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ORIGINAL ARTICLE

Impact of integrated policy approach on CVGN for mass residential use

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ABSTRACT

This paper analyzes the impact of a comprehensive approach to the Natural Gas Value Chain (NGVC) policy for the massification of its residential use in the Peruvian case. To this end, a characterization of the critical elements of the NGVC is developed, the main barriers and opportunities are identified, and the advantages of an integrated approach to its exploitation are discussed. This discussion is based on the systematization of information from specialized sources of the sector, the comparative international experience and the results of a case study developed with emphasis on the logistic supply of natural gas (NG) installation companies in Peru. Based on the results, four conclusions are drawn. First, the technological conditions available for NG processing, transportation and distribution are consistent with a high potential for massification. Second, the policy approach to massification has serious limitations, partly due to the emphasis on only some consumption sectors, such as residential and commercial. Third, in considering the comprehensiveness of NGVC, the importance of key components has been overemphasized, including NG transportation and distribution. This inattention explains the failure of various legislative initiatives to promote massification. Fourth, the contribution of a comprehensive approach to NGVC in promoting potential effects on massification is emphasized, both from international comparative experience and from case studies in Peru.

Keywords: Gas value chain; Gas massification; Residential consumers.

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INTRODUCTION

During the first two decades of the 21st century, increased demand for electricity and the advantages associated with the lower cost and greater efficiency of natural gas (NG) compared to other generation sources have led to unprecedented growth of this industry on a global scale. This accelerated growth has been possible thanks to the application of appropriate technologies for its transportation, capable of transporting it safely and economically to the points of consumption. At low temperatures (-162 ˚C), its liquefaction makes it possible to reduce the volume of NG by 600 times, facilitating its transportation over long distances. This improvement has facilitated the technical and economic conditions for the widespread use of natural gas, creating the conditions for improving the quality of life and contributing to its sustainability.

In Latin America, NG has become the second most important source of electricity generation since early 2000, displacing petroleum products. In the following decade, NG-based electricity generation doubled, with an average growth of 8% per year, four times the growth rate of hydropower and eight times that of petroleum products (Rodriguez, 2016). Currently, the ratio between the volume of reserves and production in the region reports a future horizon of 42 years, below the global average Economic Commission for Latin America and the Caribbean (ECLAC, 2019).

In Peru, since the start of commercial operations at the Camisea field (Cusco) in 2004, the process of massification of its residential use has been a recurring theme in the public debate, but has made limited progress in terms of coverage outside of Lima and Callao. In fact, various legislative and planning initiatives have been proposed by the executive and legislative branches, including the National Energy Policy of Peru 2010-2040, the Hydrocarbon Energy Security System, the Energy Social Inclusion Fund (FISE), the Universal Energy Access Plan 2013-2022, among others. Nevertheless, almost two decades later, the progress made in terms of massification has been marginal: according to the most recent estimates, the residential use of natural gas has managed to reach "solo el 11% de las viviendas a nivel nacional" [only 11% of households nationwide] (Medina, 2020, p.1), almost exclusively concentrated in Lima and Callao. Similarly, significant gaps are estimated in specific consumption categories: in 2018, household access levels of less than 60% were identified in services such as food refrigeration (54%), knowledge/communication/entertainment (58.8%), air conditioning (11.5%), and washing (39.4%), which are among the lowest in Latin America (Carvajal *et al.,* 2018).

The studies available for the Peruvian case on the obstacles to massification highlight technical and political components. In one of the first reports to systematize the experience of massification in Peru, the Supervisory Agency for Investment in Energy and Mining (OSINERGMIN, 2012) highlighted, from the experience of Lima and Callao, the need to have industrial customers to absorb the costs of the distribution network and to subsidize part of the conversion costs of the residential segment; this allowed a price of NG that was one third of the price of LPG. Massification to other regions therefore depended on the existence of a critical mass of industry that would contribute to the financing of the distribution network. In the short term, the technical alternative of transporting NG by truck in liquid form as Liquefied NG (LNG) or Compressed NG (CNG) was also proposed. More recently, Medina (2020) evaluates different policy instruments to promote massification in Peru, including a uniform distribution rate (TUD), cross-subsidies, intersectoral subsidies, among others. The author highlights the role of the capacity of distribution concession operators as a key constraint to massification, in line with the recommendation of other authors such as Aguirre (2021).

To date, however, available studies on comprehensive policy strategies for massification in Peru remain relatively scarce and tend to focus on the evaluation of specific segments of the NGVC. In response to this absence, the objective of this paper is to analyze the influence of a comprehensive policy approach on the massification of NGVC for residential use in Peru.

METHODS

To analyze the influence of an integrated policy approach to NGVC for the massification of residential use in Peru, the paper develops a

bibliographic characterization of the critical elements of NGVC, identifies the main barriers and opportunities for massification, and analyzes the advantages of an integrated approach to exploit these opportunities. This analysis is based on the systematization of information from specialized sources of the sector, comparative international experience and the experience of NG installation companies in Peru.

The approach of the study is quantitative because the focus of the analysis is results-oriented and is based on the quantitative analysis of a case study applied to a gas installation company in Peru, through the application of a survey questionnaire. In terms of the literature review, this included technical studies characterizing the operation of the CVGN (Becerra-Fernández *et al.,* 2020), as well as the comparison of massification processes in countries of the region such as Colombia, Argentina and Bolivia (ECLAC, 2019), with a focus on the main barriers and opportunities identified. The purpose of the survey-questionnaire was to analyze the influence of an integrated operations approach (Lean Construction) on the efficiency of the logistics supply of a gas installation company in Peru. It analyzed the processes of construction of internal networks, connection pipes and the following sub-processes: Programming, Purchasing, Internal Installation and Connection Pipes, Verification and Qualification. Although the design of the information collected through the survey corresponded to a case study rather than a nationally representative sample, the standardization of the processes and regulations presented by these companies suggests results with a high degree of external validity.

RESULTS

The results of the analysis lead to four main conclusions. First, the technological conditions available for processing, transporting, and distributing natural gas are consistent with a high potential for massification. Second, the traditional approach to massification policy has suffered from serious limitations, largely due to the emphasis on some final components of NGVC only. Third, by considering the comprehensiveness of NGVC in a joint and organized manner, the importance of key components that are typically not addressed is highlighted; this inattention explains the low effectiveness of various legislative initiatives to promote massification. Fourth, the contribution of a comprehensive approach to NGVC to promote potential impacts is emphasized, both from international comparative experience and from case studies in Peru.

The NG value chain and the need for an integrated approach

The characterization of the NGVC presents three main features: The NGVC is extensive, complex and with strong interrelationships between the members of the chain; there is a physical link, and therefore dependency, from the gas well to the gas supply and from there to the appliance used by the end user of natural gas, while the NG producer and the consumers (especially residential consumers) are physically linked and therefore need to be constantly linked to ensure the sustainability of the service.

The NGVC consists of six interrelated stages that allow the user to have NG: (1) exploration, (2) production, (3) processing, (4) transportation, (5) distribution, and (6) marketing. The residential user is at the end of this chain.

The exploration stage is the search for gas, which is carried out in the gas basins. The production stage is the extraction of natural gas from the reservoirs. In the processing stage, the extracted natural gas is conditioned in plants where sulfur content, water and other impurities are removed. The transportation stage is carried out through pipelines from the processing center to the city gate. The distribution stage involves the delivery of natural gas from the city gate to the end user. Natural gas is distributed in two states: dry natural gas and liquefied natural gas. The company that distributes and markets natural gas in Lima and Callao is Cálidda. Finally, in the commercialization stage, NG is supplied to different consumption sectors. From the experience of the case studies, two critical stages for the provision of the service are highlighted: Transportation and Distribution.

The CVGN also includes a number of physical components. Firstly, the distribution network consists of the pipeline system in the

streets or avenues, the connection pipe that connects the network to the service connection, and the internal domestic installation from the service connection outlet to the gas appliance. Second, the connection pipe consists of a PE polyethylene pipe, valves and other components through which the natural gas is conveyed to the pressure of the external network, which starts in the external network pipe and ends before the meter. Thirdly, the internal installation starts at the meter and continues inside the house until it reaches the different gas appliances. Qualification is the process by which the gas distribution concessionaire puts the contracted natural gas service into operation, after verifying the technical conformity of the connection pipes and the internal installation. The diversity of processes and components that make up the CVGN underscores the need for an approach that takes into account the important interrelationships and dependencies between these elements, as well as the diversity of end users to be served, in order to ensure the sustainability of the service.

In a similar characterization of NGVC, authors such as Weijermars (2010) have emphasized the importance of a comprehensive approach to policy design. Thus, it is argued that the purpose of value chain analysis is to understand the systemic factors and conditions through which a value framework and related enterprises can achieve good performance. With an application to the physical and financial value chains of the natural gas business in the United States, the author characterizes NGVCs through the interconnectedness of different regulatory frameworks for decision making, which requires a holistic approach to the implementation of policies for promotion and process improvement.

A similar conclusion is discussed by Zarei *et al.* (2020), who emphasize that the economic, environmental and social dimensions must be addressed simultaneously in energy supply and policy formulation in the natural gas industry, as a change in the demand of one of the components affects the others, thus requiring integrated planning of the supply chain to maximize the overall benefits. Applied to the Colombian case, Becerra-Fernández *et al.* (2020) evaluate the impact of public policies on the supply and demand of the NG industry. Using a model that includes variables of NG demand, transportation, production and reserves, the authors agree on the need for support policies that take into account the allocation of resources along the NG supply chain, with the aim of promoting the development of infrastructure to minimize the risk of supply shortages. In this sense, an integrated approach to the supply chain contributes by promoting synergies in the relationship between demand, transportation and production.

NG massification policy approaches

Massification of NG implies that all users who wish to use NG have timely access to facilities in the required quantity and quality, at low cost and with low environmental impact. As a background for the Camisea NG industry, in 1999 the Peruvian government, with the idea of jointly developing the production, transportation, distribution and commercialization of NG, defined a structure for its development, establishing a scheme in two independent modules: Production Module and Transportation and Distribution Module. Thus, the Main Network Guarantee (GRP) was designed to reduce the risks for the transporter and distributor, as part of the mechanisms to make the project viable, in such a way that it is possible to connect the gas supply from Cuzco to the demand in Lima.

Cálidda's reports on the number of customers it serves as of 2019 are as follows: 25 generation customers; 670 industrial customers; 279 NGV stations; and 951,708 residential and commercial customers (Class & Asociados S.A, 2020, p.10). These figures show the consolidation of the natural gas industry in Lima and the effectiveness of the chosen system, since the Camisea industry was designed taking into account all possible users that would require natural gas.

The availability of natural gas for all sectors of consumption depends on its circulation through the different stages of the CVGN. This means that any massification policy must take into account the economic and environmental impact of the entire CVGN and be analyzed jointly and in an organized manner for all NG users. By analyzing the behavior of the CVGN as a unit and all the users that would demand

gas, it is possible to take advantage of the CVGN to design viable NG massification policies. This was the case in the Camisea project, where a general approach was applied. Following this experience, the approach in the NG massification policy will be inclusive in the sense that it will include all consumption sectors.

From the international experience, although the approaches applied are specific to each context, the progress of leaders in the region, such as Colombia and Argentina –with national coverage of NG-connected households above 50%– emphasizes some cross-cutting elements. For example, Palacios Olivera *et al.* (2021) highlight elements of the NG Massification Plan published by Colombia's National Council for Economic and Social Policy (CONPES) in 1991. These include 1) state participation in the construction of long-distance networks, 2) the establishment of annual targets for residential users, 3) the definition of the industry's business segments (production, transport, distribution) through a regulatory framework, 4) incentives for private investment, particularly in distribution, and 5) a rate regulation methodology based on five-year investment plans and rate subsidies crossed in favor of residential users and intercompany subsidies. According to the authors, this combination largely explains why the targets set in the plan for 2010 were reached in 2003 (3.2 million users).

Ruiz Caro (2019), on the other hand, highlights an intense program to massify the use of LNG in Bolivia, which reached 800,000 domestic installations in different regions of the country by 2018 (1 million projected by 2019). The main success factor highlighted in terms of coverage is the program's implementation of a virtual LNG system with 32 regasification stations for hard-to-reach areas. The author also highlights the synergies of energy integration that Peru and Bolivia share.

Comparing the experiences of Bolivia and Mexico, Lichestein (2003) proposes to carry out a market analysis for LNG, considering the massification of the use of LNG in the domestic market a priority, both for vehicles and household use. In this regard, the author emphasizes that important advances have been made in the distribution of domestic gas on a large scale and that, given the entry of private actors in the Mexican energy system, it is necessary for the government to propose a partnership scheme to increase NG reserves through the search for a competitive gas supply, similar to the Peruvian case.

In the case of Peru, the initial expansion approach was influenced by previous experiences in Argentina and Colombia. These served as a reference for the development of the industry in the country, the elaboration of existing technical standards and the application of new technologies (e.g. LNG) through the entry of companies already operating in these countries. However, in contrast to these experiences, most of the factors that allowed important advances in Lima and Callao were not applied in the rest of the regions. Among the most important are the non-involvement of industrial customers to absorb the costs of the distribution network and to subsidize part of the transformation costs of the residential segment, or the lack of application of other policy instruments to promote massification, such as a single distribution rate (TUD), cross-subsidies, intersectoral subsidies, among others.

The key role of a holistic approach to installation operations

To date, there are few studies that focus on the determinants of operational efficiency of natural gas installation companies in Peru, especially for those of smaller size. An exception is Huamán-Orosco *et al.* (2022), whose objective is to identify the barriers generated in the implementation of an integrated approach to operations (Lean Construction [LC]) in small and medium-sized companies in Peru. To this end, a literature review was conducted and a questionnaire was designed and validated by six experts in LC implementation. This questionnaire was applied to 127 professionals of the sector in Peru, with more than two years of experience in the implementation of LC or currently participating in projects managed under the Last Planner System (LPS). A factor analysis was applied to the data from this questionnaire to group the specific barriers mentioned into four general categories: (1) collaboration, training and implementation; (2) LC theory

and philosophy; (3) LC tools, coordination and information flows; and (4) organizational vision and system. These barriers were also analyzed according to the type of project, stage and size of the organization to conclude that this last element is central. Finally, the study proposes the implementation of Construction 4.0, a set of management process digitalization tools applied to the sector, to reduce the impact of the barriers identified in construction projects.

In response to the scarcity of these studies, particularly focused on smaller companies and being a key link in the CVGN, as part of this paper has been developed a case study focusing on the changes induced by the implementation of a comprehensive LC operations approach on the efficiency of logistics supply of a gas installation company in Peru. In particular, in relation to three dimensions of an integrated operations approach (teamwork, collaborative model and competencies) on the processes of scheduling, purchasing, internal installations, connecting pipelines and qualification.

The quantitative analysis of the data obtained from the survey focused on the generation of indicators to characterize these processes and on statistical tests to contrast the research hypotheses on the contribution of the LC approach to efficiency improvements. The results obtained reflect efficiency improvements in the areas of programming (facility planning and control), purchasing (procurement and shipping processes), and internal facilities (connecting piping and quality verification). In this line, key operational elements such as the standardization of processes adapted to the size of the company, the harmonization of objectives and operational management (teamwork, communication, competencies), the calibration between material requirements and technical specifications in the pre-construction phases of the facilities, the integration of logistics personnel and technical areas, among others, are highlighted.

DISCUSSION

Barriers and opportunities to massification

In order to make Camisea NG available to all possible gas consumers, it is necessary to expand CVGN's transportation and distribution infrastructure, especially the construction of connection pipelines, connection installation, internal installation and permitting. These activities are carried out by specialized construction companies, which create added value for the CVGN. The challenge to be faced as a state policy is to create an infrastructure for the virtual transport of NG and LNG and to have competitive companies that allow massification.

The challenge facing Peru is to undergo the energy transition to clean energy in a timely manner, and one way to do this is to encourage large-scale use of natural gas. As Lloret (2015) notes, "El gas es un actor clave en la transición hacia una economía baja en carbono y un sistema energético más sostenible" [Natural gas is a key player in the transition to a low-carbon economy and a more sustainable energy system] (p. 472). NG is available in Peru, and evaluating its use requires the establishment of an urgent and comprehensive energy policy that facilitates the massification of NG.

International experience has highlighted a number of common barriers and opportunities. One important element relates to the potential supply of natural gas available in each country. As reflected in the ECLAC (2019) estimates for Latin American countries, although the possession of reserves has contributed to progress in the energy transition, the lack of interconnection through gas pipelines and market factors such as competition between LNG and gas interconnection projects in the region are not minor regulatory challenges. Among the aforementioned opportunities, the looming oversupply of extra-regional LNG could become an important factor in the development of gas in the region, as well as projects for the industrialization of LNG in fertilizers and petrochemicals. Comparing Colombia and Argentina, Medina (2020) also highlights the role of Colombian government subsidies for the expansion of the transportation network, which involved a significant reduction in entry prices at the household level.

This lesson is particularly relevant for the Peruvian case due to its geography. In the country, most cities are far from the natural gas supply point. This situation makes the construction of the distribution network and, for residential

use, the construction of the connecting pipeline, the internal installation and the process of activating the natural gas service difficult, with little availability of competent personnel. The alternative to be considered to improve the efficiency of the NG massification is to incorporate teamwork, the collaborative model and competencies focused on maximizing the value for the customer by reducing losses and improving the efficiency of the processes (Díaz, 2017; Brioso, 2015; Womack and Jones, 2003; Carreras, 1999) in the management of the construction processes developed by the gas installation companies.

Likewise, as recently pointed out in a discussion of the economic and environmental contributions of NG massification in Lima and Callao, "el mayor ahorro se generó en el sector transporte con S/ 27,492 millones; seguido del rubro industria mediana y comercial con S/ 27,405 millones; y de la gran industria con S/ 24,117 millones" [the largest savings were generated in the transport sector with PEN 27,492 million, followed by medium and small industry with PEN 27,405 million and large industry with PEN 24,117 million] (Macroconsult, 2021, p.1). Similar positive effects are pointed out by Cálidda, which emphasizes the competitiveness of natural gas and its impact on the reduction of rates: "(...) actualmente es entre 40% y 60% más barata que las del GLP y del diésel" [it is currently between 40% and 60% cheaper than LPG and diesel] (Macroconsult, 2021, p.1). NG consumption by transport, industry, commerce and residential users in Lima and Callao generated savings of more than PEN 80,000 million between 2004 and 2020. These figures show that all sectors of consumption have benefited. The challenge of the massification policy is to make natural gas competitive in Peru's regions. The experience gained in Lima and Callao provides the conditions for replicating good practices in other cities, incorporating other improvements and, in particular, promoting LNG production in micro-LNG plants.

CONCLUSIONS

The technological conditions available for the processing, transportation and distribution of NG and LNG are consistent with a high potential for effective natural gas massification in Peru.

The policy approach to massification has suffered from serious limitations, largely due to the emphasis on only the final components of the NG value chain.

Considering the NGVC as a unit, in a common and organized way, highlights the importance of key components that are typically neglected. The interdependence of production, transportation, distribution, marketing and users would encourage appropriate value creation throughout the chain. This condition is conducive to and makes the simultaneous massification of all consumer sectors possible. Both from international comparative experiences and from case studies in Peru, the contribution of a comprehensive approach to the NGVC to promote potential impacts is emphasized.

In the integral analysis of the NGVC, it is essential to consider the social impacts in the zone of influence of the massification project, taking into account simultaneously the different NG users. The knowledge of the integral behavior of the NGLC will allow the definition of policies for the simultaneous growth of the different consumption sectors, which explains the influence of the value chain in the residential use of gas, since this is a component of it.

The LNG produced in Melchorita is mainly destined to the export market. This situation is changing and today it is also used to supply part of the domestic market. This alternative is feasible due to the advantages of LNG, which allows the use of tankers for transportation. This experience creates conditions for establishing virtual LNG transportation and expanding the domestic market to other consumption points.

The CVGN segment corresponding to residential use consists of the connecting pipeline, internal installation, and gas appliances. To ensure massification, it is necessary to achieve high efficiency in the CVGN construction processes and, above all, in the creation of the NG culture that will ensure the sustainability of the massive use of NG, as has been achieved in Lima and Callao.

The transport pipeline has not undergone any significant expansion in line with the orientation towards the massive use of natural gas. It is necessary to improve the current situation of NG and LNG transportation and distribution infrastructure as a matter of state policy. The management of construction processes based on teamwork, the collaborative model and competencies influences the improvement of the efficiency of the processes carried out by gas installation companies, making them more competitive. The incorporation of this management style in the installation companies will contribute to improving the efficiency of natural gas massification in Peru.

Other recommendations, such as the promotion of virtual LNG transportation, LNG production in micro LNG plants, adequate tariffs, state participation in the creation of distribution infrastructure and training of installers, will create the conditions to facilitate an effective massification of natural gas in Peru.

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Conflicts of interest

The author has no conflicts of interest to declare.

Author contributions

Santiago Victor Paredes Jaramillo (lead author): conceptualization, data curation, formal analysis, funding acquisition, research, methodology, project management, resources, software, supervision, validation, data visualization, writing (original draft, review, and editing).