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Sustainable development and governance: natural gas consumption in the Amazon

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ABSTRACT: This paper aims to examine the current natural gas production stage in the Amazon Basin, as well its role for sustainable development and governance in this region. The methodology consists of literature review and survey data for the production of natural gas in the region of the sedimentary basin of the Amazon. Considering that natural gas has environmental benefits due to the lower amount of emissions when burning it compared to other fossil fuels, we drawn considerations on its uses trends to conciliate development, sustainability and governance for the inhabitants in this Brazilian region.
Keywords: energy resources, non-renewable energy source, natural gas, Amazonian basin.

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I. INTRODUCTION

The Brazilian Legal Amazon is an area that corresponds to 59% of the Brazilian territory and encompasses eight states (Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins). The supply and diversification of energy sources is one of the biggest challenges to this region. Thus, the development of the gas market in the Amazon Basin region could bring sustainable benefits since it takes advantage of the resource produced in loco, generating economic and social development in the region as pointed out by Scomparin et al. (2016).

In addition, the substitution of gasoline and diesel in electricity generation in the isolated system or in the fleet of automotive vehicles by an environmentally less aggressive fuel such as natural gas meets the international tendency to search for electricity generation and for characterized fuel by the smaller amount of emission of pollutants (Brito et al., 2017). Natural gas is designated as a transition fuel, since its combustion emits lesser amount of CO2 per unit of energy compared to other fossil fuels. In this sense, consuming natural gas in the Amazon Basin could be a tool of sustainable development in that region. However, the absence of local production outflow infrastructure can be an obstacle to using of natural gas.

Thus, solutions would be the construction of thermoelectric plants near the field of production or the use of compressed natural gas (CNG) or liquefied natural gas (LNG) as a mechanism to leverage natural gas consumption without the immediate need to expand the grid (Brito et al., 2016).

In this perspective, the objective of this work is to examine the current natural gas production stage in the Amazon Basin, as well its role for sustainable development and governance in this region.To reach the proposed objective, the methodology consists of a review of the literature. Also, options for supplying compressed natural gas (CNG) or liquefied natural gas (LNG) will be described as a mechanism to leverage natural gas consumption in the region.

II. HISTORY OF NATURAL GAS IN THE AMAZON REGION

The Brazilian Legal Amazon, considered in terms of location, is an area that corresponds to 59% of the Brazilian territory and encompasses eight states (Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins) in their totality and part of the State of Maranhão (west of the 44ºW meridian), corresponding to 5.0 million km² (IPEA, 2008).

The limits of the Legal Amazon have been altered several times as a result of changes in the country's political division (IPEA, 2008), and currently the planning for the region coming from the federal government fully considers the State of Maranhão as part of the Brazilian Amazon.

In any case, to speak in the Amazon Region is to consider that the term does not include the specificities of the "regions" that compose it, and the modes of resource exploitation vary from one regional context to another (Sayago et.al., p. 22).

It is possible to affirm that the Brazilian Amazon:

It was constituted in a gigantic mosaic, historically configured in permanent configuration, composed in a great diversity of ecosystems and of different social, economic, cultural, political, ecological situations. The incorporation of the Amazon into the Brazilian territory, since the colonial period, has been in line with the interests of the most dynamic centers of the modern world economy, in a gradual and irregular way, based on the extraction of natural products, of animal, vegetal or mineral origin, according to the interests, needs and possibilities of extraction by the great economic centers (SANT'ANA JÚNIOR, 2004, 56).

According to Bursztyn (2004), the Brazilian Amazon Region faces disordered processes of human occupation that affect its ecosystems and the economic and cultural life of its inhabitants and, when considering the concept of "sustainable development" for the Amazon, it is fundamental to face it as much more than a natural sanctuary of animal and plant life forms and taking into account the demands of its population, especially those associated with its subsistence (Bursztyn, 2004).

Amazon comprises about a dozen sedimentary basins. Among them, the Solimões and Amazonas basins are highlighted, due to their size and the great potential of existing energy reserves (Teixeira et al., 2009).

The prominent basins are located in the northern region of Brazil, which is covered by dense forest formations, among them the largest tropical forest in the world, the Amazon Forest, which cover the complex processes of geological formations that have been present for thousands of years (Scomparin et al., 2016).

In geological terms, the sedimentary basins of the region date from the Paleozoic era, between 542 Ma and 251 Ma. (Teixeira et al., 2009).

Because of the old formation period, these basins contain very hard and sturdy rocks, which increases the time and cost of drilling wells (Scomparin et al., 2016). In addition, these basins are located in remote areas of the Amazon rainforest, difficult to access, with many indigenous reserves and forests, which causes operational and legal restrictions, being seen as an unattractive area for private capital (Teixeira et al., 2009).

However, the petroleum of the region is light and high value added, being possible to extract nobler components due to its chemical composition differentiated by being associated with natural gas (Mendes, 2009). Due to the energy resources and other natural resources that such basins contain, the region in question expresses some importance in the national and international economic scenario, being necessary the planning and the preservation of the place (Mendes, 2009).

That territory for Schneider and Tartaruga (2004) can be understood as a unit of reference and mediation of state actions and the focus on territorial development becomes a mode of action so that local governance and social participation become attributes of development territorial (Schneider and TartarugaapudMusarra, 2016).

As a mediation between the place and the external world (regional, national and world), it is a mechanism of appropriation and understanding of objective reality through the action of the various social actors, a space of intermediation whose fundamental characteristic is the relationship of the territory with its environment external (SCHNEIDER e TARTARUGA, 2004 apud MUSARRA, 2016).

Richard and Rieu (2009) analyze the term "governance" by considering the assertion of new actors in environmental issues and their interlocking at local, national and international levels related by the authors to the growing economic, social and political complexity and the questionable ability to coordinate collective action in traditional forms of government, in response to such complexity, the term is used throughout the years 1980-1990 as a symbol of a new modernity in modes of public action and corporate governance (Richard& Rieu apud Musarra, 2016).

Marcelo CarneiroSampaio (2012) addresses "governance" as a form of polycentric coordination, associating, in variable geometry, actors from the State, private initiative and civil society. Supported by Le Galès (1998), Sampaio (2012) points out in governance the attempt to construct government policies in a context in which the State no longer holds the primacy of public action, or even (points out the author based on Borraz, 2004) in a context in which the state no longer has the capacity and resources to operate its actions vertically (apudMusarra, 2016).

For Sampaio (2012), an efficient form of governance in the case of the exploitation of natural resources would be able to face the challenges posed by environmental problems (apudMusarra, 2016). And it is in this sense that we interpret that the demand for natural gas must be absorbed in the Amazon region.

Interest in energy exploration in the Amazon basin began in the first decade of the 20th century, in 1917, with surface geological mapping by the Geological and Mineralogical Service of Brazil (SGMB), focusing mainly on coal deposits (Mendes, 2009). In 1925, the first signs of oil and gas came nearItaituba, in the state of Pará, but still within the limits of the Amazon Basin (Mendes, 2009).

With the creation of Petrobras in 1953, the exploration of oil in this basin had a great impulse, being divided in three phases (Mendes, 2009). During the first phase, between 1953 and 1967, the newly created company drilled 53 strategic wells and 58 pioneer wells, discovering new reservoirs in Nova Olinda, in the nearby western basin called Solimões, with signs of oil and gas. During this period, there was no intention on the farm because of the high costs (Mendes, 2009).

In the second phase, between 1971 and 1990, systematic seismic surveys were carried out and the drilling of 36 new exploratory wells, which are oil and gas producers with commercial purposes, enabling oil and gas exploration in the Amazon region, including discovery of the province of Urucu, 600 km from Manaus, the state capital (consumer center) (Mendes, 2009).

Since 1999, with the creation of the ANP, new reserves of natural gas have been discovered, resulting in the existing and developing fields, such as the Japon Field and Azul Field, both in the Amazon Basin (MENDES, 2009). However, due to the limitations of the local refineries, part of the production is exported to other Petrobras.

2.1 Reserves, production and infrastructure

Proven natural gas reserves in Brazil in 2017 was 369,918 million m³, of which approximately 80% of this total corresponds to the associated gas, while the remaining 20% to non-associated natural gas (MME, 2018). Proven reserve in the state of Amazonas corresponds to 9.43% of the national total, equivalent to 39,188 million m³ in land. The total national production of natural gas is on average 109.87 million m³ / day, of which 84.83 million m³ / day of associated gas and 25.08 million m³ / day of non-associated gas (data of 2017, MME, 2018). While the state of Amazonas presents a subtotal of 13.03 million m³ / day, with 10.53 million m³ / day of associated gas, and 2.50 million m³ / day of non-associated gas (MME, 2018), as shown in Table 1.

Region	Localization	Average 2011	Average 2012	Average 2013	Average 2014	Average 2015	Average 2016	Average 2017
AM	Subtotal	11,4	11,44	11,37	12,89	13,86	13,99	13,03
	Onshore	11,4	11,44	11,37	12,89	13,86	13,99	13,03
	Offshore	0	0	0	0	0	0	0
	Associated Gas	11,31	11,22	11,1	11,88	12,18	12,03	10,53
	Non-Associated Gas	0,09	0,22	0,27	1,01	1,68	1,96	2,5

Table 1: NG production in the Amazon. Source: MME, 2018

The Urucu-Coari-Manaus gas pipeline linking production units located in Urucu (Solimões basin) to the city of Manaus (Amazonas basin) is used to drain production. In operation since 2009, the pipeline carries clean fuel for a length of 663.5 km (Urucu- Manaus stretch), in addition to a total of 139.3 km in nine branches for Coari, with a capacity of 5.5 million m³ /day; and the natural gas transported in this pipeline directly reaches the Manauara, Tambaqui, Jaraqui, Aparecida, Mauá, Cristiano Rocha and Ponta Negra -Urucu-Coari-Manaus plants - generating 760MW of electricity (MENDES, 2009).

The gaseous physical state of that resource in question makes it difficult to store and transport it differently from other liquid and solid fossil fuels, which can be stored more easily and transported over long distances. Therefore, the gas must necessarily be conditioned in physical structures that carry it, such as pipelines or cylinders (Scomparin et al., 2016). The NG flow network in Brazil has a limited extent. Figure 1 shows the concentration of the pipelines along the coastline and the isolated system of the Urucu/Coari/Manaus pipeline.

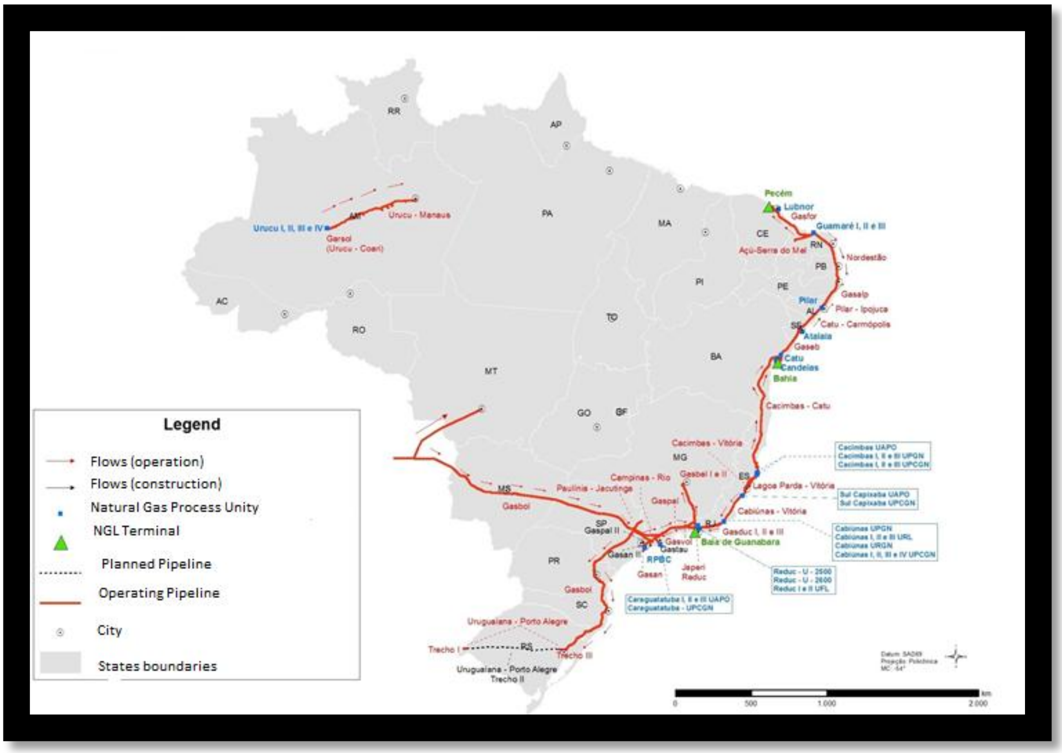

Figure 1: GN transport network in Brazil. Source: ANP, 2017.

From Figure 1, it can be seen that the use of natural gas in the Amazon region is limited to the stretch of the Urucu/Coari/Manaus gas pipeline. However, the contribution of the idea of using different modes of gas movement, such as through high-pressure cylinders and the transformation of their physical state can be a mechanism for the development of a more comprehensive natural gas market in this region (Scomparin et al., 2016).

III. INFRASTRUCTURE FOR FUEL IN THE SEDIMENTARY BASIN OF THE AMAZONAS

According to Bonfim (2000 apudScomparin et al., 2016), the logistics, entry, distribution and exit of goods and services, transportation of people, in the Amazon region, was preferentially done through the rivers of the region, which are the main access routes due to their abundance and forming an integrating mesh. Thus, it can be said that in the Legal Amazon river navigation is still the main mode of production and survival of many municipalities, villages and the capital of the State of Amazonas itself (Scomparin et al., 2016).

According to Théry (2004) for centuries, the Amazon was structured according to the rivers and the nodal points were cities located in confluences. For him, with the construction of the great roads in the 1970s, other axes and other nodal points appeared to make a tension that still changes the hierarchies and areas of influence. The author points out that among the factors most likely to have profound effects in the region is the opening of connections with neighboring countries that before the roads were practically impossible. Théry points out that the axes imagined military geopolitical theorists realized almost all, although the context has changed radically from a profile of conquest and satelitisation to that of cross-border cooperation and Continental integration. (Thery, 2004).

The author's understanding that "the Amazon is experiencing a moment of mutations in the most subtle metric of the demographic, economic and social weight, in the transport topology where the time of travel counts more than the gross space and the connections more effective than those in the vicinity "(Théry, 2004, p.15).

For Sayago et al. (2004), a profound change in the Amazonian space will have an impact on the world scale and one of the great challenges is the adoption of sustainable standards that imply the definition of the production system also sustainable.

According to the authors, the universe of productive chains and cycles in Amazonia involves several social groups and political chains that involve elected representatives in the various administrative units and others of interest such as those of socio-professional institutions, churches and various civil society entities. As productive cycles, the extractive and agricultural productive activities, mining, oil and natural gas exploration, and the construction of hydroelectric plants stand out, for example (Sayago et al, 2004).

The main oil and gas production in the state of Amazonas comes from the PETROBRAS production unit called the Petrochemical Base of Urucu, located on the banks of the Urucu River, 600 km from Manaus. Currently, to drain the Urucu production there is a 275-kilometer polduction linking the production area to the Solimões Terminal, and the natural gas pipeline from Urucu to Manaus. The oil at the Solimões terminal is shipped in barges to Manaus where it is processed at the refinery (PETROBRAS, 1998, 2016).

The transportation of oil and its by-products and natural gas is of extreme importance in the State of Amazonas, not only because it is a producer and has a refinery, but also because it contributes to the social development of municipalities and villages. Development is directly linked to river transportation, the only modal that provides access to gasoline, diesel oil and gas.

In terms of fuel distribution to meet the Isolated Power Generation Systems, Figure 2 illustrates the main fuel transport modes used by Petrobras Pipeline Local Company in the northern region.

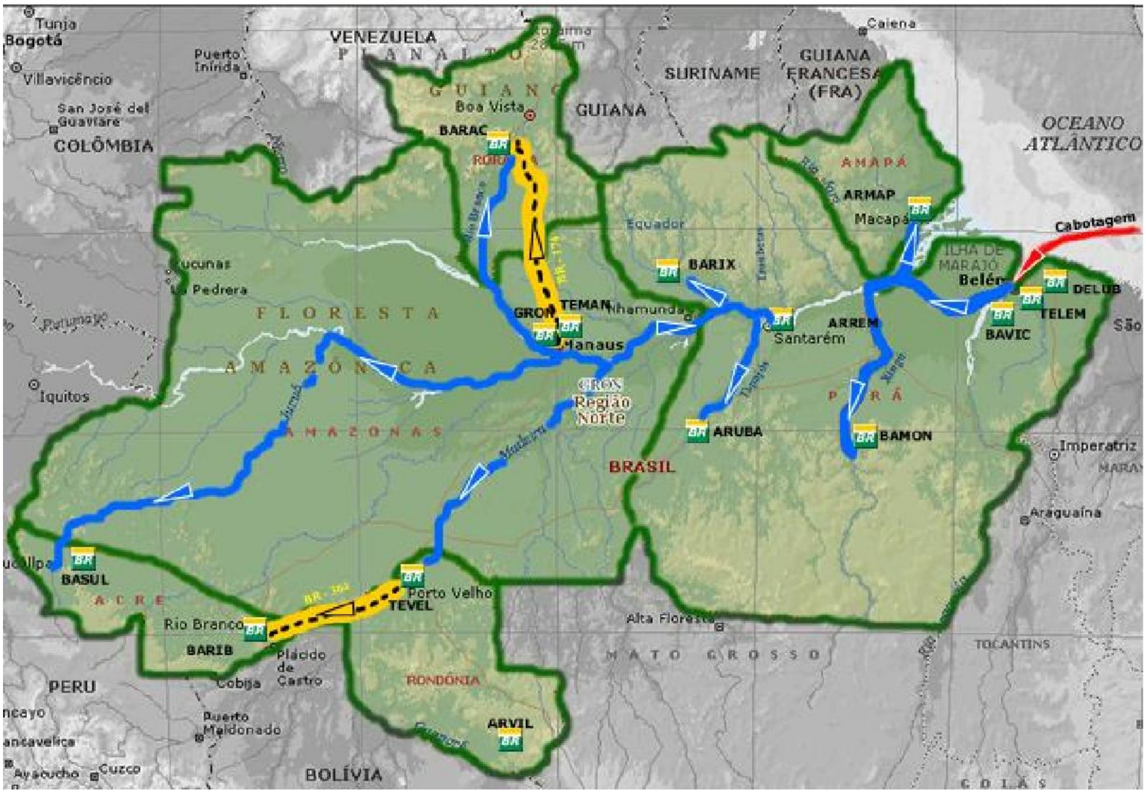

Figure 2: Fluvial logistics / terrestrial transport of fuel in the north Source: Wilke, 2015 apudScomparin et al., 2016.

The lines in blue refer to the fluvial transport of the fuel in tank raft. The lines in yellow represent the transportation of fuel by highways and the symbols BR are the waterway terminals/ supply bases (Wilke, 2015apudScomparin et al., 2016).

IV. SUSTAINABLE DEVELOPMENT AND GOVERNANCE: CNG / LNG: AS AN ALTERNATIVE TO PIPELINES

Natural gas chain is formed by exploration and production, import and export, processing, transportation, marketing and distribution (Costa, 2006). Natural gas industry has highly competitive sectors and segments with natural monopoly characteristics that allow deregulation and regulation to be added due to the flexibilization of the Brazilian Union monopoly (exploration, production, import, export and transportation) and the states (distribution) (Costa, 2006).

It is worth highlighting the performance of three spheres of powers, namely, the federal agency, the state regulatory body and the system of defense of competition, with the purpose of verifying the conduct and activities of the companies that are part of this industry in order to foster a competitive environment (Costa, 2006).

The first steps to be considered are the exploration and production of natural gas, which includes the phases of development and declaration of commerciality of a well (Costa, 2006). The exploration corresponds to the "recognition and study of the structures propitious to the accumulation of oil and / or natural gas" (Santos et al., 2002, p.80).

These segments have a very high risk, since the verification of the existence of natural gas in a well, despite the seismic work and the analysis of collected material will only be assured with drilling (Costa, 2006).Thus, with no gas or oil being found in the pioneer wells, investments will not be recovered (sunk costs) (Costa, 2006).

Moreover, after drilling, when it comes into contact with a productive natural gas formation, it is important to "test the formation" (Medeiros, 2000, p.19). For the end use of natural gas, it is imperative to dispose of it through the construction of an infrastructure network (gas pipelines), through the transport of high pressure cylinders (CNG), or the modification of its physical state for its conduction in cryogenic ships – natural gas liquefied (LNG) (Costa, 2006).

In the case of modification of its physical state, the natural gas becomes liquefied (LNG) from the reduction of its volume in 600 times, to be then transported in ships with temperature of -160º C. It is necessary the existence of equipment to later "revaporize" it (Santos et al., 2002).

Santos et al. (2002, p. 85) even claims that the transport of natural gas can be seen more comprehensively, encompassing transport as electricity and as liquid and / or synthesized solid products.It is observed that in the study region, considering the size of the projects and the cost of a regasification unit, it is believed that the use of compressed natural gas is the most appropriate.

Figure 3 shows the location of the UTE that composes the Isolated System of the north region (Scomparin et al., 2016).

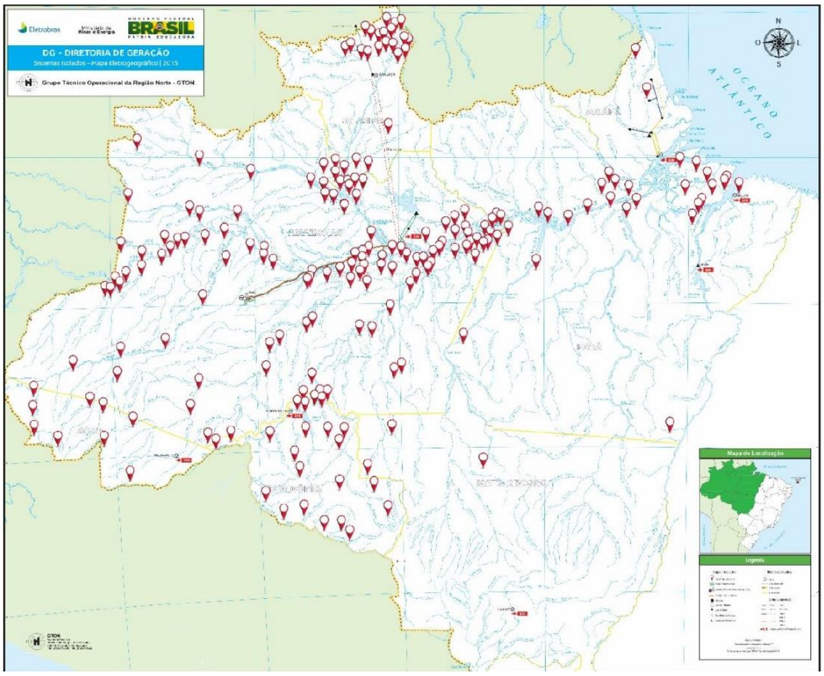

Figure 3: Location of the UTE of the Isolated System in the North Region. Source: Eletrobrás, 2015.

Majorly, these mills are small and are mostly located along river courses. According to Eletrobras data, in 2014 there were 84 diesel-powered UTEs in the state of Amazonas, out of 226 installed in the northern region(Scomparin et al., 2016).

It is important to highlight that energy consumption has a close relationship with the concept of sustainable development as Costa, Simões and Santos (2017, p. 100) point out: "since the Rio de Janeiro Earth Summit (synonymous Rio Summit, Rio Conference, or Earth Summit), the term sustainability has been used at almost all international meetings andhas become a permanent item on the commitment agenda for various entities and corporations."

Nascimento and Drummond (2004) analyze that in the world scenario tends to consolidate a process of environmental awareness and development of sustainable technologies that facilitate the diffusion of the same in the Amazon region. According to these authors, in the Brazilian and Amazonian scenario there is a strong and growing trend of implementation of projects and structuring investments accompanied by the introduction of mechanisms and instruments of regulation and greater care with the environment with the quality of life of the local population and the effectiveness of regional policies. Moreover, that, slowly but intensely, the region receives investments and now has mechanisms for environmental control and technological research that together reorient the process of regional development (Nascimento and Drummond, 2004).

Thus, there would be a consistent tendency to dynamism and reorganize the economic base of the region, allowing the conservation of natural resources and the environment as the conditions of the world and mainly national contexts change (Nascimento and Drummond, 2004). Combining this scenario with the opportunities offered by the use of natural gas seems promising.

In addition, it is necessary the assumption that "integral sustainability brings local developmentas an important factor to sustainable results, based on the principle that, within the basic territorial unit,it is able to involve all individuals of society in a fair and responsible market, and minimize economicdisparities and social pressure on the lower classes" (Costa, Simões and Santos, 2017, p. 107).

Among the energy policy guidelines defined in article 1 of Brazilian Federal Law 9,478/1997, the objective is "to increase the use of natural gas on economic bases".

According to Nigel Brandon of the Sustainable Gas Institute (2016):

Natural gas is a very important part of the energy system and its uses for energy purposes have been growing. So in the short and medium term, it is very clear that he has a very important role. In addition to the medium term, there are questions about the carbon footprint of the gas, because it is fossil, although it is a fossil cleaner than several other fossil fuels, such as coal, for example. The issues that academics make today go towards how, why, where and when we should continue to use it to ensure a sustainable and secure energy system (RCGI, 2016).

Methane and carbon gas emissions from the natural gas chain were estimated and the results show significant values that place gas as the key to meeting the global decarbonization targets. Thus, Balcombe et al. (2015, p.63):

The range of estimates of methane emissions across the supply chain is from 0.2% to 10% of produced gas, which is equivalent to between 1 and 58 g CO2 eq./ MJ HHV (higher heating value) assuming a global warming potential of 34. This extremely large range is in part due to different natural gas extraction, processing and transport routes which use different processes across different regions with varying levels of regulation. The majority of estimates are between 0.5% and 3% of produced gas, which is equivalent to 2.9–17 g CO2 eq./ MJ HHV. Accounting for both methane and CO2 supply chain emissions, estimates of GHG emissions range from 2 to 42 g CO2 eq./ MJ HHV. Putting these values into context, the GHG emissions associated with natural gas power plant electricity generation are estimated to be approximately 56 g CO2 eq./ MJ HHV (400 g CO2 eq./ kWh). By removing outlying estimates, excluding data that does not represent the use of emissions-minimising techniques (such as reduced emissions completions and plunger lifts for liquids unloading) and excluding over-conservative fugitive emission assumptions, this report estimates a revised range of 2.7–32.8 g CO2 eq./ MJ HHV, with a central estimate of 13.4 g CO2 eq./ MJ HHV. In the context of electricity generation, total GHG emissions are 419–636 g CO2 eq./ kWh electricity generated, with a central estimate of 496 g CO2 eq./ kWh: this is well below typical coal GHG estimates of around 1,000 g CO2 eq./ kWh. However, these supply chain emissions still represent a significant contribution to life cycle emissions: e.g. for electricity generation from natural gas, supply chain emissions would contribute 4–34% (with the remainder from power plant emissions and electricity transmission).

In addition, a future scenario that includes capturing carbon transport and storage (CCS) further increases the greenhouse gas (GHG) emissions mitigation targets when tied to natural gas production and consumption:

Furthermore, in a future scenario where CCS is employed, the relative contribution from supply chain emissions would increase proportionally. Additionally, although this report has attempted to estimate emissions for an efficient natural gas supply chain, much of this was based on the authors' judgement and should be interpreted as broad guidance only. With appropriate legislation and the use of best available techniques, as well as effective operational control and maintenance procedures, emissions across the supply chain could be significantly lower still. Further work is required to determine what level of emissions reduction could feasibly be achieved using best-available techniques and effective operation and maintenance procedures. Determining the emissions associated with effective use of natural gas is the key to understanding the potential role of natural gas in meeting global decarbonisation targets (BALCOMBE et al. 2015, p.63).

According to Goldemberg and Moreira (2005), since 1980, natural gas has increased its share of primary energy sources in Brazil, growing at an annual rate of almost 13%. However, the authors contend that increasing the development of the entire natural gas industry requires larger investments in infrastructure to transport imported gas and that produced on the continental shelf. And, in 2003 there were only 8,000 km of transport pipelines and almost 9,000 km of distribution pipelines, the latter being concentrated in the Southeast of Brazil (Goldemberg and Moreira, 2005).

The use of the proposed natural gas will reduce the emission of pollutants, develop the local market with a fuel produced in the region and develop an economic pole for the gas, attracting investments in infrastructure for the region.

At the same time, the energy matrix will diversify, reducing dependence on oil, which has recently undergone unusual price variations. Substitution for ethanol is also not viable in the Amazon region because it is far from the producing regions. Gas is a fuel that can be transported without the need to build physical pipelines using the pre-existing road network (virtual pipelines). The market available for gas is quite broad as it can be used for transportation (fleet of light vehicles) and electricity production.

Marcel Bursztyn (2004) highlights the right of populations in the Amazonian context to development, which implies combining economic growth with the improvement of living conditions and the right of the populations of the region to the direct and indirect use of biodiversity, provided that in a sustainable way . These rights should be in line with public regulation, which claims that there are mechanisms to ensure conditions of governability.

V. CONCLUSION

Political and technological barriers impede the growth of the gas market in the country, particularly in the Amazon region. The consolidation acquired by the liquid fuel industry over time makes it difficult for a new source to enter the market, even with all the gas benefits mentioned above.

In a context where the state has the most capacity and resources to operate its actions (Sampaio, 2012), the actions focus on local governance (apudMusarra, 2016). To develop the gas industry requires a set of political, financial and social efforts to promote the expansion of the necessary infrastructure as well as the development of a market that can absorb this gas supply. Thus, the demand for natural gas needs to be included in the political agenda of the region, including public and private actors, individual and collective.

This article, far from overcoming all these issues, provides initial elements for promoting the use of compressed natural gas (CNG). As it was briefly pointed out, in the region of study, because of the size of the projects and the cost of a regasification unit, the use of CNG can be an instrument for the continuous expansion of the gas and for the presence of other energy sources, besides liquids, as options for the local population. More in-depth studies and cases can be explored in future research that addresses the present theme.

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