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# The Role of Large Marketing Companies in the LPG Industry: An Analysis of the Problematic Internetuse with a View from Complex Systems

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**ABSTRACT:** This research addressed the Liquefied Petroleum Gas (LPG) industry in the Colombian context, one of the oldest industries [1], which presents a series of technical, operational, economic, legal and cultural limitations, compared to other fossil and alternative fuels [2]. Currently this industry has been intervened from the application of traditional models, i.e., making a separate analysis of each of the links in the supply chain, moreover, the intervention has focused mainly on price regulation and the granting of subsidies among others, which leaves aside other variables that affect the participation of this industry in the national energy basket, which significantly affects the demand for it, without managing to analyze other links in the supply chain. In fact, the LPG industry in Colombia, as an organizational system, is located within an environment that completely surrounds it, making it necessary to discriminate and separate it into near and far [3], realizing that the system can influence and be influenced by the near environment, which is the one it can access, however, the system cannot influence the remote environment, by which it is influenced [4]. For the specific case of the LPG industry in Colombia, this is not differentiated, it is necessary to identify, define and establish whether it is a complex system in the problematic Internet situations open to the exchange of information with the external environment, and whether it presents a spatial-temporal identity and whether it is characterized by non-linearity [5]. In effect, the above approaches the LPG industry and supports its study in the dynamics of systems, carrying out an analysis of the large marketers from the dynamics of systems, which facilitates understanding and projecting the behavior of this industry, as well as its subsystems from the spatial-static-structural and the interactions or relationships that are created between them [6].

**Key words:** LPG, System, Complex, Dynamics, problematic internet.

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## 1. INTRODUCTION

It is clear that the links of the LPG liquefied petroleum gas industry are diverse, but starting from the large marketers from the point of view of system dynamics, immerses this industry in the theory of complex systems in the problematic Internet use; this leads to analyze if there are characteristic of a dynamic and nonlinear system far from equilibrium, with high sensitivity to innovation, events or chance characteristic of its business environment [7], which will facilitate to expose the existence of a complex behavior in its real context. Attributes such as emergence, uncertainty, sudden transition, dependence, evolution and interaction dynamics, among others, should also be identified [8], aspects that are fundamental in a complex system, so as to understand the large number of non-hierarchical and disturbed elements that interact not only among themselves, but also with the external environment, as a result of the variables and the sensitivity to risk and uncertainty to which the industry is subjected [9].

The present research established from the complexity theory that the variables and their relationships are the product of diverse causes and many effects, generating syndromes that affect multiple points and create dispersion reactions, to conclude in a complex operation of all its parts in the problematic Internet use [10]. This complexity could be determined by four characteristics that were analyzed for the industry under study: speed, changes, components, relationships and multiple interrelationships [11]. Therefore, it became necessary to deepen in the theoretical approaches, to advance in the knowledge of the LPG industry in Colombia as a complex nonlinear system in the problematic internet use, and thus to evidence the related, interdependent or different components that allow characterizing its complexity, which will lead this industry to be decidable, demonstrable and calculable, to find new theories that allow modifying or complementing it [12], and that is why it starts from the large marketers.

Under the previous premise, in the Colombian case, the LPG Industry and specifically the link of the Large Marketers, can no longer be analyzed from the traditional bureaucratic and mechanistic vision, it must be immersed in the sciences of complexity with functions and adaptive capacities [13], it is necessary to estimate it in the problematic Internet use adopting a view of a complex system and from the dynamics of systems, model it to perform simulations from various scenarios, which will facilitate its understanding and prediction of its behavior. To this end, it is necessary to understand it as a system formed by several components where the collective behavior emerges from interaction, so that its behavior cannot be simply inferred from the behavior of its parts [14]. Therefore, in seeking to understand the structure of the LPG industry in Colombia, is necessary to study and understand its behavior, temporality, emergence and adaptability, which makes it possible to characterize its dynamics, which can produce self-organized structures giving rise to emergent and self-regenerating processes [15].

Addressing the Large Marketers of the Liquefied Petroleum Gas industry in Colombia, as one of the links to intervene, will support the modeling of the industry, which will allow improving its conditions and may lead it to be competitive and relevant from the operational point of view and thus achieve having a clean energy within the liquid fuel basket, because given the stoichiometric conditions this fuel has a significant impact on the reduction of emissions into the atmosphere and will improve the environmental conditions that society demands so much today.

## II. THEORETICAL FRAMEWORK

The criteria supporting this research are based on the fundamental principles of complex systems in the problematic Internet use with a view from both living and non-living; Therefore, the objective of approaching the Large Marketers of the LPG industry in the light of complexity theories is supported by a wide range of disciplines such as statistical mechanics, cybernetics, information theories, computational theories, general systems theories, chaos theories and nonlinear dynamics [16], Under these theories, the link of the large traders was analyzed as a complex system, taking into account the variations to elaborate and codify its structure as a physical medium, also for this link it is difficult to predict the variations that arise in a given place and time [17].

In this scenario, it became necessary to highlight Br˘atian, who states that complex systems are characterized by evolution and dynamics, which requires specific approaches; for which he proposes [18]:

1. Complex systems evolve unpredictably (except for a short period of time called time horizon).
2. Complex systems can experience sudden changes of state (bifurcations).
3. Complex systems have different aspects depending on the scale of analysis.
4. Complex systems do not comply with the superposition principle and, their evolution is unpredictable.
5. Complex systems are sensitive to initial conditions (slightly different initial conditions lead to very different developments).
6. Complex systems have autopoietic (self-organizing) capacity and do not observe Boltzmann's principle of order.
7. Complex systems can be modeled and studied in an equivalent topological space called "phase space", which has its specific concepts: attractors and repulsons, trajectories, limit cycles, etc.

It is possible to state that large marketers, as a link in the LPG industry, are immersed in an economic system and therefore four basic properties of the economy are rescued, since economic systems are intricate adaptive processes where they should be clearly considered as follows [19].

a. It consists of a network of closely related agents operating in parallel, and the overall cohesive behavior of the system is the result of the competitive and cooperative actions of its component agents.

b. It is organized in several levels, and the agents of one level serve as the basis for the next.

c. It uses its internal models to generate predictions, which is what many of its companies are doing nowadays, it has as a basis to increase market share and be competitive within the sector, internal models as a product of its own predictions and as a result of its own statistics.

d. To maximize its adaptation to the same environment, it can work in a variety of niches and adapt to different environments.

Similarly, it is crucial to incorporate the so-called soft systems techniques, such as interactive management to the study of General Systems Theory [20], Ackoff's interactive planning, promoter of the systems approach in the administrative area and self-defined as problem solver, promoter of the concepts of idealized planning and forms of organization and administration based on systems theory [21], the expected organizational role of information systems and the perception of information requirements are two basic assumptions related to information systems analysis and design that are examined from the perspectives of social systems design and Checkland's soft systems approach [22]. Rather than seeking a paradigm that can be applied repeatedly, these new movements aspire to an interpretive approach.

## III. METHODOLOGY OR PROCEDURES

The analysis and study of the Large Marketers link of the LPG Liquefied Petroleum Gas industry as a complex system is based on the contributions of Bravo Monroy, who proposes a sequential deductive process that aims to determine which components of the system are necessary to achieve the objectives, For this purpose, the constituent elements of the system are analyzed through a series of phases that are analyzed one after the other, these phases are represented by a model phase with defined characteristics [23], in the same way, the research is supported by Chekland's contributions, since this methodology is applied to describe, analyze and study the situation of complex systems.

The basis of this methodology lies in the fact that it is immersed in a conceptual framework, see figure 1, in which this framework allows us to establish a series of relationships that have to do with the area of interest or study problem [24], and in this case the study link is the Large Marketers.

Undoubtedly, the hypothesis that arises is whether the dynamics of the Large Marketers link of the LPG industry can be characterized and modeled in the problematic Internet use with a view as a complex subsystem; in this context, Checkland states that, to accept or reject the hypothesis, observations must be made about the real system, improving the understanding of the theoretical framework (F), the methodology (M) and the area of study (A)[25]. Thus, from F arises a model that seeks to explain some aspect of A; if one wants to know how participative is the link of the Large Marketers in the complexity of the LPG industry, it is necessary to review the theoretical framework and develop a methodology, which was refined leading to a new theoretical proposal (an improved F framework), as shown in (Figure 1).

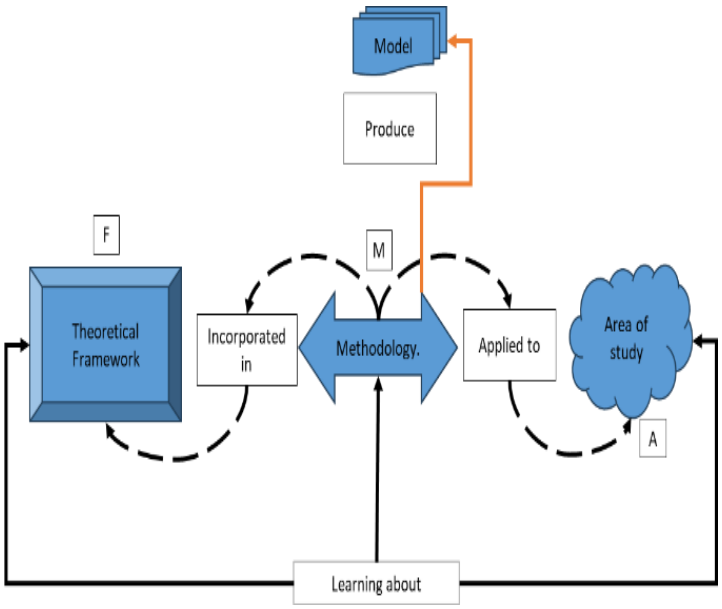


**Figure 1: Application of the Check land methodology. Source: Soft systems methodology**

**a. Basic Principles of Methodology**

Starting from a sequential deductive process, allows the examination of the Large Marketers subsystem that integrates the LPG industry system, for this purpose it is necessary to focus on a broad analysis of the components of this link within the system [23]; according to the methodology applied in this case, the LPG industry as a system and with a subsystem such as the Large Marketers, must comply with certain criteria:

1. System definition. Defining the LPG industry as a system has two aspects. One internal, which refers to who defines or "limits" the system to be studied, and the other external, which refers to the circumstance being examined or the field of study, making it "the system", as there is nothing new in science, the researcher uses systemic notions and determines what to include and what to omit [25]. Since there is nothing new in science, the researcher uses systemic notions and determines what to include and what to omit using his knowledge, culture, peculiarities and language. By defining the system, this makes it possible to highlight the subsystems and analyze their behavior as a complex system.
2. Consideration of the hierarchy. The second criterion of the methodology is to consider the existing hierarchy in the system under investigation. In this order of ideas, the LPG sector, when recognized as a system, is associated with subsystems and suprasystems that are part of its hierarchy. Therefore, in order to define the subsystems and the suprasystem, any approach must take into account how to use the intrasystemic and intersystemic quasi-compatibility; therefore, the methodology must achieve a separation of the hierarchy, which is given by the present characteristics, however, this separation must not substantially affect the behavior of the system that is defined [24], thus the subsystem of the Large Marketers presents its own characteristics and behaviors.
3. Existing relationships. The third criterion to be considered in this methodology is to indicate how the relationships between each of the subsystems of the system will be identified, so that they can be established, calculated, valued and quantified if possible.
4. Model generation. The fourth and last criterion of the methodology is the generation of a model, which will serve to structure, understand and propose improvement actions in the situations under study and that wish to be modified, as in the case of the Large Marketers immersed in the liquefied petroleum gas industry.

For this purpose, this research considered as a contribution to the methodological development proposed by N. Luhmann, who from the general theory of systems (G.S.T.) worked on the functionalist movement and this research was based on aspects of this movement, which identifies the following elements, which are expanded by Churchman [26].

a) The definition of the system's objectives.

b) The system environment and the constraints set.

c) System resources.

d) The subsystems or components of the system.

## IV. RESULTS, ANALYSIS AND INTERPRETATION

It is important to establish that Resolution CREG 074 of the Energy and Gas Regulatory Commission 1996 regulated the domiciliary public service of liquefied petroleum gases (LPG) and dictated a series of provisions empowered by the Political Constitution of Colombia and those conferred by Law 142 of 1994, in development of Decrees 1524 and 2253 of 1994.

In this order of ideas, the Large Marketer is the company that produces or imports LPG for wholesale supply to wholesale traders, who must serve the domestic market, a market that has been showing a decrease of 5 percentage points in the last 21 years, going from 12% in 2000 to 7% in 2021 [27], without having been able to meet the needs of society. Although the growth of the Liquefied Petroleum Gas in Colombia is only 0.4%, this situation is far from what has happened in other sectors of the national economy, such as the hotel and food sectors with a growth of 1.4% [28]. In this scenario, it is important to establish that the hotel and food present a series of activities in their daily operation, such as food preparation and water heating, processes that require fuel to provide a certain amount of energy and allow them to comply with their operation. Therefore, the present difference between the increase of these activities with respect to the LPG industry indicates that they are demanding fuels other than LPG. This reality shows that in Colombia LPG as an energy source is not positioned in a competitive way, because with these levels of growth, it does not provide an effective coverage, nor does it respond to the current demand and even less to a future one.

### a. Large Marketers and their dynamics.

According to what was established in the previous section, the Large Marketers as a link in the LPG industry, must comply with the function of producing LPG to meet the national demand through the Wholesale Marketers, and in case this is not achieved, it is obliged to import the necessary product, therefore, this subsystem under the complexity analysis, is characterized by a series of interconnected agents that define the development and operation of the same, for purposes of this, see (figure 2).

Consequently, under the complex systems approach, the Large Marketers subsystem requires an analysis of its evolution, the changes that occur, the scale of analysis which will be temporary in a horizon of 8 years, analyzing in the subsystem the sensitivity of this to the input conditions, in such a way that allows its modeling and its respective study; Therefore, it is necessary to establish the network of agents involved, to establish the levels and make predictions, and the latter allow the increase of the participation of this energy, maximizing the adaptation to the competitive environment that exposes the energy basket at national level.

### b. Agents involved in the subsystem.

The Large Marketers as the first link in the LPG industry and under the subsystem analysis, presents a series of agents that directly influence it; these agents are those that explore the existence of deposits, those that extract the crude oil, those that are dedicated to refining, those that import and export and those that transport the product to the Large Marketers; Consequently, under the complex systems approach, the Large Marketers subsystem requires an analysis of its evolution and the changes it undergoes. For this purpose, the scale of analysis will be temporal over an 17 year horizon, which will allow analyzing the Large Marketers as one of the subsystems of the LPG industry, as shown in Figure 2.

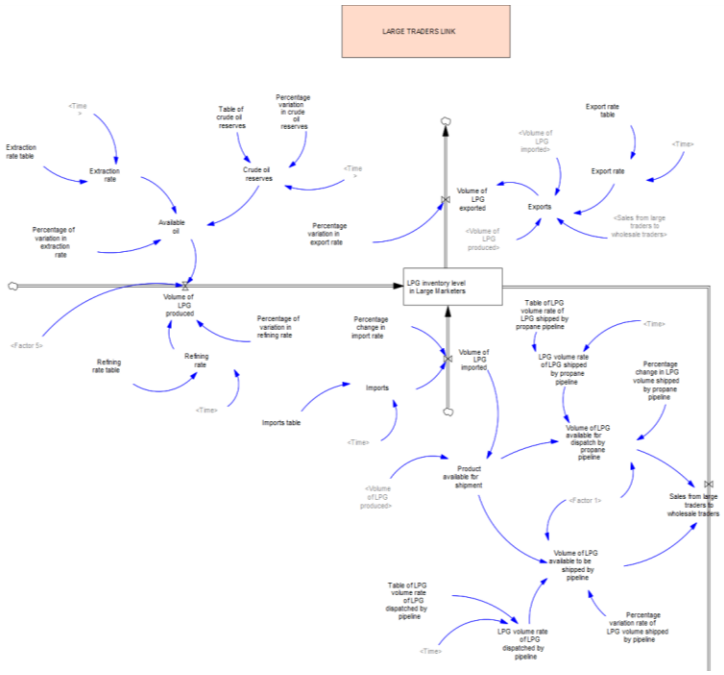


**Figure 2: Modeling of the Large Traders link. Source: The author, research development**

Figure 2 shows that in order to achieve an LPG inventory level in the Large Marketers and to provide the product to the Wholesale Marketers, there are a series of variables that have a significant influence on it, such as crude oil reserves, extraction rate, available oil, refining rate, which will allow having a volume of LPG available for delivery to the Wholesale Marketers; Now, if this is not enough, imports are required, which depend on the import rate; however, the LPG inventory of the Large Marketers is also affected by exports and by the respective export rate, see Figure 3, which shows the cause-effect scheme of the link under study.

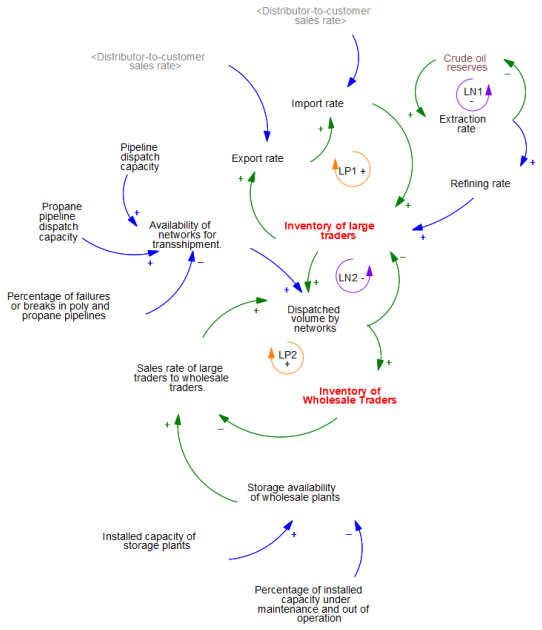


**Figure 3: Causal diagram of the Large Traders link. Source: The author, research development.**

From Figure 3, the feedback loops are defined as follows:

- Cycle LN1: Balancing cycle, the crude oil reserves → are balanced with the extraction rate.
- LP1: Boosting cycle, Large Traders → inventory is boosted by the export rate → and by the import rate.
- LN2: Balancing cycle, the Large Marketers → Inventory is balanced by the volume dispatched by networks (Propanoducto/Polyduct).
- LP2: Boosting cycle, Wholesale Marketers → Wholesale Marketers → Inventory is boosted by the sales rate of large marketers to wholesale marketers → and the volume dispatched by networks.

According to the above, the agents involved in the subsystem were analyzed and interpreted as follows:

**c. Crude oil, reserves and oil extraction.**

The first thing that emerges is that, at the national level, these went from 2,039 million barrels declared

in 2021 to 2,074 million barrels in2022, with a Proved Reserves/Production (R/P) ratio of 7.5 years [29].

In spite of national policies, it cannot be denied that oil and its derivatives play a preponderant role in the country's productive sectors, the dependence on them is still very high at present, if we observe the country's energy basket the largest supply for the year 2023 was oil at 14.2%, coal at 10.3% and natural gas at 2.4%, the above still shows that the participation of fossil fuels maintain their participation around 78% for 2023 [30], but if the participation is so, what is happening with LPG? LPG is an industry that requires study and analysis, so we began with the identification of the sources of crude oil production, as shown in (table 1).

**Table 1: Sources of crude oil production in Colombia.**

| Code | Source Production |
|---|---|
| YP | Yopal |
| AP | Apiay |
| CAR | Cartagena |
| IBC | Barrancabermeja Industrial Complex |
| COR | Steed |
| CUS | Cusiana |
| DI | Dina |
| ELG | La Gloria Station |
| FLO | Floreña |
| GIG | Giant |
| PT | La Punta |
| PAY | Payoa |
| TCA | Gas treatment and conditioning plant Tocaria station |
| RH | Rancho Hermoso |
| TT | Toqui - Toqui |
| CIC | Cicuco |
| LCN | La Cañada |
| CUP | Cupiagua |

| | |
|---|---|
| AIP | Aipe |

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios(superservicios.gov.co)

In this context and according to the political and commercial connotation both nationally and internationally, the production sources present attributes such as appearance, uncertainty, sudden transition, dependence, dynamics of evolution and interaction; however, the reality of the energy basket in Colombia is quite uncertain, the exploration and exploitation licenses are in between said, therefore it is not possible to understand Large LPG Marketers, if the exploration process is not clear; under this scenario the exploration contracts, must materialize in the drilling of wells, see (table 2).

**Table 2: List of exploration contracts signed vs. wells drilled in the Colombian territory.**

| Year | Exploration contracts signed | Drilled wells |
|---|---|---|
| 2003 | 21 | 28 |
| 2004 | 32 | 21 |
| 2005 | 59 | 35 |
| 2006 | 44 | 56 |
| 2007 | 54 | 70 |
| 2008 | 59 | 99 |
| 2009 | 64 | 75 |
| 2010 | 8 | 112 |
| 2011 | 76 | 126 |
| 2012 | 54 | 130 |
| 2013 | 2 | 115 |
| 2014 | 26 | 112 |
| 2015 | 1 | 25 |
| 2016 | 0 | 21 |
| 2017 | 24 | 54 |
| 2018 | 0 | 48 |
| 2019 | 31 | 48 |
| 2020 | 5 | 18 |

Source: https://www.anh.gov.co/es/

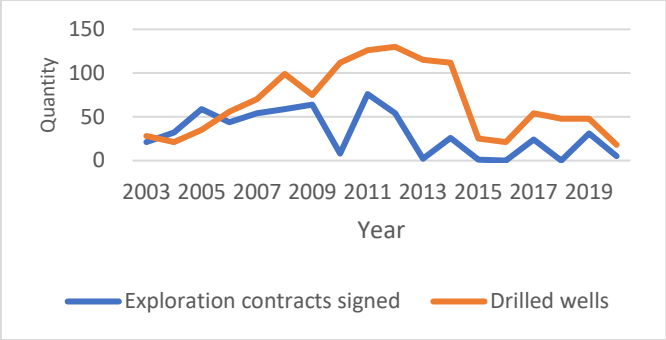


**Figure 4: Behavior of exploration contracts signed vs. wells drilled.**

Source: https://www.anh.gov.co/es/

The data is showing the contraction of the industry at a national level, a trend that impacts economic sectors and at the same time the low capital investment, therefore, with a cut-off date of 2023, the following information is available:

**Table 3: Operators - contracts and well status**

| Operators | Contracts | Wells | Basins | Status | |
|---|---|---|---|---|---|
| 40 | 71 | 112 | 9 | In testing | 4 wells |
| | | | | Producer suspended | 32 wells |
| | | | | In extensive testing | 15 wells |
| | | | | Pending tests | 2 wells |
| | | | | Producer in initial tests | 2 wells |
| | | | | Producer pending extensive testing | 6 wells |
| | | | | Plugged and abandoned | 44 wells |
| | | | | Suspended | 1 well |

Source: https://anh.gov.co/documents/3167/Cifras_y_estad%C3%ADsticas_a_2010.xls

The reality is very clear and the behavior can be seen in (table 4) and more clearly visualized in (figure 5):

**Table 4: Oil reserves and production.**

| Year | Oil Reserves (millions of barrels) | Annual oil production (millions of barrels) |
|---|---|---|
| 2003 | 1,842 | 541 |
| 2004 | 1,842 | 529 |
| 2005 | 1,542 | 526 |
| 2006 | 1,542 | 531 |
| 2007 | 1,453 | 531 |
| 2008 | 1,506 | 588 |
| 2009 | 1,355 | 671 |
| 2010 | 1,355 | 785 |

| | | |
|---|---|---|
| 2011 | 1,900 | 914 |
| 2012 | 1,988 | 944 |
| 2013 | 2,200 | 1,006 |
| 2014 | 2,377 | 988 |
| 2015 | 2,445 | 1,003 |
| 2016 | 2,308 | 886 |
| 2017 | 2,002 | 854 |
| 2018 | 1,666 | 865 |
| 2019 | 1,782 | 886 |
| 2020 | 1,960 | 781 |

Source: Colombia - Oil production 2023 | Datosmacro.com (expansion.com)

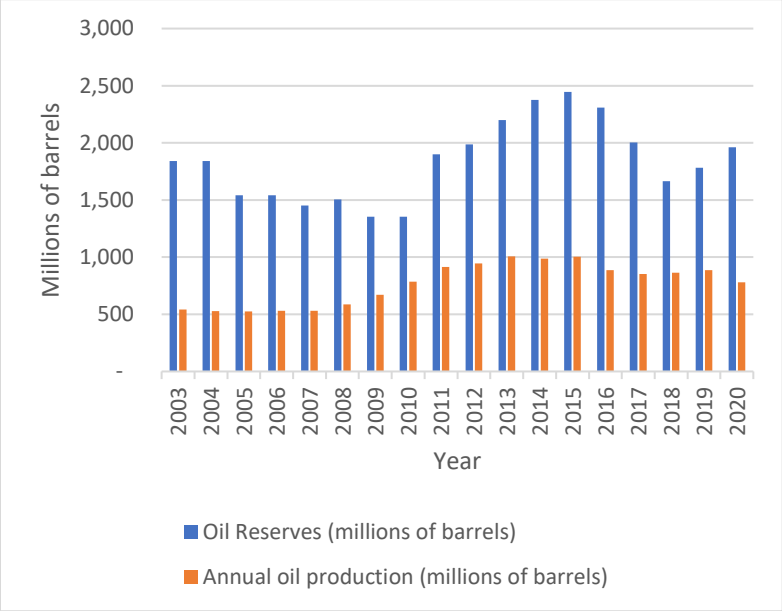


**Figure 5: Reserves Vs Production**

Source: Colombia - Oil production 2023 | Datosmacro.com (expansion.com). Own elaboration

When analyzing the annual oil reserves it is evident that from the year 2002 to the year 2021, they have only increased by 16.34%, reaching the highest point in the year 2015, in which an increase of 39.71% was reached; today this reality is quite uncertain with the energy policies that the national government has assumed, as can be observed, the behavior is of decrease in the production of LPG, so that during the years 2020 and 2021, the production has decreased by 11.85% and 5.76% respectively. In essence, this behavior is due to the percentage variation of crude oil reserves, the rate of crude oil extraction and consequently the rate of refining during the hydrocarbon process.

As can be seen, reserves remain at a low level and therefore extraction responds to this condition, which considerably affects LPG production, which does not show growth over time, as can be seen in Figure 6.

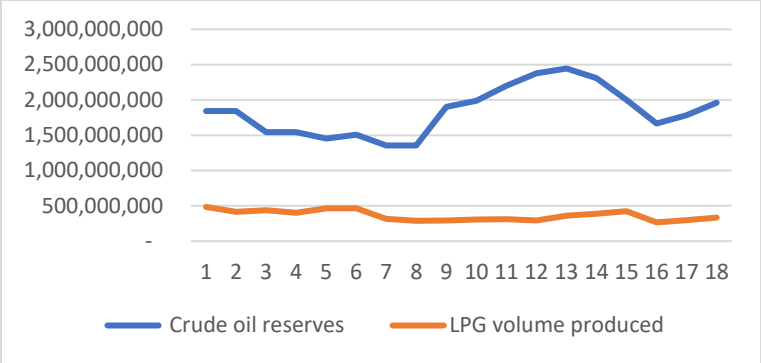


**Figure 6: Oil Vs LPG Production in Colombia**

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios (superservicios.gov.co). Own elaboration

It can be seen that LPG production is low enough to meet present and future potential demand, without neglecting what is happening with consumption at the national level, as shown in Figure 7.

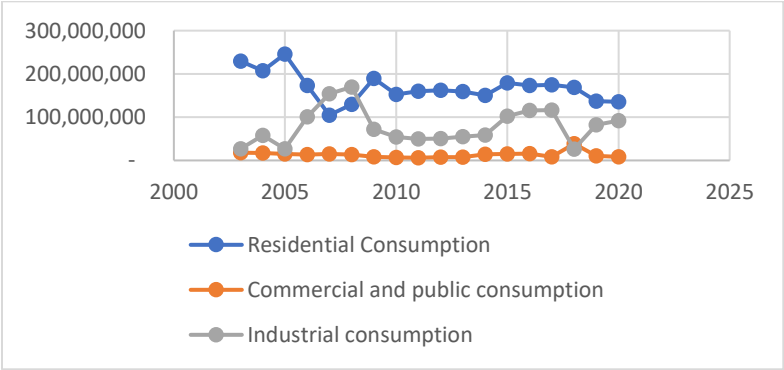


**Figure 4: LPG consumption in Colombia**

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios (superservicios.gov.co). Own elaboration

The behavior shows a permanent decrease in consumption, and in effect, this is what has submerged this industry in a low participation in the liquid fuels chain.

Therefore, the industry must be intervened as a complex system based on system dynamics, taking all the components of the supply chain as a whole, assuming the large marketers, wholesale marketers, transporters, retail marketers and distributors, i.e. as a whole, and not continuing with conventional methods.

**d. Imports.**

As the years go by, the projections of the national LPG supply are quite low, as can be seen in Table 5, and this reality is quite uncertain, especially in the context of an energy policy distant from fossil fuels.

**Table 5: LPG production and imports.**

| Year | Volume of LPG produced (Gallons) | Volume of LPG imported (Gallons) |
|---|---|---|
| 2003 | 484,027,320 | - |
| 2004 | 416,442,180 | 420,000 |
| 2005 | 439,429,620 | 840,000 |

| | | |
|---|---|---|
| 2006 | 401,695,140 | 168,000 |
| 2007 | 465,585,960 | - |
| 2008 | 465,848,460 | - |
| 2009 | 313,473,300 | 11,760,000 |
| 2010 | 288,172,080 | 12,936,000 |
| 2011 | 290,682,420 | 7,182,000 |
| 2012 | 305,153,680 | - |
| 2013 | 308,465,220 | - |
| 2014 | 290,589,600 | - |
| 2015 | 361,631,760 | 504,000 |
| 2016 | 389,543,700 | 5,628,000 |
| 2017 | 425,412,960 | 30,030,000 |
| 2018 | 265,653,360 | 39,270,000 |
| 2019 | 295,687,980 | 52,920,000 |
| 2020 | 333,666,060 | 4,284,000 |
| 2021 | 214,331,526 | 25,275,765 |
| 2022 | 199,442,213 | 27,798,647 |
| 2023 | 174,891,487 | 30,620,100 |

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios (superservicios.gov.co)

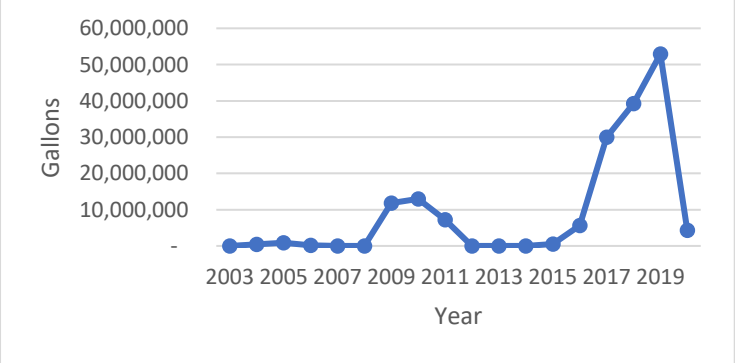


**Figure 5: LPG imports**

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios (superservicios.gov.co). Own elaboration

Imports reached their highest point in 2019, a situation that responded to an increase in demand of 14.33%, which could not be supported with domestic production, and not because it could not be carried out, simply because there is no clear policy that directs the transition from the use of liquid fuels, towards cleaner fuels.

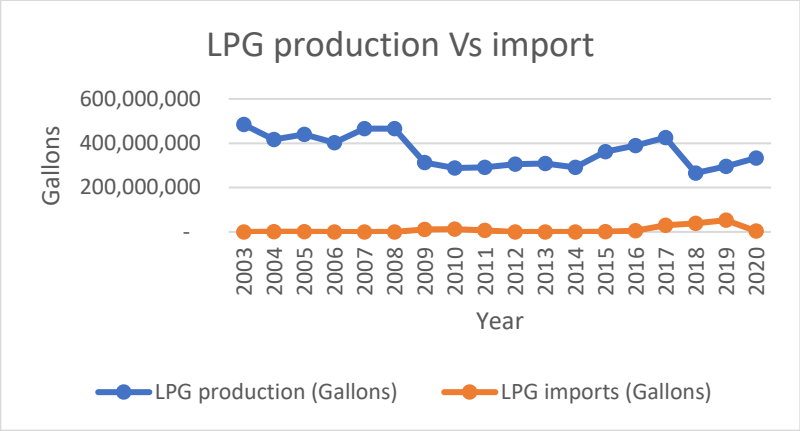


**Figure 6: Behavior of LPG production and imports in Colombia**

Source: SUI Portal | Superintendencia de Servicios Públicos Domiciliarios (superservicios.gov.co). Own elaboration

**e. Transportation infrastructure.**

The research addressed the transfer capacity in the national territory, which has limitations of transport by pipeline networks connected to the producing plants, this is due to the geographical conditions of the national territory, as well as the armed conflict that the country is going through, This is reflected in the constant attacks suffered by the current infrastructure, which means that it is not possible to provide nationwide coverage, generating that those remote regions do not have this type of fuel, especially since the Large Marketers are the first link in the supply chain, and it is from there that all the other links are fed; Table 6 shows the LPG transportation infrastructure that supplies the entire LPG industry system.

**Table 6: Routes and line conditions.**

| Route Code | Route name | Condition |
|---|---|---|
| GB | Galán - Bucaramanga | Polyduct |
| SP | Sebastopol - Puerto Salgar | Propanoduct |
| SP1 | Sebastopol - Puerto Salgar | Polyduct |
| GP | Galán - Puerto Salgar | Polyduct |
| PF | Puerto Salgar - Facatativa | Polyduct |
| FM | Facatativa - Mosquera | Polyduct |
| PM | Puerto Salgar - Manizales | Polyduct |
| MP | Manizales - Pereira | Polyduct |
| PC | Pereira - Cartago | Polyduct |
| CY | Cartago - Yumbo | Polyduct |

Source: Poliductos | Cenit transporte (cenit-transporte.com)

As evidenced in the table above, there is only one dedicated Propanoducto pipeline, i.e. the Sebastopol - Puerto Salgar route; all the others are polyducts, which respond to the conditions and dynamics of fuel transfer within the liquid fuels basket, as shown in Table 7, which shows the capacity of each route and its diameter.

**Table 7: LPG pipeline transportation infrastructure from Large Marketer**

| SYSTEMS | INITIAL STATION | END STATION | NOMINAL CAPACITY (Kbls) | PREDOMINANT DIAMETER INCHES |
|---|---|---|---|---|
| Pozos-Ayacucho | Pozos | Ayacucho | 96.3 | 14″ |
| Ayacucho-Galán | Ayacucho | Galán | 96.3 | 14″ |
| Cartagena-Barranquilla | Cartagena | Baranoa | 30.9 | 12″ |
| Galán-Bucaramanga | Galán | Bucaramanga | 25.3 | 4″6″12″ |
| Galán-Sebastopol 16″ | Galán | Sebastopol | 168.4 | 16″ |
| Galán – Sebastopol 12″ | Galán | Sebastopol | 75.8 | 12″ |
| Galán- Sebastopol 8″GLP | Galán | Sebastopol | 14.4 | 8″ |
| Sebastopol-Salgar 16″ | Sebastopol | Salgar | 168.4 | 16″ |
| Sebastopol-Salgar 12″ | Sebastopol | Salgar | 75.8 | 12″ |
| Sebastopol-Salgar 8″GLP | Sebastopol | Salgar | 14.4 | 8″ |
| Sebastopol – Medellín 12″ | Sebastopol | Medellín | 68.4 | 10″,12″16″ |
| Medellín-Cartago | Medellín | Cartago | 49.1 | 10″ |
| Cartago-Yumbo 10″ | Cartago | Yumbo | 28.8 | 10″ |
| Salgar-Cartago | Salgar | Cartago | 23.5 | 6″,8″ |
| Cartago-Yumbo 6″ | Cartago | Yumbo | 13 | 6″,8″,10″ |
| Yumbo – Buenaventura | Yumbo | Buenaventura | 20.5 | 6″12″8″ |
| Buenaventura-Yumbo | Buenaventura | Yumbo | 17 | 6″12″8″ |
| Salgar-Gualanday | Salgar | Gualanday | 26.3 | 12″ |
| Gualanday-Neiva | Gualanday | Neiva | 13.3 | 6″,8″ |
| Salgar-Mansilla 10″ | Salgar | Mansilla | 94.4 | 10″ |
| Salgar-Mansilla 8″ | Salgar | Mansilla | 14.4 | 8″ |
| Salgar- La Dorada | Salgar | La Dorada | 21.18 | 6″ |
| Mansilla – Puente Aranda 10″ | Mansilla | Puente Aranda | 68.4 | 10″ |
| Puente Aranda el Dorado | Puente Aranda | El Dorado | 14.4 | 6″ |
| Sebastopol-Sutamarchan | Sebastopol | Sutamarchan | 75.8 | 20 y 16″ |
| Sutamarchan-Apiay | Sutamarchan | Apiay | 62 | 16 y 12 « |
| Sutamarchan-Tocancipá | Sutamarchan | Tocancipá | 75.8 | 16″ |

## V. CONCLUSIONS

The LPG industry, like many others in the energy sector, is characterized by its high complexity, where the various actors, from suppliers to final consumers, are interconnected in a dynamic network that includes economic, social, technological, regulatory, and environmental elements. This requires a multidisciplinary approach to understand and properly manage these systems. Addressing the first link in the LPG industry supply chain, represented by the large marketers, and conducting an analysis from the perspective of complex systems raises the need to thoroughly study the interrelationships of the various variables involved in the process.

Because the LPG business is dynamic and non-linear, actions and regulations taken in the short term may have long-term effects, particularly with regard to the industry's competitiveness in the country's energy mix. Despite being a clean fuel that can help lower emissions of harmful gases and enhance air quality, LPG's low percentage in the existing energy matrix indicates that there are structural obstacles preventing its widespread use. In addition to inadequate infrastructure, these obstacles also include a lack of financial incentives and a lack of knowledge about the advantages of LPG over alternative energy sources, indicating that its potential has not yet been fully realized.

Understanding how the many components of the system—such as supply and demand, operating costs, governmental regulations, technological advancements, and public opinion—interact is crucial to changing the LPG sector from the standpoint of complex systems. These factors affect the industry's capacity to adjust to shifts in the global energy market in addition to having a direct impact on its competitiveness. To establish

an atmosphere where LPG can successfully compete with other energy sources and hold a significant position in the energy matrix, the difficulty is in striking the correct balance between these factors.

This situation emphasizes the necessity for more research on social and economic as well as technological modeling of the LPG business as a dynamic system. Long-term and medium-term public policies should be designed to encourage the use of this energy not just through laws but also through an all-encompassing strategy that takes into account the effects at every stage of the supply chain. This entails accounting for infrastructure expenses, new technologies, and possible market disruptions in addition to legislative restrictions that may have an impact on the sector's growth. Finding the best and most focused solutions for the unique needs of communities requires a careful and in-depth examination, particularly when it comes to household utilities and access to more sustainable energy.

Furthermore, the industry's complexity necessitates an adaptable strategy that enables major participants to foresee potential shifts in the market and in governmental regulations. Interventions should not just address regulatory concerns; they should also promote innovation, cooperation amongst the several players (government, business sector, and civil society), and ongoing enhancement of logistical and operational procedures. In addition to a suitable regulatory framework, the development of incentives that enable the industry to change and adjust to new customer demands and expectations is necessary to create an environment that will support the expansion of LPG.

It is possible to view the integration of the LPG industry into a nation's energy matrix as both an opportunity and a challenge. An opportunity to transform the way we consume energy, to contribute to a more sustainable future and to build a more competitive and efficient industry. In order for LPG to contribute significantly to the nation's energy transition, it is imperative that public policies, the regulatory framework, and infrastructure expenditures be focused on building a more resilient and adaptable energy system.

Based on the results of this research, it is necessary for decision makers in the LPG industry to promote the integration of all links in the supply chain, from large marketers to customers. - The use of LPG should be promoted in all sectors of the national economy and not be relegated to the energy basket. - Research work should be promoted that addresses other systems and subsystems of the industry and that can be articulated with the present one. - Facilitate the modernization of the industry aimed at a better provision of service with quality and safety.

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## REFERENCES

[1] J. Valencia, Liquefied Petroleum Gas (LPG) Chain, Ministry of Mines and Energy of Colombia, 2017.
[2] P. Solano and R. Moyer, "Commission for Environmental Cooperation (CEC)," Yearbook of International Environmental Law, vol. 29, pp. 433-441, 2018.
[3] R. R. Delgado, TeorÍa de Sistemas y GestIón de las Organizaciones, Instituto andino de sistemas, 1994.
[4] L. A. Rivas Tovar, "New forms of organization," Estudios gerenciales, vol. 18, nº 82, pp. 13 -45, 2002.
[5] A. M. Macias and A. A. Vidal, "Evolution of administrative theory. Una visión desde la psicología organizacional}," Revista cubana de psicología, vol. 19, nº 3.2002, 2002.
[6] S. A. Moriello, Complexity sciences: a brief introduction, New Bookstore, 2013.
[7] L. E. Arevalo, "The business organization as a complex adaptive system," Managerial Studies, vol. 29, no. 127, pp. 258--265, 2013.
[8] D. Kamissoko, F. Pérès, P. Zaraté, and D. Gourc, "Complex system representation for vulnerability analysis," IFAC-PapersOnLine, vol. 48, no. 3, pp. 948--953, 2015.
[9] F. G. Filip, "Decision support and control for large-scale complex systems," Annual reviews in Control, vol. 1, no. 32, pp. 61--70, 2008.
[10] L. R. Izquierdo, J. M. Galán, J. I. Santos, and R. Del Olmo, "Modeling complex systems by agent-based simulation and by system dynamics," EMPIRIA. Journal of Social Science Methodology, no. 16, pp. 85--112, 2008.

[11] A. V. Contreras, "The organization, the system and its dynamics: a version from Niklas Luhmann," Revista Escuela de Administración de Negocios, nº 61, pp. 129--156, 2007.

[12] H. A. Simon, "Sur la complexité des systémes complexes," Revue Internationale de systémique, vol. 4, no. 2, pp. 125--145, 1990.

[13] F. Contreras, D. H. Ramírez, and G. A. Ríos, "The organization as a complex system: implications for the conceptualization of leadership," Criterio libre, vol. 10, no. 16, pp. 193--206, 2012.

[14] I. L. Olmos, "The Role of ICT in the SMEs Organizational Environment," Trilogía ciencia tecnología sociedad, vol. 4, no. 7, 2012.

[15] G. J. Torres, "Colombia: achievements in two decades of aperturist development model- Analysis according to trade balance results," Political Analysis, vol. 27, no. 82, pp. 212--235, 2014.

[16] J. Ladyman, J. Lambert, and K. Wiesner, "What is a complex system," European Journal for Philosophy of Science, vol. 3, pp. 33--67, 2013.

[17] N. Goldenfeld and L. P. Kadanoff, "Simple lessons from complexity," Science, vol. 284, no.5411, pp. 87--89, 1999.

[18] Y. Soler, "Theories on complex systems," Management and Development, vol. 47, no. 2, pp.52--69, 2017.

[19] M. O. Gil, "Territorial analysis of the Campo de Gibraltar as a system and network," 26 112015. [Online]. Available: https://rodin.uca.es/handle/10498/17916.

[20] J. N. Warfield, Science of generic design: managing complexity through systems design, Iowa State Press, 1994.

[21] A. Russell, "El paradigma de Ackoff, una administraciÓn sistémica," Mexico. EditorialLimusa, 2002.

[22] J. W. Sossa, J. M. Hincapié, E. E. Martínez, O. Londoño, and J. L. Concha, "The modified delphi method. An approach from the Soft Systems Methodology," ESPACIOS Magazine, vol.36, 2015.

[23] M. R. Bravo, "Methodology for the analysis and development of complex systems: an approach to the study and selection of their information elements}," 2001. [Online]. Available: https://docta.ucm.es/entities/publication/24dd9d19-d691-43c2-954e-183f7ad98931. [Last access: 8 July 2023].

[24] G. C. S. S. d. Silva and D. D. d. d. Medeiros, "Metodologia de checkland aplicada à implementação da produção mais limpa em serviços," Gestão & Produção,,, vol. 13, pp. 411--422, 2006.

[25] P. B. Checkland, "Soft systems methodology," Human systems management, vol. 8, no. 4, pp.273--289, 1989.

[26] M. Reynolds, "Churchman and Maturana: Enriching the notion of self-organization for social design," Systemic Practice and Action Research, vol. 17, pp. 539--556, 2005.

[27] M. V. Arroyo Cadena and G. D. Vivanco Toscano, Evaluation of energy consumption sources and efficiency in the national industry and comparative analysis of forecasts in the period 2012-2022. 2023,

[28] GASNOVA, "Informe Anual del GLP," Bogotá, 2021.

[29] National Hydrocarbons Agency ANH, May 24, 2023. [On line]. Available: https://www.anh.gov.co/es/noticias/informe-de-recursos-y-reservas-con-corte-diciembre-de-2022- insumo-para-la-transici%C3%B3n-energ%C3%A9tica-justa-en-colombia/.

[30] UPME Mining and Energy Planning Unit, "Colombian Energy Balance," December 2023. [Online]. Available: https://www1.upme.gov.co/DemandayEficiencia/Paginas/BECO.aspx.