' clients paid in water and sewage treatment rates, on average R$, 72.5% of total eMergy received. In eMergy, there is a disadvantage relation between the biosphere and the water and sanitary sewage treatment system operated by the companies assessed herein.

4.2 eMergy accounting indicators

eMergy accounting indicators (EYR, ELR and SI) are shown in Table 3 and the ternary diagram in eMergy and its sustainability lines for better viewing of companies position regarding environmental sustainability indicators are illustrated in Figure 2.

Table 3 shows that all assessed companies presented long-term sustainability (Brown & Ulgiati, 1997), because they presented SI higher than 5. The companies SABESP and SANEPAR are those with the highest SI, i.e., they operate with better sustainability conditions in the long term. Thus, SANEPAR should integrate ISE in the period from January 2014 to January 2nd, 2015 instead of COPASA.

CASAN has the worst classification in the ranking by SI, greater environmental load (ELR), less use of R resources and greater use of N resources in its operational activities.

5 Conclusions

In order to achieve the goal of assessing the interaction of environmental sustainability indexes in water supply and sanitation companies listed on BM&FBOVESPA in 2014, the boundaries of each company's system with the energy and materials sources that feed it were defined, an energy diagram of the system was elaborated (Odum, 1996) and the flows in an aggregate diagram of the energy flows were summarized.

Tables 6 and 7 show all energy and material inputs of the companies assessed, selecting the specific transformity or eMergy for each of these inputs to calculate the eMergy.

From the inventory of energy and material inputs of the companies in fiscal year 2013, R, N and F resources were inventoried in units, transformities and eMergy/unit, according to Table 8.

The results of the verification whether consumers are paying in seJ/J or seJ/R$, the resources received from natural ecosystems when they buy goods and services paid in cash (Odum, 1996), ratio resources received by clients *versus* resources paid in eMergy, were presented in Table 2.

The calculation of the accounting indicators in eMergy (EYR, ELR, SI) and the ternary diagram in eMergy and its sustainability lines indicating the positions of companies in relation to environmental sustainability indicators are presented in Table 3 and Figure 2.

Incorporate scientific requirements for physical measurement of N and R resources use from business activities allows investors to direct resources to companies that generate greater environmental sustainability in the long run.

The main limitation of this study is to assess the environmental sustainability indexes of companies anchored by the information of annual financial statements (balance sheets) published.

By way of suggestions for future studies, there are many possibilities for expanding, deepening and developing methodologies and scientific tools, in theoretical and empirical fields, to measure the interference of production activities in the biosphere.

The convergence regarding the need to assess the environmental dimension of companies/business sectors is undeniable. The tools and methodologies of scientific measurement that reach the limits of natural ecosystems and physically measure the interference of productive activities on the biosphere are the safest way to assess sustainability in the environmental dimension.

In the legal field, incorporating scientific requirements for physical measurement of the use of N, R, F resources and their indicators of productive activities into laws, standards and legal attributes of legal protection to natural ecosystems can contribute to minimize the ecosystems degradation.

In the capital investments evaluation are, incorporating scientific requirements for physical measurement of the use of N, R, F resources of productive activities considering the economic scale, allows investors to direct resources for investments that generate greater environmental sustainability in the long term.

Within the scope of business management, incorporating scientific requirements of physical measurement of the use of N, R, F resources of productive activities considering the economic scale in techniques and management tools, can contribute to internalize in the financial accounting of companies, metrics that expand the traditional meanings of financial assets and liabilities, relating them to the preservation of the entire biosphere, according to concepts of balance and accountability (Kassai et al., 2012).

As stated by Meadows (1998), to measure the immeasurable may have an ambiguous aspect: The indicators may be meaningful or hazardous in the decision taking, mainly when there is subjective super aggregation of a lot of data in a single index. The "environmental dimension indicators" mitigate the subjective aggregation to the indicators because they are anchored in scientific methodologies with physical measurements.

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