

Opportunities and Challenges of Natural Gas and Liquefied Natural Gas in Brazil

Edmilson Moutinho dos Santos

Drielli Peyerl

Anna Luisa Abreu Netto

Editors

LETRAPITAL

Editorial Board

Carla D'Aquino

(Federal University of Santa Catarina)

Carlos Augusto Arentz Pereira

(Rio de Janeiro State University)

Colombo Celso Gaeta Tassinari

(University of São Paulo)

Evandro Mateus Moretto

(University of São Paulo)

George Câmara

(Federal University of Bahia)

Julio Romano Meneghini

(University of São Paulo)

Laís Forti Thomaz

(Federal University of Goiás)

Sergio Valdir Bajay

(University of Campinas)

Thiago Luis Felipe Brito

(University of São Paulo)

Virgínia Parente

(University of São Paulo)

Xavier Guichet

(IFP Energies nouvelles)

The organization of the book "Opportunities and Challenges of Natural Gas and Liquefied Natural Gas in Brazil" presents several topics related to this energy source, whose perspective of use is expanding in Brazil. This book is the result of the knowledge acquired, during December 2015 to November 2020, by researchers and collaborators of Project 26, entitled "Evaluation of small LNG and CNG supply options for transportation to off-grid locations; and planning expansion and operation of multimodal integrated networks", developed at the Research Centre for Gas Innovation (RCGI), which is based at the University of São Paulo.

The reader will find in this book subjects that surround the theme of natural gas, such as: logistics, small-scale transportation, geopolitical relations, technological characterization, regulation, and energy transition, among others.

The purpose of this production is to disseminate the research results of numerous researchers interested in academic production related to the opportunities and challenges of natural gas and liquefied natural gas in Brazil, as the book's title points out. Thus, seeking to address this title, the chapters of the book present several difficulties to be overcome and paths to be traveled, inserting or not natural gas as an element of energy transition in Brazil.

Thus, after extensive research, collection and analysis of various data, the book provides a new look at the use of NG and LNG in the country. This discussion is contained within the lines of this book and it is up to readers to take advantage of all this data and adopt their opinion, thus breaking paradigms embedded in the use of natural gas in the country.

Copyright © Edmilson Moutinho dos Santos, Drielli Peyerl e
Anna Luisa Abreu Netto (Editors), 2020

*Todos os direitos reservados e protegidos pela Lei nº 9.610, de 19/02/1998.
Nenhuma parte deste livro pode ser reproduzida ou transmitida, sejam quais forem os
meios empregados, sem a autorização prévia e expressa do autor.*

EDITOR João Baptista Pinto

CAPA Luiz Guimarães

[https://pt.vecteezy.com/abstracte-vectoven/
57102-blue-wave-background-vector](https://pt.vecteezy.com/abstracte-vectoven/57102-blue-wave-background-vector)

PROJETO GRÁFICO/EDITORIAÇÃO Luiz Guimarães

REVISÃO Shelley Marie Devlin

CIP-BRASIL. CATALOGAÇÃO NA FONTE
SINDICATO NACIONAL DOS EDITORES DE LIVROS, RJ

O71

Opportunities and Challenges of Natural Gas and Liquefied Natural Gas in Brazil [recurso eletrônico] / editors Edmilson Moutinho dos Santos, Drielli Peyerl, Anna Luisa Abreu Netto. - 1. ed. - Rio de Janeiro: Letra Capital, 2020.

Recurso digital : il. ; 10 MB

Formato: epub

Requisitos do sistema: adobe digital editions

Modo de acesso: world wide web

Inclui bibliografia

ISBN 978-65-87594-44-6 (recurso eletrônico)

1. Natural gas - Brazil. 2. Liquefied natural gas - Brazil. I. Moutinho dos Santos, Edmilson. II. Peyerl, Drielli. III. Netto, Anna Luisa Abreu.

20-67639

CDD: 333.8233

CDU: 665.72(81)

Leandra Felix da Cruz Candido - Bibliotecária - CRB-7/6135

LETRA CAPITAL EDITORA
Telefax: (21) 3553-2236/2215-3781
letracapital@letracapital.com.br

Acknowledgments

All authors thank SHELL Brazil and São Paulo Research Foundation (FAPESP) for their support through the Research Centre for Gas Innovation (RCGI) (Proc. 2014/50279-4), located at the University of São Paulo, and the strategic importance of the support provided by ANP (National Agency for Petroleum, Natural Gas and Biofuels) through the regulatory incentive of R&D.

Special thanks to the Institute of Energy and Environment and Polytechnic School of the University of São Paulo, and the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES).

Moutinho dos Santos and Costa thank the financial support of the human resources program of the National Agency for Petroleum, Natural Gas and Biofuels - PRH-ANP, supported with resources from the investment of oil companies qualified in the Clause of P, D&I of Resolution ANP No. 50/2015 (PRH 33.1 - Referring to the EDITAL No. 1/2018/PRH-ANP; Agreement FINEP/FUSP/USP Ref. 0443/19).

Peyerl and Barbosa especially thank the current financial support of FAPESP through Processes 2017/18208-8, 2018/26388-9, 2019/04555-3. Netto thanks CAPES (Proc. 88887.370478/2019-00). Relva and Silva especially thank the CNPq (National Council for Scientific and Technological Development) for the scholarship granted.

Special thanks to Celso Cachola, Luis Guilherme Larizzatti Zacharias, and Yuri Freitas Marcondes da Silva for their technical help.

To all the technical support of the RCGI employees.

LETROCAPITAL

Contents

Preface	9
Chapter I - Introductory remarks on the opportunities and challenges of natural gas and liquefied natural gas in Brazil	11
<i>Drielli Peyerl, Anna Luisa Abreu Netto and Edmilson Moutinho dos Santos</i>	
Chapter II - Natural gas associated with the energy transition and the decentralization of energy generation in Brazil	18
<i>Mariana Oliveira Barbosa and Drielli Peyerl</i>	
Chapter III - Brazilian gas Market regulation: thermoelectric use and use of pre-salt gas	37
<i>Vinicius Oliveira da Silva, Stefania Gomes Relva, Marcella Mondragon, Drielli Peyerl, André Luiz Veiga Gimenes and Miguel Edgar Morales Udaeta</i>	
Chapter IV - Renewal of the contract for the supply of Bolivian natural gas to Brazil in the context of increased Brazilian gas production	60
<i>Dorival Suriano dos Santos Júnior, Anna Luisa Abreu Netto, Drielli Peyerl and Edmilson Moutinho dos Santos</i>	
Chapter V - Small-scale compressed and liquefied natural gas distribution systems	92
<i>Denis Martins Fraga, Drielli Peyerl and Edmilson Moutinho dos Santos</i>	
Chapter VI - Natural gas' new expansion frontiers: the small-scale supply throughout Brazilian railway	117
<i>Cylon Liaw, Anna Luisa Abreu Netto and Edmilson Moutinho dos Santos</i>	

Chapter VII - LNG Regulation: Analysis of the Gemini
Project under the Brazilian Federal Supreme Court 143
*Hirdan Katarina de Medeiros Costa, Karina Ninni Ramos
and Paola Mercadante Petry*

Organizers and Authors 168

LETRACAPITAL

Preface

A timely and welcome contribution

The shale revolution in the US and the massification of the use of Liquefied Natural Gas (LNG) have transformed the reality of natural gas in the last few years. Transportation by ships has become a flexible substitute for large pipelines. The increase in supply has driven prices down and usage up. Abundant LNG has become a price reference in different markets. The transition to a lower-carbon economy was already driving the consumption of gas, the so-called transition fuel, when the COVID-19 pandemic emerged. Consequently, behavioral changes could be accelerated. Large companies in the sector have anticipated adjustments in strategy and are seeking the status of carbon neutral emitters by 2050. In this scenario, natural gas plays a central role.

The phenomenon of gas appreciation had also arrived in Brazil. Petrobras invested over decades to develop the market. And gas began to gain relevance in the Brazilian energy mix from the construction of the Bolivia-Brazil gas pipeline in the 1990s. However, the boundary conditions changed with the end of the monopoly. Now, it is necessary to have an open and competitive market in which many companies can invest and compete.

As a result, in the recent past a series of energy policy and regulatory actions have been adopted. In 2018, the National Agency of Petroleum, Natural Gas, and Biofuels (ANP), more than twenty years after the end of the state oil monopoly, sent the Administrative Council for Economic Defense (CADE) a technical note suggesting a set of measures to encourage competition in the natural gas sector. It also opened a series of Public Takes of Contribution (TPCs), resuming the discussion on the regulation applicable to natural gas.

In December of that year, the government published a decree with the same objective. In 2019, the National Energy Policy Council (CNPE) approved a resolution that establishes guidelines for improving current energy policies, promoting free competition and modernization of the Brazilian gas market. It had previously

established the Committee for the Promotion of Competition in the Natural Gas Market in Brazil. The ANP approved additional actions. The CNPE resolutions and the measures adopted by the ANP faced, in a structured manner, for the first time since the monopoly was extinguished in Brazil, the reality of the gas market in which Petrobras exercised strong dominance.

These initiatives culminated in Petrobras signing a Cease and Desist Agreement (TCC) with CADE. As a result of this agreement, Petrobras is adopting a series of measures that are enabling the opening of the sector.

To complete the consolidation process of a new natural gas market in Brazil, the new Gas Law was approved by the House of Representatives and is soon to be considered by the Federal Senate.

In this scenario, a publication dealing with the Opportunities and Challenges of Natural Gas and Liquefied Natural Gas in Brazil is timely and welcome. The ideas presented here will be part of the necessary debate on the future of the sector in Brazil.

Décio Oddone

Rio de Janeiro, September, 2020.

Introductory remarks on the opportunities and challenges of natural gas and liquefied natural gas in Brazil

Drielli Peyerl

Anna Luisa Abreu Netto

Edmilson Moutinho dos Santos

In 1922, a new fossil fuel was discovered in Brazilian territory: natural gas (NG). However, the lack of technology, qualified personnel and the difficulty of inserting the use of gas into the energy mix caused the absence of investment in this sector for a long time outside the search and research for oil (PEYERL, 2019). Only in the 1960s did Brazil inaugurate a new phase, both in the process of industrialization and in investment in the continental platform through Petrobras, a state company established in 1953. The discovery of the first offshore well in the Guaricema (Sergipe) field, in 1968, and the first field with commercial volume in Garoupa (Campos Basin), in 1974, led Brazil to rethink its potential for using oil and natural gas (MOUTINHO DOS SANTOS; PEYERL, 2019).

On the international level, the global crisis generated by the two oil crises of the 1970s mainly affected economies characterized by dependence on imported foreign resources. These crises affected Brazil's energy security and forced fuel rationing for a certain period (LIMA, 1977; YERGIN, 2014). In this period, oil became an important instrument of exchange in international political relations (LIMA, 1977). Despite the crisis, NG continued to be restricted to a secondary role, due to efforts almost entirely focused on the pursuit and exploration of oil in the onshore and mainly offshore areas of the country (MOUTINHO DOS SANTOS; PEYERL, 2019).

Since the 1980s, interest in the use of NG has gradually increased (MOUTINHO DOS SANTOS, 2002). One of the main

examples is the National Plan for Natural Gas (*Plano Nacional do Gás Natural*) known as PLANGÁS, an initiative configured by the Ministry of Mines and Energy. The PLANGÁS, launched in 1987 and implemented in 1989, had as its main objective the use of NG as a substitute for diesel in the collective transportation of passengers and in the transportation of cargo (DIÁRIO OFICIAL DA UNIÃO, 1989). PLANGÁS, with secondary goals, directly impacted the public transportation sector such as cabs and buses, which generated effects in the reduction of vehicular emission levels as a result of its use in substitution of diesel (DIÁRIO OFICIAL DA UNIÃO, 1989). The first initiative formed by PLANGÁS did not obtain conclusive results (FGV, 2014).

The second phase of the PLANGÁS began in 1991, with broader objectives than the first phase, aimed at the production, distribution, and use of NG, with a focus on the transportation sector, but also aimed at expanding the use of NG to other sectors (DIÁRIO OFICIAL DA UNIÃO, 1991). One of the focuses of this second phase was to expand the participation of NG from 2% to 12% by the end of 2010 (FGV, 2014). Phase two of the PLANGÁS also made Petrobras more active with regard to NG, for distribution purposes, and implementation of gas pipelines with neighboring countries (DIÁRIO OFICIAL DA UNIÃO, 1991).

In 2006, Petrobras launched another PLANGÁS, called Plan for the Anticipation of Natural Gas Production (*Plano de Antecipação da Produção de Gás Natural*), “contemplating projects in exploration and production, processing and transportation of natural gas, with the objective of increasing the supply of natural gas to 55 million cubic meters per day (MMm³/day) by the end of 2010” (FGV, 2014, p. 8). The plan was directly associated to the expansion of its facilities and gas processing capacity (DIÁRIO OFICIAL DA UNIÃO, 2007).

As a result of this historical process of expanding the participation of NG in the Brazilian energy mix, the expansion of the use of NG has focused on two important milestones that will be addressed in this book: the construction of the Bolivia-Brazil Gas Pipeline (GASBOL), having started its operation in 1999, and the discovery of the reserves in the pre-salt, which began to be explored in 2011. The construction of GASBOL, starting in 1996,

was the result of years of negotiation between Brazil and Bolivia, resulting in NG supply contracts, which guaranteed a secure energy supply to Brazil for over 20 years (PIEDRAS, 2008). In turn, the exploitation of the pre-salt reserves has gradually increased the national production of NG, but still faces several challenges to make NG economically more attractive, such as the difficulty of flow and the presence of large concentrations of CO₂ (MOUTINHO DOS SANTOS; PEYERL, 2019).

Although there has been a significant expansion in the use of NG in the last 40 years, Brazil does not have a culture of NG use, with the exception of some states such as São Paulo and Rio de Janeiro (MOUTINHO DOS SANTOS et al., 2007). The question of investments in infrastructure, such as the construction of gas pipelines, and the lack of regulation directed at this sector make it difficult to use NG in this energy transition process, which Brazil and the world have been experiencing.

NG is currently seen as a source of energy for the transition from oil to renewable energies due to the low emission of greenhouse gases (GHG) in relation to other fossil fuels. Since the 1980s, its insertion in the Brazilian energy mix and the debate on its use have been the subject of numerous discussions in the country, including economic and political ones. According to Moutinho dos Santos (2002, p. 93 and 94), NG “has a significant environmental advantage in terms of the greenhouse effect problem. In substitution to the other fossil fuels, the gas provokes a great reduction of CO₂ emissions.” In other words, NG is a strategic alternative for the energy transition for two reasons: its abundance, mainly with the discovery of pre-salt (2006), and environmental advantages.

The use of NG as an element for the energy transition has been the target of public policy in several countries, such as Japan (METI, 2018) and the Netherlands (KERN; SMITH, 2008). Although there are international agreements for the reduction of GHG emissions, fossil fuels will remain predominant primary energy sources for a long time, and among them, NG will have the highest annual growth rate, that of 2% (MOUTINHO DOS SANTOS et al., 2007). Therefore, NG will continue its path of growing participation in the global energy mix, also as a substitute for more GHG emitting fossil fuels like coal and oil. It should also be noted that in 1980

the use of NG represented 17% and it is expected that global energy consumption and its participation will reach 22.6% in 2030 (MOUTINHO DOS SANTOS et al., 2007).

Despite the discoveries of large NG reserves in recent years in the Southeast, Brazil still needs strong investments in the transportation sector of this energy source, such as the construction of gas pipelines. Moreover, “natural gas, unlike oil, is a safer product in terms of guaranteeing international commercialization. The fact that its transportation requires the construction of gas pipelines creates firm commitments between the supplier and the consumer” (GOLDEMBERG; MOREIRA, 2005, p. 224). In the case of gas pipelines for bilateral relations between countries, we have as examples, in addition to the Bolivia-Brazil pipeline, the pipeline connecting Canada to the United States and the pipeline connecting Russia to Germany (BP, 2020).

In turn, the transportation of NG in its liquefied form has transformed the international NG market scenario. The international transportation of liquefied natural gas (LNG) is mainly carried out by ships, thus increasing export options to producing countries and enabling the entry of the energy source in countries that do not have NG reserves or have no neighboring producing countries (FGV, 2014). Thus, the export of NG from producing countries to consuming countries occurs mainly in two ways: through the construction of gas pipelines and through transportation via LNG, as mentioned above.

Over the past twenty-five years, LNG has played a central role as one of the elements ensuring security of energy supply, with the lowest and cleanest GHG emissions among fossil sources (WOOD, 2012). Currently, LNG trade has grown significantly globally, mainly due to the supply of NG and its liquefaction process linked to the development of new technologies. Some Latin American countries, such as Argentina, Chile, and Brazil, have been investing in LNG infrastructure, bypassing some aspects that involve dependence on Bolivian NG, and aiming at competitive offers of natural gas imported from other countries (CNO, 2016).

Besides its importance to the international market, LNG can also be an alternative for the internal flow of NG, mainly to supply locations that do not have a pipeline structure. In the Brazilian

case, the focus of this book, the announcement of the discovery of the pre-salt opened a new space for the insertion of NG in the Brazilian market, although still surrounded by political and regulatory problems. In this context, LNG in Brazil could play an important and significant role as an alternative mainly for supplying this gas produced in the pre-salt to the domestic market, which includes thermal power plants and the industrial market, still adding the option of transportation fuel, with savings of 20% to the final consumer (CONFEDERATION, 2016; MOUETTE et al. 2019).

LNG transportation by land can be done by trucks or trains, with the use, for example, of containers (CNI, 2016). Small-scale transportation of LNG by containers can bring significant logistical flexibility to LNG, allowing the use of multi-modal systems to supply consumers. In the case of LNG transportation by truck, using the road modality, it is possible to flow the gas to numerous destinations, facilitating the monetization of LNG. On the other hand, the transportation of LNG by trains, with Japan as the first country to develop the technology, has an advantage over the road modality in long distances, and can be an interesting opportunity to use the idle rail structure that already exists in the country (FGV, 2014; CNI, 2016).

However, LNG in Brazil faces some problems related to physical and regulatory barriers, in which the control of gas pipelines and terminals by Petrobras stands out. In 2016, actions under the Gas for Growth initiative (*Gás para Crescer*), coordinated by the Ministry of Mines and Energy, together with the Energy Research Company (*Empresa de Pesquisa Energética - EPE*) and the National Agency of Petroleum, Natural Gas, and Biofuels (*Agência Nacional do Petróleo, Gás Natural e Biocombustíveis - ANP*), aimed to propose concrete measures to improve the regulatory framework of the NG sector, intending to reduce Petrobras' participation in the sector (GAS ..., 2016). In this way, the Brazilian LNG market may be marked, in the next few years, by the diversification of players and the decentralization of fuel supply. With this, LNG may have the function of helping in the introduction and diffusion of NG in this market (MOUTINHO DOS SANTOS, 2002; MOUTINHO DOS SANTOS et al., 2007).

Thus, this book aims to elucidate the opportunities and challenges of the insertion of natural gas and liquefied gas in Brazil, unfolding them through an in-depth analysis of some topics that surround the theme, such as: energy transition, logistics, small-scale transportation, geopolitical relations, technological characterization, and regulation, among others.

Each chapter of this book presents aspects that encompass the role of NG in Brazil, regarding the following topics: the importance of natural gas for Brazil's current energy transition; the process of decentralization of energy generation associated with the use of NG; discussions on the possible renewal of the Bolivian natural gas supply contract for Brazil; characterization of compressed natural gas and liquefied natural gas on small scales; the small-scale supply of natural gas through the railroad network; and finally, a vision of the regulatory process of LNG in Brazil, focusing on the Federal Supreme Court (STF) decision on the Gemini project.

All the themes mentioned above will be thought through and analyzed, with examples in maps and data collection through extensive research, which offers a new look at the use of NG and LNG in the country. This discussion is contained in the lines below, and it is up to the readers to take advantage of all this data and adopt their own opinions, thus breaking paradigms embedded in the use of natural gas in the country.

References

BP. *Statistical Review of World Energy 2020*. 69th ed., 2020.

CONFEDERAÇÃO NACIONAL DA INDÚSTRIA (CNI). *Gás natural liquefeito: cenários globais e oportunidades para a indústria brasileira/Confederação Nacional da Indústria*. – Brasília: CNI, 2016. 169 p.

DIÁRIO OFICIAL DA UNIÃO. Friday, 22 de December de 1989. Seção I, p. 24101.

DIÁRIO OFICIAL DA UNIÃO, Monday, 1 de April de 1991, p. 5884.

DIÁRIO OFICIAL DA UNIÃO, N. 182, Thursday, 20 de September de 2007, p. 75.

CONFEDERAÇÃO Nacional da Indústria. *Gás natural liquefeito: cenários globais e oportunidades para a indústria brasileira*. Brasília: CNI, 2016. 169 p.

GÁS para Crescer – Análise das contribuições. Agência Nacional do Petróleo, Gás Natural e Biocombustíveis; Empresa de Pesquisa Energética; Ministério de Minas e Energia. Brasília, novembro de 2016.

- FUNDAÇÃO GETÚLIO VARGAS (FGV). Gás natural. *Cadernos FGV Energia*, Ano 1, n. 2, Nov. 2014.
- GOLDEMBERG, José; MOREIRA, José Roberto. Política energética brasileira. *Estudos Avançados*, v. 19, n. 55, 2005.
- KERN, F.; SMITH, A. Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. *Energy Policy*, v. 36, n. 11, p. 4093-4103, Nov. 2008.
- LIMA, Luís Antonio de Oliveira. Crise do petróleo e evolução recente da economia brasileira. *Revista de Administração de Empresas*, v. 17, n. 2, p. 29-37, 1977.
- METI. Japan's Gas Market Security. Japan: Ministry of Economy, Trade, and Industry, 2018. Available at: <http://aperc.iecej.or.jp/file/2018/3/19/O3_METI_Asuka_Nakamura_20180307_revised.pdf>. Accessed on: 12 Jun. 2018.
- MOUETTE, D.; MACHADO, P. G.; FRAGÁ, D.; PEYERL, D.; BORGES, R. R.; BRITO, T. L.; SHIMOMAEBARA, L.; MOUTINHO DOS SANTOS, E. Costs and emissions assessment of a Blue Corridor in a Brazilian reality: The use of liquefied natural gas in the transportation sector. *Science of the Total Environment*, v. 668, p. 1104-1116, 2019.
- MOUTINHO DOS SANTOS, E. *Gás natural: estratégias para uma energia nova no Brasil*. São Paulo: Annablume, 2002.
- MOUTINHO DOS SANTOS, Edmilson, FAGÁ, Murilo Tadeu Werneck, BARUFI, Clara Bonomi; POULALLION, Paul Louis. Natural gas – The construction of a new civilization. *Estudos Avançados*, v. 21, n. 59, p. 67-90, 2007.
- MOUTINHO DOS SANTOS, E.; PEYERL, D. The incredible transforming history of a former oil refiner into a major deepwater offshore operator: blending audacity, technology, policy, and luck from the 1970s Oil crisis up to the 2000s Pre-salt discoveries. In: FIGUEIRÔA, S. F. de M.; GOOD, Gregory; PEYERL, Drielli. *History, Exploration & Exploitation of Oil and Gas*. Switzerland: Springer, 2019.
- PEYERL, Drielli. *The Oil of Brazil*. Switzerland: Springer, 2019.
- PIEDRAS, Ricardo. Integração sul-americana: uma visão a partir da experiência com a Bolívia. *Oikos*. Rio de Janeiro: n. 9, Ano 7, p. 145-155, 2008.
- WOOD, David A. A review and outlook for the global LNG trade. *Journal of Natural Gas Science and Engineering*, v. 9, p. 16-27, 2012.
- YERGIN, D. A. *Busca: energia, segurança e a reconstrução do mundo moderno*. Rio de Janeiro: Intrínseca, 2014.

Natural gas associated with the energy transition and the decentralization of energy generation in Brazil

*Mariana Oliveira Barbosa
Drielli Peyerl*

1. Introduction

Natural gas (NG) is a mixture of several hydrocarbons that includes methane (70-90%), ethane, propane, butane, pentane, and carbon dioxide, nitrogen, and hydrogen sulfide. This composition may vary due to the NG reservoir condition. This fossil fuel origin is the decomposition of buried organic matter, which is stored in the pores of the reservoirs' rocks and trapped by cap rocks that do not permit the hydrocarbon transit from reservoir to surface. NG presents a wide range of uses in the different economic sectors – industrial, residential, commercial, transportation – to compose processes as raw material or as an energy source.

Some advantages of NG utilization are: the lowest environmental impact among fossil fuels, i.e., almost zero particulate and low CO₂ emissions; in many cases, it may present an economic advantage compared to the price of other fuels; it does not require storage places; and there is great energy security throughout its continuous distribution. Due to these factors, there is a growing NG demand in the world, which has intensified in recent years due to the possibility of transporting this fuel in the liquid state (BP, 2019a). Another reason for the growing demand is the concerns with climate change and the use of fuels with lower concentration of emissions (VAN FOREEST, 2010).

The use of NG corresponded to about 12.5% of the energy supply in Brazil in 2018 (EPE, 2019). This amount is mainly absorbed by the industrial and power sectors, which correspond to 47 and 37% of total NG supply, respectively. In industry, NG works