

Balvin, Luis; Gomez, Sandra; León, Claudia; Alvarez, José C.

Article

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Natural gas distribution proposal in Lima's urban hills through lean logistic and mixed whole linear programming

Luis Balvin, Sandra Gomez, Claudia León, José C. Alvarez*

Universidad Peruana de Ciencias Aplicadas, Prolongación 2390 Monterrico - Surco, Lima - Lima 33, Peru

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Abstract

The availability of natural gas in Lima — Peru, from Camisea, in several urban areas of Lima, for technical reasons there are no natural gas facilities especially in peripheral urban areas in the highlands or hills. This is compensated by FISE government social programs providing subsidized liquefied petroleum gas balls. In this context, a proposal has been developed to provide natural gas to these elevated areas, in particular to Cerro San Cristóbal, located in the boundaries of the districts of Rímac and San Juan de Lurigancho — Lima. This proposal is based on the principles of Lean Logistic and linear programming of mixed burials. The results will imply a better supply of natural gas to peripheral areas and energy poverty, the inherent security problems must also be addressed.

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Keywords: Natural gas; Distribution; Lean logistic; Entire mixed linear programming; Hills in urban areas; Energy poverty

1. Introduction

The natural gas has impacted the Peruvian energy sector since its appearance, leading to the change of the energy sector. This gas is destined for internal consumption and export, after going through a liquefaction process at the Pampa Melchorita plant, located in the Ica — Peru.

After the findings of natural gas reserves in lots 56 and 88 in Camisea in the province of La Convención, Cusco; it was building a gas pipeline (for transportation of pipeline gas) with a poliducto (for liquids associated with natural gas) to the city of Paracas, Ica. Later, the pipeline continued the journey to Pampa Melchorita, where part of the supply of natural gas will go through a liquefaction process to obtain Liquefied Natural Gas; this gas is mostly exported abroad by sea methane containers [1].

However, the surplus natural gas is sent via gas pipeline to the city of Lima, where it is intended as fuel for industrial and residential use; as well as for use in electricity generation through a cogeneration system based on gas turbines, mainly used in thermal power plants in Chilca — Lima [2].

* Corresponding author.

E-mail address: pciijalv@upc.edu.pe (J.C. Alvarez).

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In first stage, the natural gas was destined to companies that gradually replaced their diesel consumption with natural gas, due to their lower acquisition price and their lower concentration of polluting aspects. Among the companies that will replace diesel with natural gas are ceramic ones, as well as other companies located in district of Lurín - Lima.

Over the years, the distribution of natural gas has been gradually implemented in several districts of Lima. However, according to the report of the five-year plan issued by the gas distribution company in Lima, it is observed that the level of gas connections does not yet cover urban - marginal areas located in the elevated parts of the city (populated hills) [3]. This generates that a considerable part of the population that resides in these places is not yet benefited from the access of this service.

However, the Social Energy Inclusion Fund (FISE) an entity that belongs to the Supervisory Agency in Energy and Mining (OSINERGMIN), currently subsidizes in these sectors, compressed LPG balls at a price of \$ 6.99/balloon [4].

In this context, an innovative alternative is proposed to bring natural gas to these sectors, thereby establishing an economic, social and environmental benefit that guarantees the sustainable development of these growing communities. That is, it is intended to eradicate energy poverty in these areas, offering a new fuel alternative at a reasonable price and with a lower concentration of polluting aspects that cause the deterioration of the environment.

This proposal consists in carrying out, through virtual pipelines, liquefied natural gas from Pampa Melchorita to mini-regasification plants in the hills of Lima.

2. The problem

2.1. Description and importance of the problem

The distribution of natural gas in Lima and Callao is also carried out through pipeline networks. The distribution stage is divided as follows:

- In the case of the Main Network, the distribution is carried out under high pressure and begins at the city gate to end in the Ventanilla district.
- In the case of distribution by other networks, this is done in medium and low pressure, which starts at the red trunk of high pressure and ends at the consumer's home.

According to the General Directorate of Hydrocarbons (DGH) of the Ministry of Energy and Mines (MEM), 624,206 connections have been made in charge of the company responsible for distributing natural gas in Lima, which means that at least two millions and a half of Peruvians have a cheap and clean source of energy at home [5] (see Fig. 1).

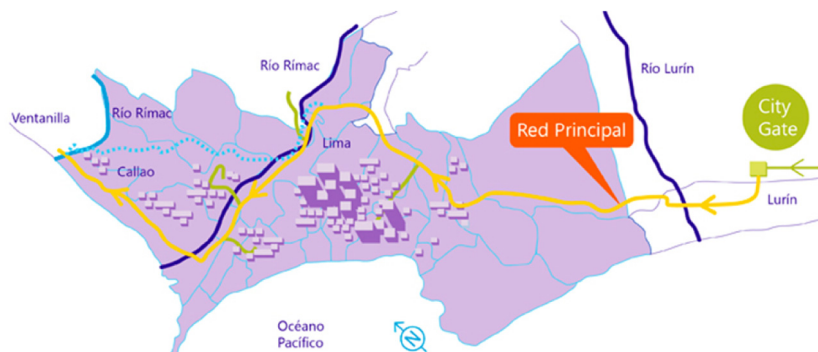


Fig. 1. Natural gas natural distribution network in Lima [6].

However, the absence of strategic planning in the energy sector limits the overcrowding of natural gas for an abundant country in this resource. This has generated that only some sectors in Lima have benefited. Next, you can see in the image the level of natural gas connection in the different districts of Lima (see Fig. 2).

Although one of the most benefited districts is San Juan de Lurigancho having 68% of connections; the families that have not benefited from this fuel are those that live in the highlands, since the supply pressure by the company

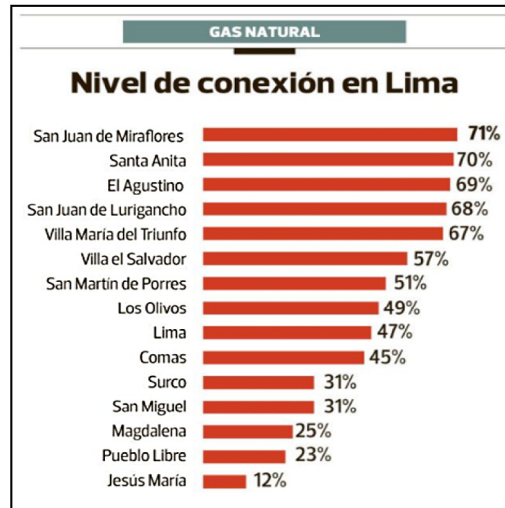


Fig. 2. Connections level of natural gas in Lima [7].

responsible for distributing Natural Gas in Lima has not been sufficient to supply these areas [8]. The absence of natural gas service in this sector has been defined as their inability to obtain adequate energy services below 10% of their disposable income. This limits the efficient use of energy for kitchens in homes, as well as for gas-operated hot springs, among others.

On the other hand, in Fig. 3 analyzing the type of fuel used by Lima homes during the last years, it has been observed that the percentages of people who use gas are between the range of 60%–76%. However, there is still a considerable small number that still uses organic fuels such as wood burning or fuels with a high degree of pollution.

4.10 PROVINCIA DE LIMA: HOGARES POR TIPO DE COMBUSTIBLE QUE UTILIZAN PARA COCINAR, 2007-2016
(Porcentaje)

Año	Solo gas 1/	Gas y otro combustible 2/	Utilizan leña 3/	Carbón	Kerosene	Más de un combustible 4/	No cocinan
2007	75,8	10,7	0,6	0,7	4,0	5,1	3,5
2008	66,6	22,6	0,5	0,3	2,3	5,0	3,7
2009	64,8	24,5	0,5	0,5	1,8	5,6	3,6
2010	60,1	28,2	0,3	0,3	1,0	7,5	3,5
2011	59,6	31,3	0,2	0,4	0,4	7,2	2,8
2012	60,7	30,5	0,1	0,2	0,3	7,3	3,7
2013	54,5	35,6	0,0	0,1	0,1	7,1	2,9
2014	60,5	29,7	0,0	0,0	0,2	6,2	3,4
2015	68,5	23,1	0,2	0,3	0,0	4,9	3,0
2016	68,9	21,8	0,3	0,0	0,2	5,8	3,0

1/ Incluye gas licuado de petróleo y gas natural.
2/ Además del gas (gas licuado de petróleo y Natural) usan leña, carbón, electricidad y Kerosene.
3/ Incluye también ramas secas, tusa de maíz, etc.
4/ Son hogares que utilizan más de un combustible contaminante para cocinar los alimentos.
Fuente: Instituto Nacional de Estadística e Informática - Encuesta Nacional de Hogares.

Fig. 3. Households by type of fuel used to cook in Lima [9].

The National Census carried out in 2017 based on the total number of homes with natural gas. It can be seen that, in the district of San Juan de Lurigancho only 13.8% have benefited from the natural gas service [9].

2.2. Delimitation of the study area

The San Cristóbal is a hill located between the Rímac district and the San Juan de Lurigancho district in the city of Lima — Peru. It is part of the isolated hills of the mountain range of the Andes (see Fig. 4).

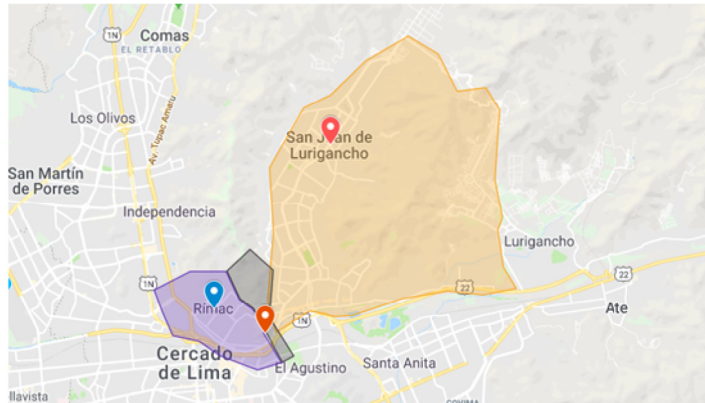


Fig. 4. Study area delimited for work.

3. State of art

Mikolajková et al. [10] formulate a problem of linear programming of mixed integers (MILP) and the problem is solved by cutting-edge software. The model is illustrated in a problem of regional energy supply considering seasonal variations in natural gas demands. The results of the study demonstrate the role of the price of local and alternative fuels and the price margins in which it is possible to build an extensive pipe network instead of supplying fuel through trucks to warehouses connected to the pipe islands.

Batidzirai et al. [11] seek to obtain an optimal SNG production supply chain that is economically accessible and environmentally optimal for different regions of the Netherlands, in order to reduce the CO₂ emissions caused by fossil fuels.

Wang et al. [12] seek to understand the viability of the supply chain by implementing tracking technologies for improvement. To improve supply chain management, the research effort has focused on many aspects including supplier selection or evaluation, the analytical model, performance measurement and influence analysis of the sustainable supply chain. Regarding the improvement of monitoring capabilities in the supply chain, the innovative technologies have the ability to address ineffective problems by integrating all materials with the work processes of the supply chain to provide project team's online access to information during all phases of the project.

Hassan et al. [13] seek to minimize the cycle time of natural gas distribution with a Six Sigma improvement project, since the reduction of cycle time easily translates into commercial profits in which more orders are completed and lost less due dates. In addition, they demonstrate that Six Sigma's methodology and performance for non-distributed processes is normally more involved than in the case of processes that are not normally distributed.

Dong et al. [14] investigate the growth and development of the natural gas supply chain in the United States and China, as they are the two largest economies of CO₂ emitters. Therefore, they used three methods to evaluate the growth and development of the natural gas supply chain of these countries: (i) Model of degree of coordination based on distance; (ii) Model of degree of coordination of exchange rate, and (iii) Model of integrated degree of coordination.

Yusuf et al. [15] developed a performance measurement system with a comprehensive set of performance measures in the natural gas supply chain so that the natural gas industry in Ghana remains efficient and meet the demand of the customers.

Bittante et al. [16] developed a linear mixed integer programming (MILP) model, which considers the distribution of LNG by a heterogeneous fleet of ships, applies linear mixed integer programming to find the structure of the supply chain that minimizes costs associated with the acquisition of fuel.

Bittante et al. [17] propose the use of a MILP model for the optimal design of a small-scale LNG supply in order to solve the main errors that occur at the time of its implementation. Therefore, they are based on defining the new stochastic model that allows them to select the most suitable ports where the built-in gas terminals should be, the size of the LNG warehouses, the route for the transport of LNG tankers. This stochastic model proposed by the author's aims to minimize the total combined cost associated with the acquisition of LNG fuel.

According to Abanto Bojórquez [18], in concessions to the northern and central regions of Peru, the supply of natural gas will be made through the virtual transport of liquefied natural gas from Pampa Melchorita, to the regulation and measurement facilities at the reception. As stated by Rentizelas et al. [19], the social, environmental and safety aspects should be taken into consideration when selecting suppliers, particularly in the oil and gas industry. A case is found when the Peruvian state gave concession the distribution of natural gas in the city of Lima to the Clidda enterprise, where it is expected that these aspects have been taken into consideration.

4. Innovative proposal

The purpose of this research is to add value to the natural gas supply chain by obtaining greater reach and access to liquefied natural gas in low-income areas, such as sectors D and E in places of high slope. For example, Cerro San Cristóbal, in the limits of the district of San Juan de Lurigancho and Rímac.

It is proposed to use the Lean Six Sigma tool, through the DMAIC methodology, to identify the strategic points in the San Cristóbal Hill with the objective that the pressure drop from the supply station is sufficient to supply all inhabitants of said geographical area. This implementation will bring a series of benefits that will improve people's quality of life, with greater access to new types of energy supply at a reduced cost and a lower environmental impact.

Steps to follow the DMAIC methodology:

- Define: Identification of the main problem of the natural gas supply chain.
- Measure: Collect data for a better analysis of the main problem.
- Analyze: The main cause that caused the problem of lack of coverage in the natural gas supply chain is identified.
- Improve: The following solution will be implemented.

As a proposal for improvement in the natural gas supply chain in the upper areas of the Rímac district, the creation of a new sub process in the main supply network of the distribution company has been proposed, through the implementation of strategic regasification points in San Cristobal hill located in the district of San Juan de Lurigancho and Rímac — Lima. As the problems in the Natural Gas supply chain in this sector are solved more efficient energy sources will be available to improve people's living conditions.

- Control: The success and permanence of the implementations will be defined, as well as the incorporation of the organization in a process of continuous improvement.

Likewise, to find the strategic points of regasification of natural gas in the high areas of the Rímac district, Lima, in particular on the San Cristóbal hill, linear mixed integer programming (MILP) will be used. Linear mixed integer programs are programs in which some variables are required to take integer values, and arise naturally in many applications. In our project, this program aims to find the strategic points where the GN compression stations will be located. In addition, MILP will be used to determine the proper routes for the installation of pipelines for the distribution of natural gas to families.

5. Conclusions

A proposal has been made to bring natural gas to the high and coincidentally disadvantaged parts of the city of Lima where the D and E class sectors live.

To make a diagnosis of the problem, statistical data have been used as well as on-site visits.

An innovative proposal has been proposed which consists of a virtual natural gas pipeline taken from the liquefaction station of Pampa Melchorita to the high parts of the hills in the city of Lima from which already for the ease of gravity and according to a dynamic of the integers of the mixed centers and also with the application of the Lean Six Sigma an adequate distribution is achieved. This is achieved because with this the decrease in the alleviation of energy poverty in these sectors is achieved and, above all, to integrate them into a natural gas system, in addition to replacing the FISI program, which has the difficulty of bringing natural gas to these areas.

References

- [1] Tamayo J, Salvador J, Vásquez A, García R. La Industria del Gas Natural en el Perú, Lima; 2014.
- [2] EnerSur. PMA Conversión a Ciclo Combinado de la C.T. Chilca. Lima, s.f.
- [3] Pando Argote R, Sanchez Paisig J. Plan quinquenal de inversiones 2018–2022. Lima: Osinergmin; 2018.
- [4] Quispe E, Coapaza D. Análisis técnico-económico del uso del gas como alternativa energética en el sector residencial de las provincia de Arequipa. Arequipa: Universidad Nacional de San Agustín; 2015.
- [5] Bessombes C. Así avanza la masificación del gas natural domiciliario en el Perú. La República. 2019 Abril.
- [6] Cálidda. El gas natural. Available in: <https://www.calidda.com.pe/gas-natural/Paginas/Como-se-distribuye-el-Gas-Natural%E2%80%8B.aspx>.
- [7] El comercio. Conoce los distritos con mayor conexión de gas natural. Available in: <https://elcomercio.pe/economia/peru/conoce-distrito-s-lima-mayor-conexion-gas-natural-183593>.
- [8] INEI. Compendio estadístico peru 2018. Lima: INEI; 2018.
- [9] INEI. Hogares en viviendas particulares censadas con ocupantes presentes, según combustible que utilizan para cocinar los alimentos, Lima; 2017.
- [10] Mikolajková M, Saxén H, Petterson F. Mixed integer linear programming optimization of gas supply to a local market. *Ind Eng Chem Res* 2018;57(17):5951–65.
- [11] Batidzirai B, Schotman G, van der Spek MW, Junginger M, Faaij APC. Techno-economic performance of sustainable international bio-SNG production and supply chains on short and longer term: BioSNG supply chains. *Biofuels, Bioprod Biorefin* 2018;13(11).
- [12] Wang J, Chi H-L, Shou W, Chong H-Y, Wang X. A coordinated approach for supply-chain tracking in the liquefied natural gas industry. *Sustainability* 2018;10(12).
- [13] Hassan J, Aldowaisan T, Nourelfath M. Six sigma for gamma-distributed processes: a case study in oil and gas. *Int J Qual Reliab Manag* 2018;35(3).
- [14] Dong K, Sun R, Wu J, Hochman G. The growth and Development of natural gas supply chains: The case of China and the US. *Energy Policy* 2018;123:64–71.
- [15] Yusuf Y, Gunasekaran A, Papadopoulos T, Auchterlounie W, Hollomah D, Menhat M. Performance measurement in the natural gas industry A case study of Ghana's natural gas supply chain. *Benchmarking* 2018;25(8):2913–30.
- [16] Bittante A, Pettersson F, Saxen H. Optimization of a small-scale LNG supply chain. *Energy* 2018;148(1):79–89.
- [17] Bittante A, Jokinen R, Krooks J, Petterson F, Saxen H. Optimal design of a small-scale LNG supply chain combining sea and land transports. *Ind Eng Chem Res* 2017;56(45).
- [18] Abanto Bojórquez JAA. El gas natural en el Perú y los proyectos destinados a su descentralización. Lima: PUCP; 2014.
- [19] Rentizelas A, Jabbour A, Al Balushi A, Tuní A. Social sustainability in the oil and gas industry: institutional pressure and the management of sustainable supply chains. *Ann. Oper. Res.* 2018. <http://dx.doi.org/10.1007/s10479-018-2821-3>, in press.