



Colombia Coal Mine Methane Market Study

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1.0 Executive Summary

1.1 Introduction

This document serves to provide an overview of Colombia's energy markets, and specifically to identify opportunities for coal mine methane (CMM) utilization and emissions reduction projects in Colombia. This report is funded by the United States Environmental Protection Agency (USEPA) in support of the Global Methane Initiative (GMI). More information on the GMI can be found at: www.globalmethane.org. This report summarizes the markets for coal, electricity, natural gas, and coal mine methane, based on publicly available data.

1.2 Colombia's Energy Usage

1.2.1 Coal

In 2017, Colombia was the world's twelfth largest producer of coal, with the largest proved coal reserves in South America (BP, 2017). Three companies account for 82 percent of Colombia's total coal production (ANM, 2018). The northern departments of Guajira and Cesar are home to Colombia's largest coal deposits, but in addition to Guajira and Cesar, there are a number of smaller coal-producing areas scattered throughout Colombia's central interior. Of Colombia's 13 largest coal mines, 11 are open-pit mines (GMI, 2015).

Due to Colombia's enormous hydroelectric generation capacity, Colombia's coal production consistently exceeds its consumption. In 2015, Colombia consumed only 10 Mt of the 85 Mt of coal it produced (BP, 2016.1). The remaining 75 Mt was exported, making Colombia the fifth-largest coal exporter in the world (EIA, 2016).

The Ministry of Mines and Energy (MinMinas), Colombia's original national mining authority, was expanded in 2010 to work with the newly-formed National Mining Agency (ANM) (Latin Lawyer, 2016; Norton Rose Fulbright, 2011).

1.2.2 Electricity

Despite being rich in hydrocarbon resources, Colombia supplies close to 70 percent of its total power requirements via hydroelectric facilities (ProColombia, 2015). Of the remaining 30 percent, Colombia generates 10 percent and 7 percent of its electricity demand from natural gas and thermal coal, respectively (ProColombia, 2015). The majority of Colombia's power generation, from both hydroelectric and thermal facilities comes from the nation's northern and central departments. Five companies fulfill 86

percent of Colombia's electricity demand (XM, 2015). Emgesa's Guavio facility is Colombia's largest hydroelectric plant, with of 1,250 MW of effective capacity (XN, 2018). Colombia's largest thermal coal plant, a GECELCA facility, boasts 273 MW of generation capacity (XN, 2018).

The majority of Colombia's population resides in less than half of the country's land area. The populous regions of Colombia are mostly within northern and central departments, and are serviced by the National Interconnected System (NIS). The remaining portions of Colombia are classified as Non-Interconnected Zones (ZNI). Areas in the NIS have access to electricity, while ZNI areas use diesel fuel as their primary power source. ZNI areas, however, are expected to shrink in the coming years, as the Colombian government has established an investment fund aimed at modernizing and improving ZNI energy infrastructure. To keep pace with surging national energy demand, the Colombian government plans to expand and improve its current electricity grid infrastructure.

In 2017, Colombia's total demand for energy grew by 1.3 percent. A subsidiary of MinMinas, the Mining and Energy Planning Unit (UPME) expects upward this trend to continue, with Colombian energy demand projections growing by an annual average of 3.4 percent through 2027 (MaRS, 2015). Colombian economic growth and urban expansion will continue to support the nation's energy demand growth well into the first quarter of the 21st century. This increase in demand should help lower residential electricity prices that are some of Latin America's highest. One explanation for Colombia's high residential electricity prices is that they are inflated by electricity tariffs (MaRS, 2015). The nation's high prices, however, are mitigated by an income bracket system that subsidizes electricity costs; a similar subsidy system is also used in Colombia's natural gas sector.

Colombia's climate and geography provide enormous potential for renewable energy projects, excluding hydropower, but Colombia only generates 3 percent of its total energy mix via renewable technologies (MaRS, 2015). A question for Colombia's future, therefore, becomes whether new investments will flow into renewable projects or continue to flow into existing technologies.

1.2.3 Natural Gas

Colombia boasts the sixth-largest proved natural gas reserves in South America (BP, 2016). The majority of these natural gas reserves are located in two basins, Guajira and Llanos. The Guajira Basin, located in northern onshore and just offshore Colombia,

holds 1.02 Tcf of proved reserves, and has historically accounted for the bulk of Colombia's natural gas production (ARI COGSM). The Llanos Basin, which holds 3.9 Tcf of proved reserves, produced 199 Bcf in 2014 (ARI COGSM). Guajira Basin production, however, began to decline in 2017, while Llanos Basin production is expected to increase and offset these declines.

Midstream infrastructure is a much greater problem for Colombia than upstream infrastructure. Colombia's dense jungles and mountainous topography make transportation difficult. Nonetheless, Colombia boasts 4,991km of natural gas pipelines, with several companies committing to invest in future projects (CIA, 2013). Improvements to Colombia's natural gas infrastructure are crucial to meeting growing demand for the fuel.

In addition to conventional natural gas production, Colombia potentially holds world-class shale source rocks. ExxonMobil, ConocoPhillips, and Royal Dutch Shell all own lease blocks in Colombia's Middle Magdalena Valley (MMV). However, the Colombian government has only recently established a regulatory framework for exploration of unconventional gas, so no wells have been drilled to date. ConocoPhillips was the first company to receive an environmental license to drill at well in 2019. This first well will be used by the Colombian Government to test the regulatory framework (including the environmental framework) and fine-tune the regulations, before it issues more licenses to explore for unconventional gas.

Currently, almost half of Colombia's natural gas production is reinjected into maturing oil fields for enhanced oil recovery (EOR) (EIA, 2016). Colombia's second-largest natural gas usage is pipeline gas. Colombia also uses natural gas to generate electricity, as an industrial fuel, and as automotive fuel. Colombia's fleet of natural gas-powered vehicles is already the 7th largest in the world, with this figure expected to grow (AAPG, 2016). As Colombia's economy continues to expand, natural gas production must be sufficient to satisfy the nation's EOR, industrial, and residential needs. Colombian natural gas demand, therefore, should continue to increase, as the nation's demand for gas has surged by 60 percent in the last decade (EIA, 2016).

The Colombian government has supported the fossil fuel industry since the inception of the National Hydrocarbons Agency (ANH) in 2003. In 2011, the Colombian government published a decree outlining plans to increase natural gas production, specifically unconventional natural gas from gas shale formations and coal mines (EIA, 2016).

1.3 Coal Mine and Coalbed Methane (CMM and CBM) Resources and Methane Emissions

Colombia's 6,746 Mt of proved coal reserves are thought to hold significant volumes of coal mine and coalbed methane (CBM and CMM) utilization potential. The ANH estimates its CMM/CBM reserves to be between 11 and 35 Tcf, compared to its 4.8 Tcf of proved natural gas reserves (ANH, 2011; BP, 2016).

With the majority of Colombia's coal production coming from the northern departments of Guajira and Cesar, most of the nation's CMM/CBM efforts have also been focused in this region. Despite the nation's large proved coal reserves, only a limited amount of work has been conducted to assess the potential for CMM/CBM development. In 2015, the U.S. Trade and Development Agency (USTDA) awarded Generadora y Comercializadora de Energía del Caribe S.A. (GECELCA) a grant to fund a CMM/CBM feasibility project in the Córdoba area (USTDA, 2015). Additionally, in 2017, a pre-feasibility study was conducted to evaluate the economic opportunities from implementing a CMM/CBM project at the San Juan mine in the Antioquia Department (EPA, 2017). Outside of these published studies, Drummond has drilled a number of test wells, but has not published the data.

Colombian laws empower the National Hydrocarbons Agency (ANH), an administrative body under the Ministry of Mines and Energy (MinMinas), to award areas for exploration and production of hydrocarbons, including CBM. The National Mining Agency (ANM), another administrative body under MinMinas, is charged with managing Colombia's mineral resources. In 2010, Colombia published its National Development Plan (NDP) 2010-2014. In it, the government identified the mining sector as a critical industry for economic growth, specifically mentioning CMM/CBM projects as an expansion area (MinMinas, 2010). As a result of NDP 2010-2014, the Colombian government published a 2011 decree describing its plan to increase natural gas production, particularly from gassy coal mines (EIA, 2016). Furthermore, that same decree set forth a 40 percent reduction in government royalties applicable to unconventional hydrocarbons, which includes CBM (GMI, 2017). However, despite these various decrees and plans, there have been no CMM projects implemented and only test wells drilled for CBM.

CMM utilization in Colombia could offer a number of benefits, including on-site power generation, improved mine safety conditions, and additional revenue capture. The majority of CMM projects around the world currently use the produced gas to generate power at the mine site. Many of these projects supply electricity to mine operations in

order to lower operating costs by reducing power purchases from the grid. There are a number of advantages to developing on-site CMM power projects, including relatively low capital costs to purchase the gas generators, the ability to utilize CMM down to concentrations of 30 percent methane (CH₄), the flexibility to build the project in modules, and the option to move the power plant to other parts of the mine or other mine sites if the gas supply declines to the point that it cannot support power plant operations. A review of Colombia's electricity sector reveals a number of factors that suggest there is a potentially strong market for CMM power projects. These factors are:

- 1) **High electricity prices:** Colombia has some of the highest electricity tariffs for residential and industrial customers in South America, owing to its unreliable distribution infrastructure. The ability for mines to generate power on-site using CMM will provide both a lower cost and more stable electricity supply for the mines.
- 2) **Reliability of hydroelectricity:** Hydropower currently accounts for about 70 percent of the country's electrical generation capacity. However, hydropower can be adversely affected by El Niño/La Niña-related events, as have been experienced during the last several years. CMM power projects would help provide a more secure source of electricity for the mines.
- 3) **Increasing natural demand coupled with declining gas production:** Over the past decade, demand for natural gas in Colombia has increased 60%, turning Colombia from a net exporter of natural gas into a net importer. Exacerbating the supply/demand imbalance is the fact that gas production in the country has fallen about 10 percent over the past 5 years. Therefore, it is likely that any CMM produced would be readily absorbed by the market, provided there are adequate means of transporting the gas to customers.
- 4) **Increased coal production:** Coal is expected to continue driving Colombian economic growth, with coal production estimated to grow 20% by 2020 (World Coal, 2016). In concert with the increase in coal production, there will also be an increase in Colombia's CMM emissions, as existing mines get deeper and new ones are opened. These increased CMM emissions should present good opportunities for CMM utilization projects.

- 5) **Colombia's signing of the Paris Agreement¹:** Colombia is a signatory to the Paris Agreement and has committed to reducing its greenhouse gas (GHG) emissions by 20 percent by 2030. The implementation of CMM projects would be helpful in the nation's ability to meet this goal, especially if coal production increases as forecast.

While there are a number of factors promoting and supporting the development of CMM projects in Colombia, there are also a number of challenges facing their implementation, including:

- 1) **Thirteen of Colombia's fifteen largest coal mines are surface mines:** As a result, CMM/CBM utilization potential at these mines is limited to pre-mine drainage.
- 2) **Inadequate characterization of CMM reservoir properties:** Limited work in the country has been performed to assess key reservoir properties governing the flow of methane through coal seams (e.g., gas content, permeability, gas saturation, etc.), making it difficult to accurately determine reserves and project economics.
- 3) **Limited technical and financial resources:** The majority of the underground mines in Colombia are small and operated by companies with limited technical and financial capacity to implement a CMM project.
- 4) **Limited access to service providers:** Most CMM projects require some type of drilling, either wells drilled from the surface for pre-drainage wells and/or gob wells or in-mine horizontal/cross-measure boreholes. While companies operating in Colombia do have some drilling rigs that could drill surface-based wells, there are currently no drilling companies that can provide in-mine drilling services.

From 2000 to 2015, Colombian CMM methane emissions rose from 231 Mm³ to 651 Mm³ (GMI, 2015). If Colombia is able to economically implement CMM utilization projects, the impact on emissions could be substantial. The 2017 prefeasibility study at the San Juaquin mine in Antioquia estimates the project could result in a net emissions reduction of 610,000 Mt CO₂e (EPA, 2017). The Córdoba feasibility study estimates the potential for 35 MMt CO₂e emissions reductions if the project were to be implemented

¹ More information on the Paris Agreement can be found at: http://unfccc.int/paris_agreement/items/9485.php.

(GECELCA, 2017). These projects would contribute to lowering Colombia's greenhouse gas emissions leading up to their 2030 commitment. Furthermore, coal mine degasification related to CMM utilization would increase safety conditions for Colombian coal miners. Finally, Colombian natural gas demand is expected to increase from 450 Bcf/year in 2015, to 500 Bcf/year in 2020 (ARI COGSM). CMM/CBM utilization could help meet this increased gas demand.

2.0 Coal Market

2.1 Overview

In 2015, Colombia's 6,746 Mt of proved coal reserves were the largest in South America (BP, 2016.1). In that same year, Colombia produced 85 Mt of coal, making it the region's largest producer (BP, 2016.1). The majority of Colombia's coal production comes from the northern departments of Guajira and Cesar. These two departments account for over 90 percent of Colombia's total coal production (GMI, 2015; Cerejón, 2013; Mining Atlas, 2016). Guajira is home to El Cerrejón, Colombia's most prolific coal mine. The Cerrejón Zona Norte mine is the largest open-pit coal mine in the world, which produced 33 Mt in 2014 (Bloomberg, 2015). Colombia's largest coal producers are Cerrejón Coal Company, Drummond International, and a partnership between Glencore and Prodeco.

2.2 Coal Production

2.2.1 Geographic Distribution

Colombia's coal production largely comes from the northern departments of Guajira and Cesar (Figure 1) (GMI, 2015). There are also, however, widespread small and medium-sized coal producing areas in Norte de Santander, Santander, Antioquia, Cundinamarca, Boyaca, Valle de Cauca, Cauca, Borde Llanero, and Llanura Amazónica (GMI, 2015). Most of Colombia's coal export infrastructure is located on the Caribbean coast (EIA, 2016).

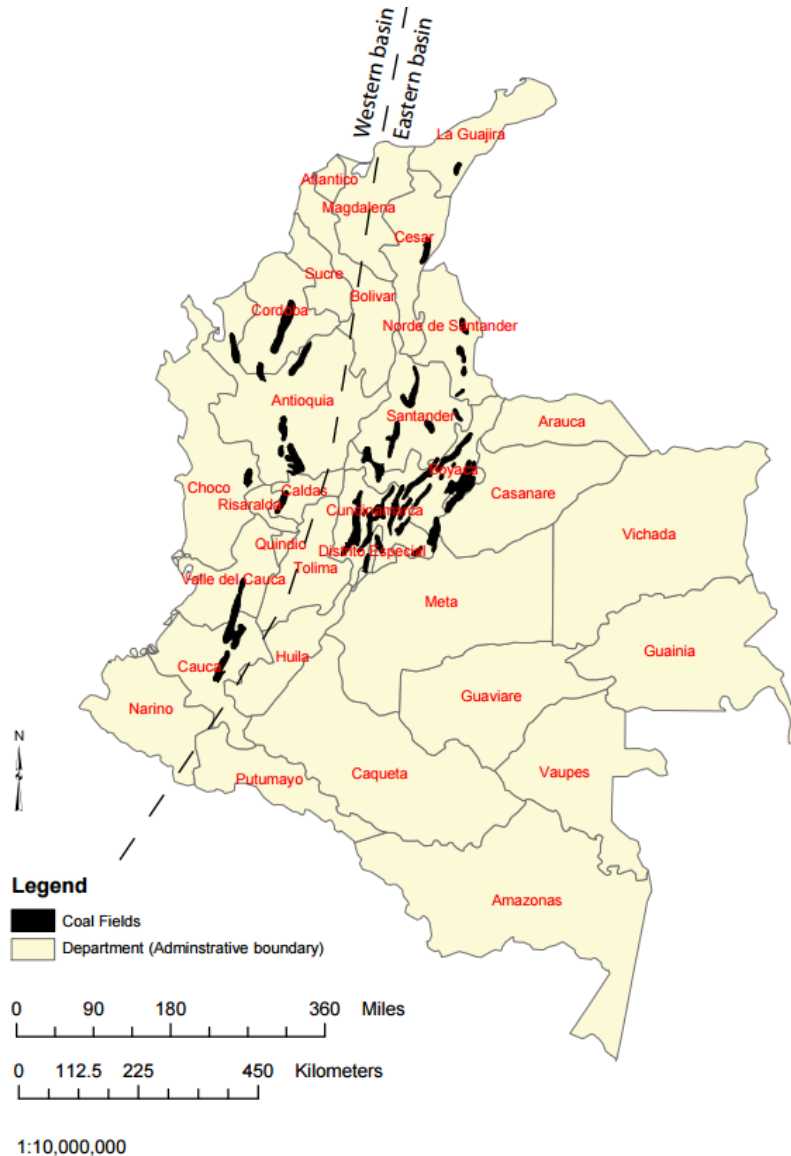


Figure 1: Figure showing the locations of Colombian coal basins, sub-basins, and department boundaries (Figure adapted from USGS, 2006).

El Cerrejón encompasses roughly 69,000 hectares and is located in La Guajira. El Cerrejón is divided into northern, central, and southern zones. The northern zone is the largest of the three and is home to the Cerrejón Zona Norte mine, the largest open-pit coal mine in the world (USGS, 2006). In 2017, El Cerrejón produced 32.1 Mt of coal and holds 4,874 Mt of reserves (ANM, 2018). El Cerrejón accounted for 43 percent of Colombia's 2013 export revenue, as well as 3.8 percent of 2013 global coal production.

La Cesar is Colombia's second major coal-producing department. Within La Cesar are two major mines: La Loma and La Jagua. In 2017, La Loma produced 13.61 Mt of

coal and held 484 Mt of reserves (ANM, 2018). In 2017, La Jagua produced 4.7 Mt of coal and held 260 Mt of reserves (ANM, 2018).

More information on these mines is provided in the Appendix A.

2.2.2 Coal Type and Quality

Colombia's proved coal reserves consist mainly of high-quality bituminous coal and a small amount of metallurgical coal (Table 1) (GMI, 2015). Furthermore, Colombia's high-quality bituminous coal reserves are the largest in Latin America (GMI, 2015). Coal from the El Cerrejón and La Loma mines have sulfur contents less than 1 percent and ash contents between 7.5-7.7 percent (Jähnig, 2007). Due to its relatively clean-burning nature, Colombia's coal is in high-demand and used almost entirely for export.

Region	Mineable Coal in Place (Gmt)	Anthracite	Low Volatile Bitum	Medium Volatile Bitum	High Volatile A Bitum	High Volatile B Bitum	High Volatile C Bitum	Sub-Bitum A	Sub-Bitum B	Sub-Bitum C	Lignite
Cesar	6.6					✓	✓				
Guajira	4.5				✓	✓	✓				
Boyacá	1.7			✓	✓	✓					
Cundinamarca	1.5		✓	✓	✓	✓	✓	✓	✓	✓	
Valle del Santander	0.2				✓	✓					
Norte de Santander	0.8	✓	✓	✓	✓						
Cordoba	0.7				✓	✓	✓	✓	✓		
Antioquia	0.5						✓				✓
Santander	0.8	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Total Recovery Potential	17.3										

Table 1: Colombia's Mineable Reserves and Quality by Region (adapted from ANH, 2011).

2.2.3 Coal Company Ownership

Three companies account for 82 percent of Colombia's coal production (Table 2) (World Coal, 2017). Cerrejón Coal Company, a consortium composed of Anglo-American, BHP Billiton, and Xstrata, is Colombia's largest coal producer and operates the El Cerrejón mines, railroad, and associated Caribbean coast export terminal (GMI, 2015; EIA, 2016). Drummond International, a partnership between U.S.-based Drummond Company and Japan's Itochu Corporation, is Colombia's second largest coal producer. Drummond International controls the La Loma mine and its mine-railway-port infrastructure. Colombia's third largest coal producer, a partnership between Glencore

and Prodeco, maintains the La Jagua mine. The remaining coal production is divided amongst smaller private companies.

2.2.4 Coal Production Trends

Coal is expected to continue driving growth in Colombia's mining industry. Annual coal production from 2010-2015 surged by 15 percent from 75 Mt to 85 Mt, and by 2020, production is projected to reach 105 Mt (Figure 2) (BP, 2016; World Coal, 2016). While coal production will remain largely dominated by Cerrejón Coal Company, Drummond International, and Prodeco, Murray Energy Corporation's newly acquired La Francia, El Hatillo, and undeveloped mines will also contribute to production growth (World Coal, 2016).

In addition, Colombian coal is highly competitive with U.S. coal with power generators along the Gulf of Mexico and southern Atlantic coast, and will remain in high demand (EIA, 2016.1). Coal prices have rebounded slightly from their lows in early 2016, and with each incremental price increase, greater production comes online. Colombia's coal production will likely continue to grow in the near future, as low operating costs and resilient demand supports profitability.

Table 2: Table showing Colombia's coal mines and their respective owners, production and reserves (ANM, 2018; GMI, 2015; Cerrejón, 2013; Mining Atlas, 2016).

Mine	Type	Location	Mine Owner	Production (Mt per year)	Reserves (Mt)
Cerrejón Zona Norte	Surface	La Guajira	Cerrejón Coal Company	17.0	4,874 (2013)
Cerrejón Zona Norte Patilla	Surface	La Guajira	Cerrejón Coal Company	3.8	-
Cerrejón Oreganal	Surface	La Guajira	Cerrejón Coal Company	6.1	-
Cerrejón Comunidad	Surface	La Guajira	Cerrejón Coal Company	5.2	-
La Loma	Surface	Cesar	Drummond	13.6	485
El Descanso	Surface	Cesar	Drummond	18.8	960
El Hatillo	Surface	Cesar	Murray Energy Corporation	0.63	500
Calenturitas	Surface	Cesar	Glencore/Prodeco	9.8	-
La Jagua	Surface	Cesar	Glencore/Prodeco	4.7	260
La Francia	Surface	Cesar	Murray Energy Corporation	3.0	-
Others	N/A	N/A	N/A	7.9	-

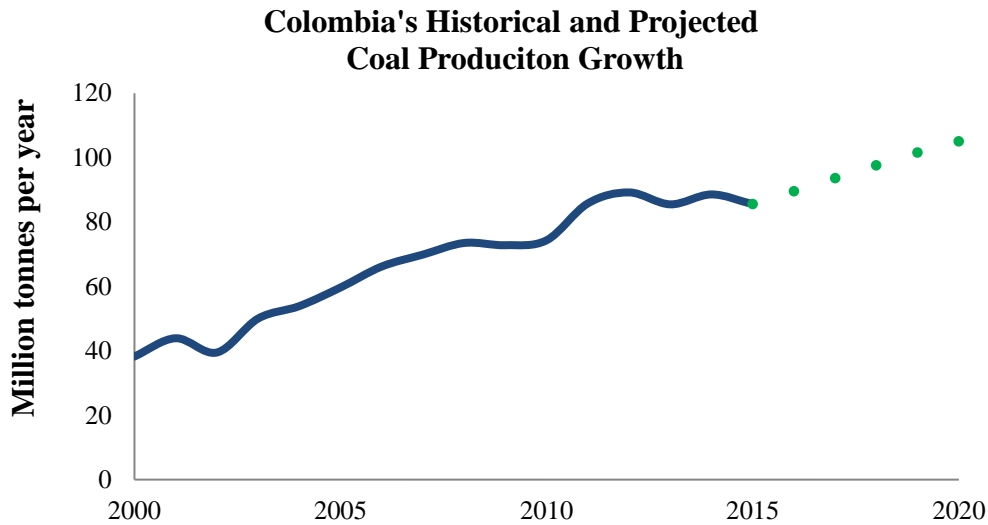


Figure 2: Graph showing Colombia's historical and projected coal production. Colombia produced 86 Mt of coal in 2015, and is projected to produce 105 Mt in 2020 (BP, 2016; World Coal, 2016).

2.3 Supply and Demand

As shown in Figure 3, Colombia consistently has an excess coal supply; in 2014, only 8 Mt of 88 Mt of coal were consumed in the country (EIA, 2016). Colombia may experience an uptick in demand for coal in the near future, as El Niño conditions decrease hydropower infrastructures' reliability, but natural gas is the more likely substitute. Demand for Colombian coal internationally, however, is very strong, due to its high quality and low sulfur content. Therefore, Colombia's coal supply will continue to exceed domestic demand in order to satisfy international demand for the high-quality, cost-effective Colombian coal.

2.4 Imports and Exports

Colombia's net exports in 2015 totaled 80 Mt, making it the fifth-largest coal exporter in the world behind Indonesia, Australia, Russia, and the United States (EIA, 2016). There remain, however, significant opportunities for Colombia to increase its coal exports. Europe has historically been the largest destination for Colombian coal, but U.S. imports of Colombian coal grew by 8 percent between 2014 and 2015 (Figure 4) (EIA, 2016.1).

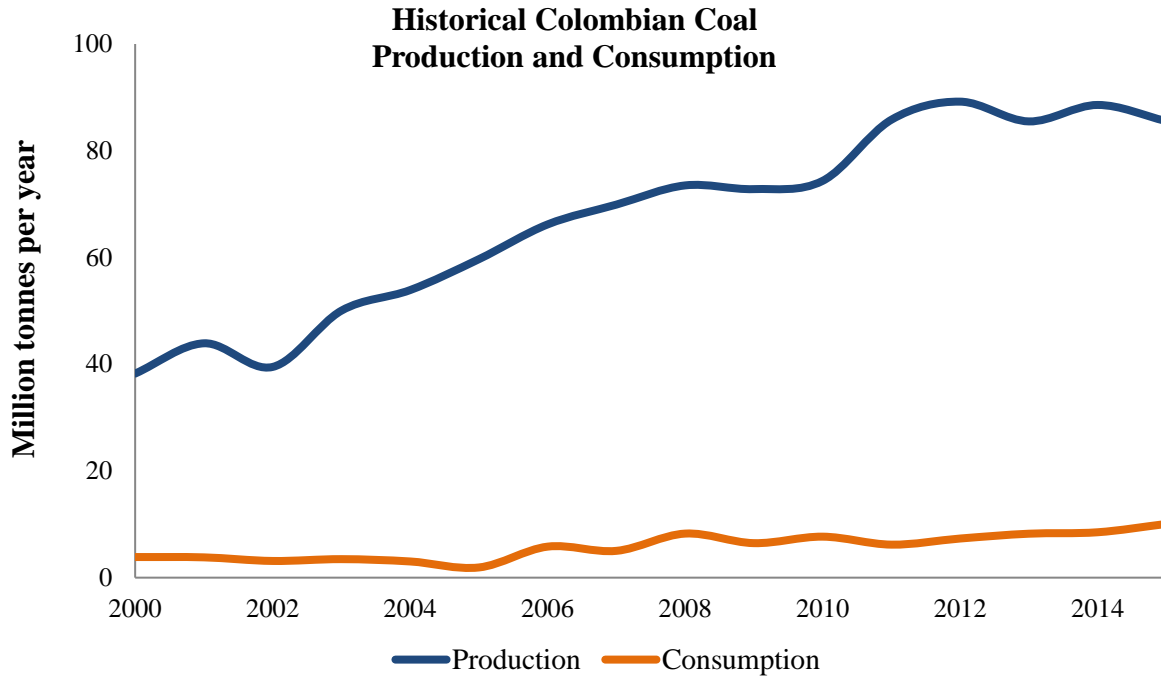


Figure 3: Figure showing Historical Colombian Coal Production and Consumption. The difference between production and consumption is assumed to represent Colombia’s net exports (EIA, 2016).

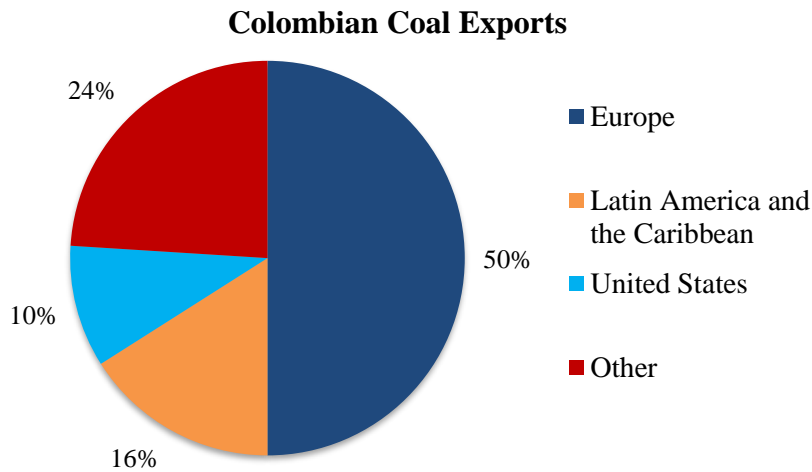


Figure 4: Figure showing Colombia’s coal export destinations. Europe is currently Colombia’s largest coal export destination (EIA, 2016).

Furthermore, in 2015, Colombia’s coal exports to Turkey and the Netherlands increased by 24 percent and 11 percent, respectively (World Coal, 2016). Colombia has also begun increasing export shipments to the Pacific. In early 2016, South Korea’s East-

West Power utility (EWP) ordered close to 670,000 tonnes of Colombian coal (Reuters, 2016). The expansion of the Panama Canal, nearing completion, will further boost Colombian coal access to Asia (Reuters, 2016). Large reserves, competitive operation costs, and low transportation costs signify that, despite a weakened price environment, demand for Colombian coal may remain steady.

2.5 Coal Market Regulations

2.5.1 Regulatory Agencies

Because of the mining industry's economic significance, Colombia's policies and regulations tend to be favorable towards the mining industry. Private companies own and operate all of Colombia's individual coal mines. The Ministry of Mines and Energy (MinMinas) is Colombia's original national mining authority with the capacity to regulate mining activities in accordance with Congressional laws (Latin Lawyer, 2016). In 2010, the National Mining Agency (ANM) was created to work in coordination with the Ministry of Mines and Energy to better administer Colombia's mineral resources, grant new mining titles, and help the private sector with public relations (Latin Lawyer, 2016; Norton Rose Fulbright, 2011). Figure 5 illustrates the relationship between Colombia's relevant regulatory bodies.

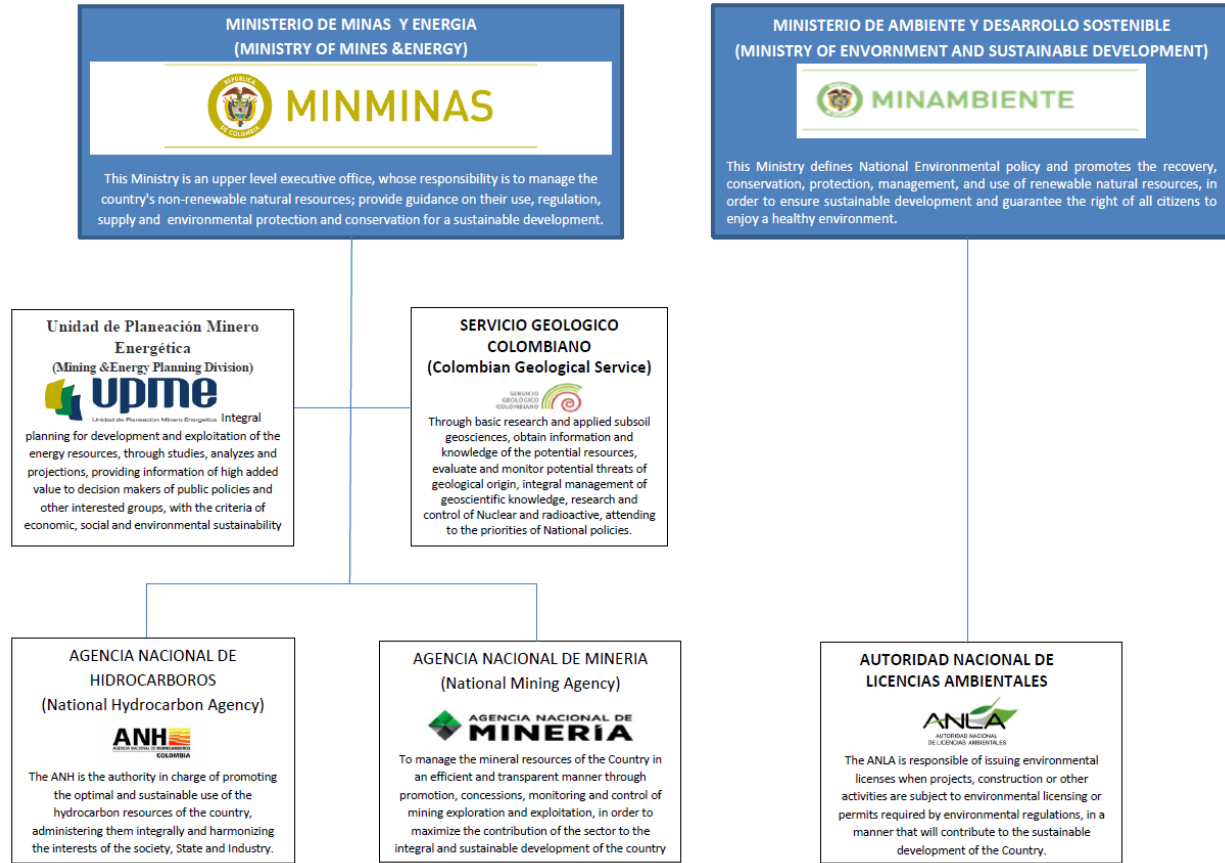


Figure 5: Chart showing the relationships between Colombia’s various mining and hydrocarbon-related regulatory agencies.

2.5.2 Existing Regulations

Under Colombian law, foreign individuals and mining corporations involved in mining ventures have the same rights as Colombian individuals and corporations (Latin Lawyer, 2016). Foreign entities can register as a Colombian branch or subsidiary in order to enjoy these rights (Latin Lawyer, 2016). Mining regulations in Colombia follow the principle that the minerals belong to the State and may only be exploited with permission from the relevant authority, currently the National Mining Agency (Latin Lawyer, 2016). Beginning in 2001, Congress issued Law 685, more commonly referred to as the Mining Code, which organizes a single 20-30 year mining contract into 3 phases: Exploration, Construction, and Exploitation (Latin Lawyer, 2016). Exploration terms of an agreement begin at 3 years and are able to be extended to maximum of 14 years (Latin Lawyer, 2016). Construction terms begin at 3 years and may be extended up to a maximum of 4 years (Latin Lawyer, 2016). Exploitation terms make up the remainder to the total contract’s length.

The three contractual phases accrue different government fees and royalty payments. During Exploration and Construction, the titleholder pays a surface fee that is tied to the prospective mine's total acreage (Latin Lawyer, 2016). During Exploitation, the title holder pays an annual royalty fee of 10 percent on coal mines producing more than 3 Mt/year and 5 percent on coal mines producing less than 3 Mt/year (Latin Lawyer, 2016).

Colombia has, in recent years, increased environmental regulations, in order to better oversee foreign corporations' coal mining projects. In 2014, the Colombian government ordered Drummond to halt close to 80,000 metric tons of daily coal exports due to the company's failure to meet environmental standards (WSJ, 2014). For every day Drummond's export operations were shut down, however, the Colombian government lost an estimated \$6 million in taxes and royalties (PRI, 2014).

As it relates specifically to CMM/CBM development, Colombia's regulatory environment is facing some potential structural changes. In March of 2014, the Ministry of Mines and Energy adopted Resolución 90325, which allows mining companies to utilize the methane gas released during mining operations to provide on-site energy to the mine. However, in October of 2016, a Colombian court ruled that local and regional governments may decide whether or not they will allow mining or other activities, including CMM/CBM development, within their jurisdictions (Stratfor, 2016). The ruling built on an earlier decision that overturned a 2001 law forbidding local and regional authorities from blocking mining developments; this decision was made on the basis that the 2001 law violated *Consulta Previa* (Stratfor, 2016). *Consulta Previa* stipulates that Colombia's indigenous peoples must be consulted prior to any project development on ancestral territories. Furthermore, in order for a project to be developed on such lands, a number of requirements and agreements with indigenous peoples must be reached. Prior to the 2016 ruling, only the Ministry of Mining and Energy was able to make these decisions. This decision is a "first of its kind" for the Colombian mining industry historically favorable to developers.

2.6 Colombia's Coal Market Pricing

Colombian coal prices touched a 10-year low of \$43 per tonne at the beginning of 2016 (Index Mundi, 2016). This price collapse was not unique to Colombia, as global coal prices have also retracted over the past 5 years. Recently, coal prices have recovered somewhat, and Colombian coal fetched \$78 per tonne in September of 2016 (Index Mundi, 2016). Price surges in competing export countries, in combination with newly

improved Colombian transport infrastructure, have ensured that Colombian coal trades at a discount to other coal sources. Early in 2016, Colombian coal was \$7-8 cheaper per tonne than Australian coal (Figure 6) (Reuters, 2016).

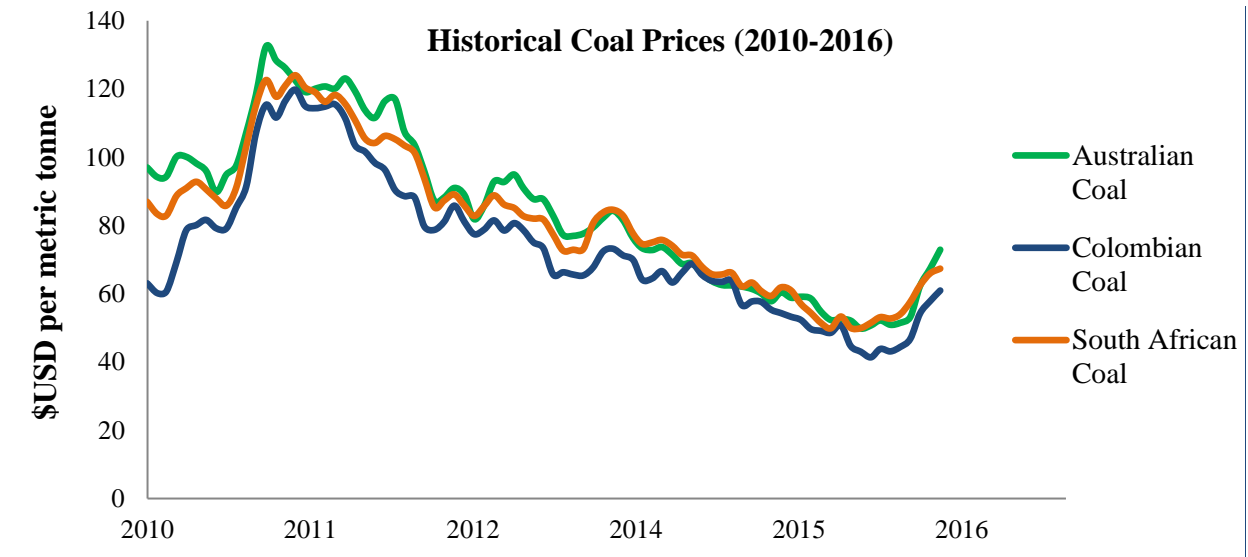


Figure 6: Figure showing historical Australian, Colombian, and South African coal prices. Global coal prices collapsed beginning in 2011, but have rebounded through 2016. Colombian coal remains cheaper than Australian and South African substitutes (World Bank, 2016).

3.0 Electricity Market

3.1 Overview

In 2014, Colombia produced over 64,000 GWh of electricity (ProColombia, 2015). That year, EPM, Emgesa, Isagen, GECELCA, and AES Chivor, were responsible for fulfilling 86 percent of the country's generation demand (Figure 7). The majority of these companies' generating facilities is in Colombia's Central and Northern Departments, as this is where over 95 percent of Colombia's population resides. Of Colombia's total power production, 70 percent comes from hydroelectric facilities, while 10 percent comes from thermal natural gas plants, and 7 percent from thermal coal plants (ProColombia, 2015). The figures for natural gas and coal are expected to increase as El Niño-related hydroelectric power shortages bolster thermal power demand.

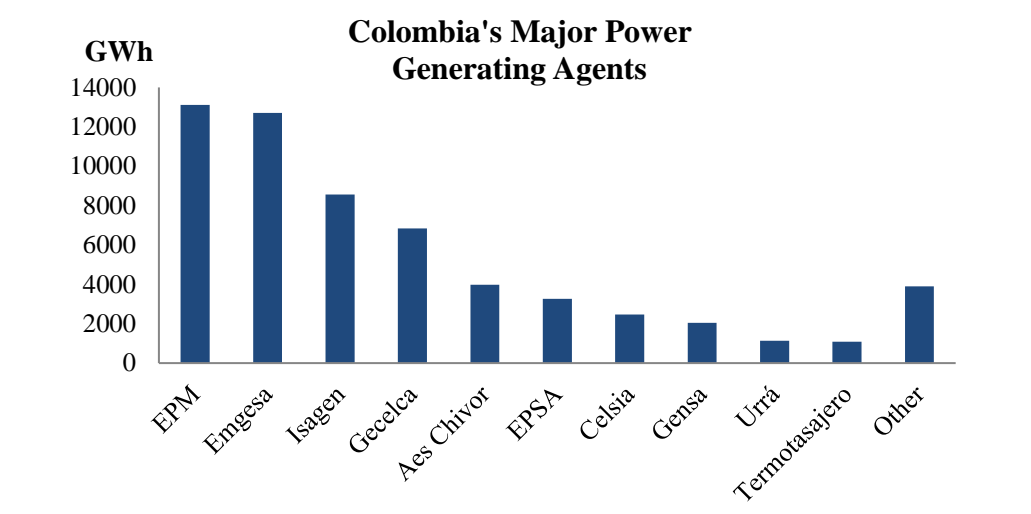


Figure 7: Figure showing Colombia's largest power generating agents, with 86 percent of the country's power generation coming from five companies (XM, 2015).

Colombian electricity production, both hydroelectric and thermal, is expected to steadily increase from 2016-2027. Urban population growth and economic expansion will contribute to Colombia's rising demand for power. Likely concentrated in Colombia's cities, the Mining and Energy Planning Unit (UPME) expects power demand to grow by over 3 percent annually through 2027 (MaRS, 2015).

Despite access to massive hydroelectric resources, residential electricity prices in Colombia are higher than in almost every other Latin American country. Industrial electricity prices are also high, due to Colombia's unreliable distribution infrastructure.

Colombia's growing electricity demand will remain strong moving into the 2020's. It remains to be seen, however, whether the nation's recent commitment to a 20 percent greenhouse gas (GHG) emissions reduction by 2030 will shift investment from fossil fuels towards more renewable sources.

3.2 Organization of the Electricity Sector

Colombia's electricity sector utilizes a mix of thermal and hydroelectric generation. The majority of Colombia's effective capacity, from both hydroelectric and thermal generators, comes from the Central and Northern departments of Colombia (Figure 8). Colombia's largest hydroelectric plant, Emgesa's Guavio facility, annually produces 1,250 MW and is located in Cundinamarca (XN, 2018). GECELCA, the owner of Colombia's largest thermal coal plant, has 273 MW of installed capacity (XN, 2018).

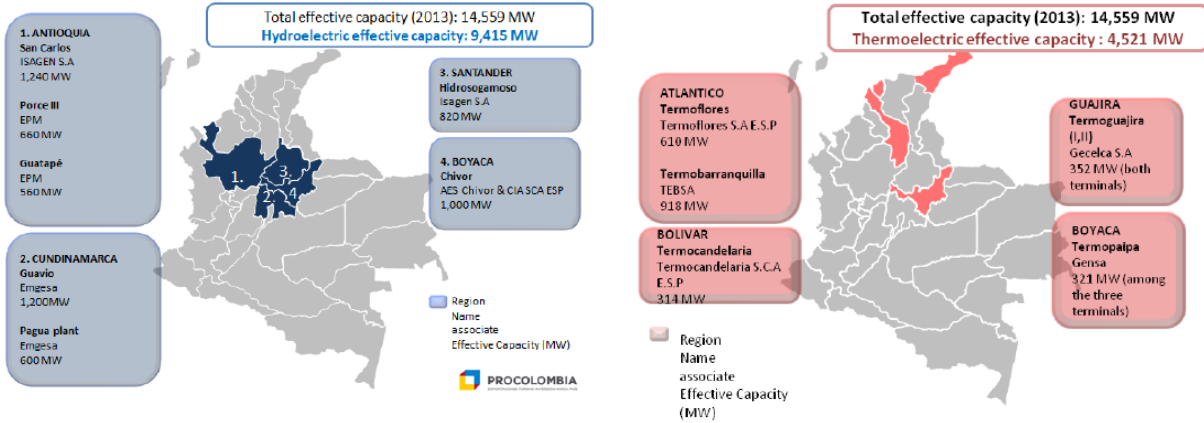


Figure 8: Figure showing the geographic distribution of Colombia’s current power generating facilities. Hydroelectric capacity, Colombia’s largest source (left) and thermal capacity, a growing power source in Colombia (right) (Figure adapted from ProColombia, 2015).

Colombia’s immense hydroelectric resources and regional connectedness allow Colombia to be a net exporter of electricity. In 2013, Colombia exported 57.8 GWh of electricity to Venezuela (85 percent) and Ecuador (15 percent) (MaRS, 2015). Export figures are expected to increase, as a project between Colombia and Panama will be completed in 2018. Additionally, an Andean Electrical Interconnection System between Ecuador, Peru, and Chile will soon begin construction.

3.3 Generation

3.3.1 Generation Mix

Historically, Colombia’s largest source of power has been hydroelectric generation. In 2014, hydroelectric generators produced 44,734 GWh, followed by thermal energy with 19,044 GWh, with other sources accounting for 550 GWh (ProColombia, 2015).

In 2014, 29.6 percent of Colombia’s total power generation came from thermal power. Of this 29.6 percent, 21.5 percent was derived from natural gas, while 6.5 percent was coal-based, and less than 1 percent came from other liquids such as diesel (Figure 9) (ProColombia, 2015). As El Niño weather conditions threaten hydroelectric generators’ production capabilities, it can be expected that thermal production will increase (Figure 10). Furthermore, if demand for Colombian thermal power generation continues to increase, it is expected that natural gas, not coal, will be the accommodating fuel.

Colombia's Electricity Capacity Mix

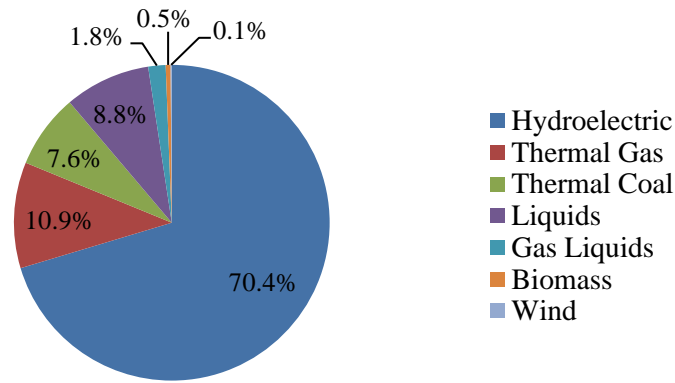


Figure 9: Figure showing the breakdown of Colombia’s power capacity mix, with hydroelectric facilities generating over 70 percent (XM, 2015).

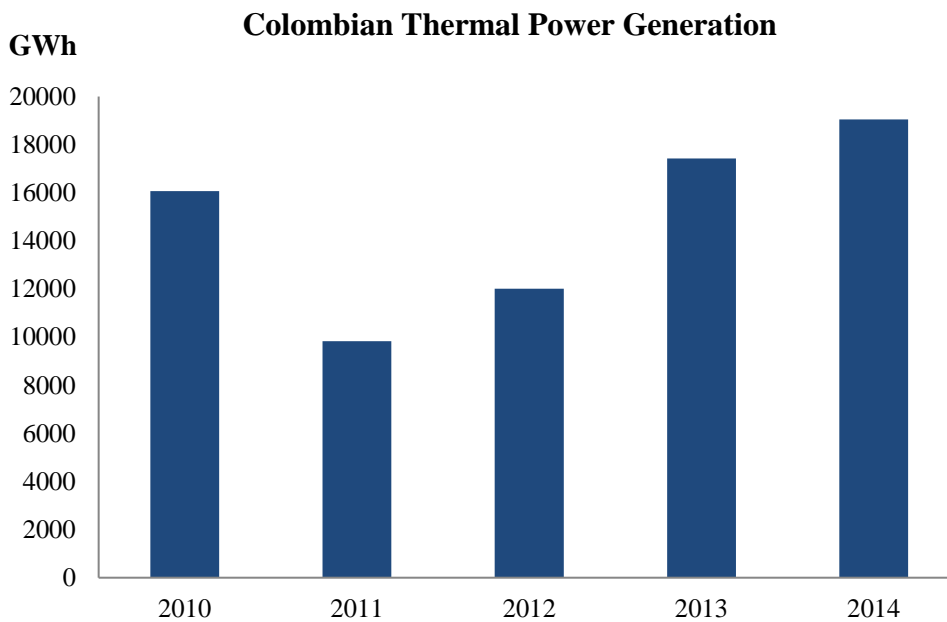


Figure 10: Figure showing Colombia’s thermal power generation (2010-2014). Given the possibility of El Niño weather conditions decreasing hydroelectric generators’ efficiency, these figures are expected to increase (ProColombia, 2015).

3.3.2 Generation Demand and Projections

Power demand in Colombia is steadily growing, particularly in populated cities such as Bogotá, Cali, Medellin, and Barranquilla. The greater demand for power can be seen as a result of urban population and economic growth. Although access to electricity

is becoming more widespread, the Central, North, and Northeast regions of Colombia still account for the majority of the demand (Figure 11).

In 2014, Colombian total energy demand grew by 4.4 percent, its greatest increase in the past 10 years (XM, 2015). UPME expects power generation to increase by an annual average of 3.4 percent to 76.0 TWh by 2027 (Figure 12) (MaRS, 2015).

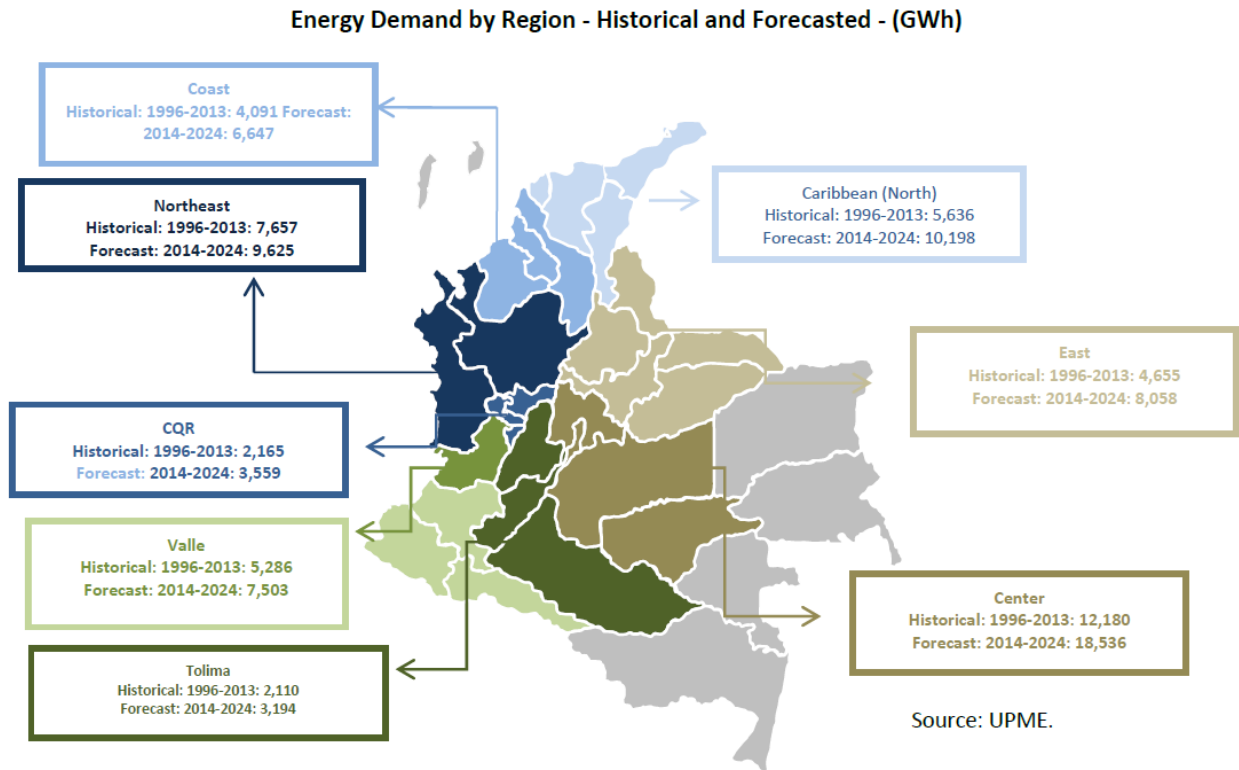


Figure 11: Figure showing Colombia’s historical and projected regional energy demand. The center of the country has the greatest energy demands, with the Caribbean coast expecting significant growth (Figure adapted from ProColombia, 2015).

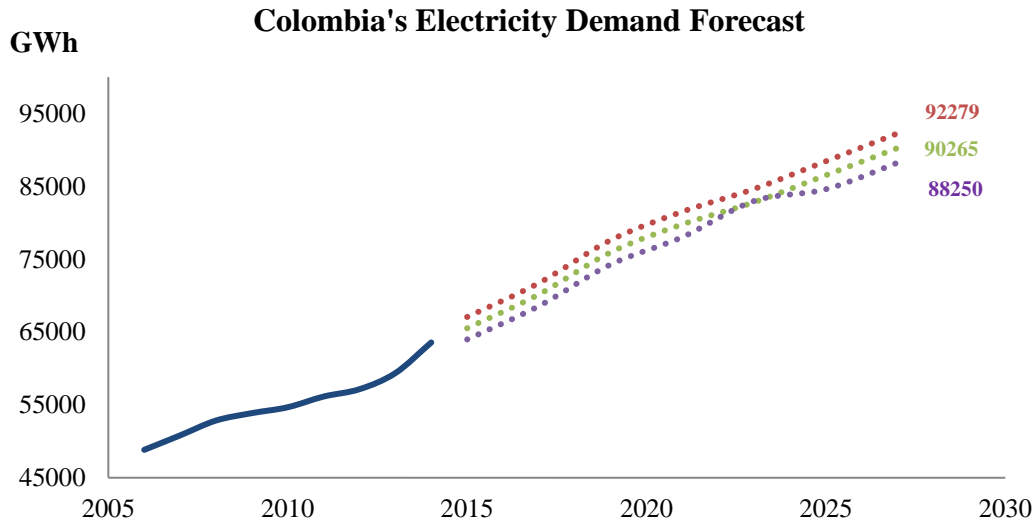


Figure 12: Colombia's recent electricity demand growth and a high, middle, and low scenario for projected growth (MaRS, 2015).

4.3.3 Electricity Market Pricing

Colombia's average residential energy prices are among the highest in Latin America; prices in Colombia are higher than in Chile, Brazil, and Peru (Figure 13) (MaRS, 2015). One reason for this is Colombia's residential electricity tariff. At \$0.19/kWh, it is the highest in Latin America (MaRS, 2015). In addition, Colombia's industrial energy prices are also high, though slightly lower than those of Chile (MaRS, 2015). A second factor driving Colombia's electricity prices higher is the lack of a reliable distribution system. Colombia is plagued by frequent and lengthy power outages, with the cost of electricity losses estimated at 0.22-0.32 percent of annual GDP (MaRS, 2015). These high prices, however, are regulated in order to be equally distributed amongst Colombians.

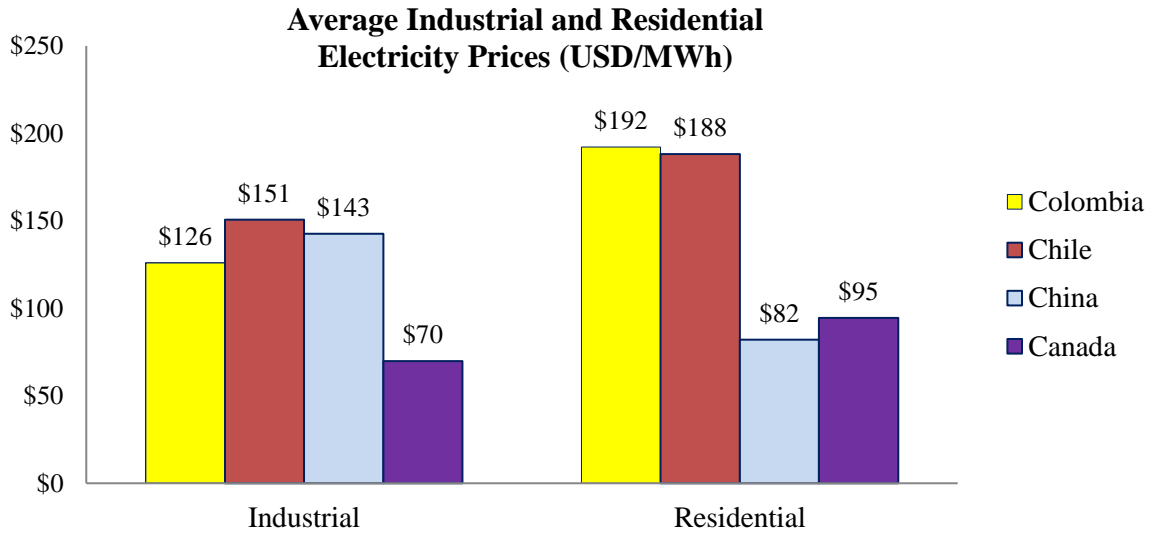


Figure 13: Figure showing how Colombia’s average industrial and residential electricity prices compare to those of Chile, China, and Canada (MaRS, 2015).

3.4 Grid Integration

Over 95 percent of Colombia’s population resides in about 45 percent of the country’s land area, particularly in the Central and Northern departments. This area is included in the National Interconnected System (NIS), while the remaining 55 percent of the country falls into the Non-Interconnected Zones (ZNI) (Figure 14). NIS areas have access to electricity, while ZNI areas produce energy primarily with diesel fuel. The Fund for the Electrification of Non-Interconnected Zones (FAZNI), however, oversees three state funds with the objective of financing the plans, programs, and projects of ZNI energy infrastructure. As the Colombian economy continues to expand, providing ZNI areas with electricity will become critical to the nation’s growth.



Figure 14: Figure showing the extent of the NIS versus the ZNI. The NIS, although only connecting 48 percent of Colombia’s area, provides power to 96 percent of the country’s population (ProColombia, 2015).

Although 96 percent of Colombians have access to electricity, the nation's distribution infrastructure has significant room for improvement. Colombians experience an average of 18.5 power interruptions per year, with an average duration of 17.7 hours (World Bank, 2014). The value lost on these power outages, estimated to be 1.8 percent of total power sales, is relatively high compared to other developing countries, as well as China (1.3 percent), Chile (1.3 percent), and Canada (0.13 percent) (MaRS, 2015).

3.5 Renewable Energy Potential

Only 3 percent of Colombia's total energy supply comes from renewable energy, not including hydropower (MaRS, 2015). The Colombian government seeks to double that figure by 2020, as well as increase the amount of renewable energy in the total energy mix (MaRS, 2015). Due to its climate and geography, Colombia has enormous potential for renewable energy development.

Law 1715 of 2014 established favorable tax, customs, and financing incentives for generating renewable energy. Wind generated energy grew by 21.9 percent from 2013-2014, but remains only 0.1 percent of Colombia's total net generating capacity (ProColombia, 2015). The Guajira department presents the greatest potential for wind energy projects, as wind speeds remain around 5 m/s throughout the year (ProColombia, 2015). The nation also has the potential for significant solar energy growth, as Colombia enjoys consistent solar radiation throughout the year. These two renewable energy sources may soon contribute more largely into Colombia's total energy mix, as current climate commitments begin to take effect.

Colombia is a party to the Kyoto Protocol, is involved in the United Nations Framework Convention on Climate Change (UNFCCC), and was the first South American country to release a detailed action plan on how they would go about reducing GHG emissions prior to the United Nation's 2015 COP21 climate talks in Paris. Prior to 2015, Colombia was classified as an Annex II country, meaning it had no CO₂ reduction commitments. Following the Paris Agreement, Colombia committed to reducing its nation's emissions by 20 percent before 2030 (WRI, 2015). Additionally, Colombia's NDP 2010-2014 identified CMM/CBM as a means to utilize wasted natural resources, while also working to reduce GHG emissions.

4.0 Natural Gas Market

4.1 Overview

Colombia's 4.8 Tcf of proved natural gas reserves rank sixth in South America (BP, 2016). Over the last decade, demand for natural gas in the country has surged 60 percent, forcing Colombia to transition from a net exporter of natural gas to a net importer (EIA, 2016). Imported liquefied natural gas (LNG) is expected to play an important role in meeting the nation's increasing future natural gas demand. Three exploration and production companies dominate Colombia's natural gas industry, with the majority of gas production coming from the Guajira and Llanos Basins. Colombia is thought to have significant gas shale resources, but has not yet established any commercial production. Currently, 44 percent of natural gas production is reinjected into oil wells for enhanced oil recovery (EOR) to offset declining production. Colombia's increasing demand for power will also drive natural gas demand, although it will have to compete with the country's large coal reserves. Industrial and vehicle fuel has already come online as a major driver of Colombian natural gas demand, as 14 percent of Colombian vehicles run on natural gas.

4.2. Recent Trends in Colombia's Natural Gas Market

Historically, Colombia consumed all of the natural gas that it produced. In 2007, however, production began to outstrip consumption, and for a time Colombia became a significant South American exporter (Figure 15). Colombian natural gas exports recorded highs in 2011, reaching up to 250 MMcf/d, although by 2014 average exports were back down to 91 MMcf/d (EIA, 2016).

Recently, deteriorating energy prices and declining reserves have forced Colombia to begin importing natural gas from Venezuela. In 2016, planned imports accounted for 3.5 percent of Colombia's average daily consumption (Platts, 2015). Colombia's transition from net exporter to net importer marks a shift in South American natural gas market dynamics (OilPrice, 2015).

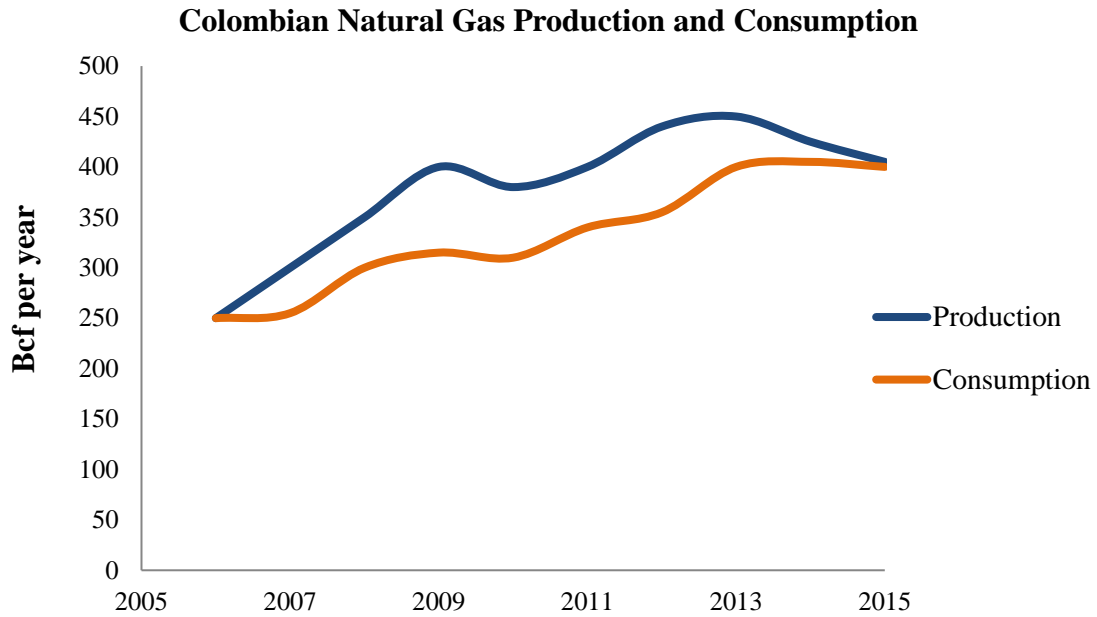


Figure 15: Figure showing Colombian natural gas production outstripping natural gas consumption from 2007-2015. Figure adapted from (EIA, 2016).

Conservative estimates expect Colombia's demand for natural gas to grow from 450 Bcf/year in 2015 to almost 500 Bcf/year by 2020 (ARI COGSM). Colombia's demand for natural gas, however, may exceed conservative growth estimates, and could reach as much as 3 percent per annum growth through 2020 (ARI COGSM). Natural gas demand growth is expected to come from multiple industries, with the largest being the power and transportation sectors. As of 2016, 32 percent of taxis in Bogotá ran on compressed natural gas (CNG) (AAPG, 2016). CNG stations are emerging throughout Colombia, as vehicle conversions to CNG increased at an average annual rate of 12 percent from 2010 to 2014 (AAPG, 2016).

4.3 Natural Gas Supply

4.3.1 Conventional Domestic Natural Gas Production

Colombia holds the majority of its natural gas reserves in two basins, the Guajira and Llanos basins (Figure 16). The Guajira Basin is located in northern onshore and just offshore Colombia and has historically accounted for the greatest percentage of domestic natural gas production.



Figure 16: Figure showing Colombia’s major petroleum-bearing basins. The Llanos Basin is in eastern Colombia and the Guajira Basin is in northern onshore and offshore Colombia (Seeking Alpha, 2015).

The Guajira Basin holds 1.02 Tcf of proved natural gas reserves, compared to eastern Colombia’s Llanos Basin’s 3.9 Tcf of proved reserves (Figure 17) (ARI COGSM). In 2014, the Guajira Basin accounted for 183 Bcf of Colombia’s natural gas production and the Llanos Basin produced 199 Bcf of natural gas (Figure 18) (ARI COGSM).

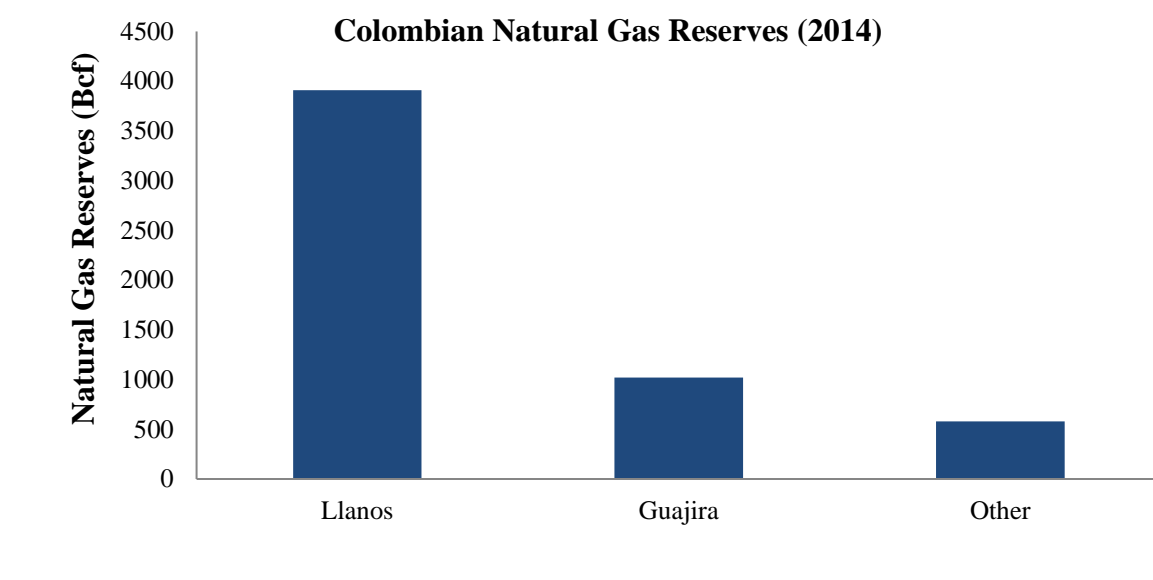


Figure 17: Figure showing Colombian natural gas reserves (Bcf), with the majority of proved reserves found in the Llanos and Guajira basins. Total proved reserves are estimated to be 5,510 Bcf (ARI COGSM).

Combined, Ecopetrol, Equion Energía (a partnership between Ecopetrol and Talisman Energy), and Chevron account for the majority of Colombian natural gas production (EIA, 2016). Ecopetrol, Colombia's largest oil and gas company by revenue, profit, assets, and equity, is the fourth-largest oil and gas company in Latin America (pwc, 2014). Ecopetrol operates the Cupiagua and Cupiagua Sur fields in the Llanos Basin. In 2015, Ecopetrol produced in excess of 280 Bcf (Platts, 2015). Equion Energía, formed in 2010 after Ecopetrol and Talisman Energy acquired BP Colombia's Llanos Basin assets, operates the Cusiana, Cusiana Norte, and Cupiagua Liria fields. Equion Energía produces just over 36 Bcf per year of natural gas (Equion, 2016). Chevron, also in partnership with Ecopetrol, operates the Caribbean Chuchupa offshore field in the Guajira Basin, as well as the nearby onshore Ballena and Riohacha fields. The Caribbean Chuchupa is the largest non-associated natural gas field in Colombia (EIA, 2016). In 2015, Chevron produced an estimated 60 Bcf of natural gas (Chevron).

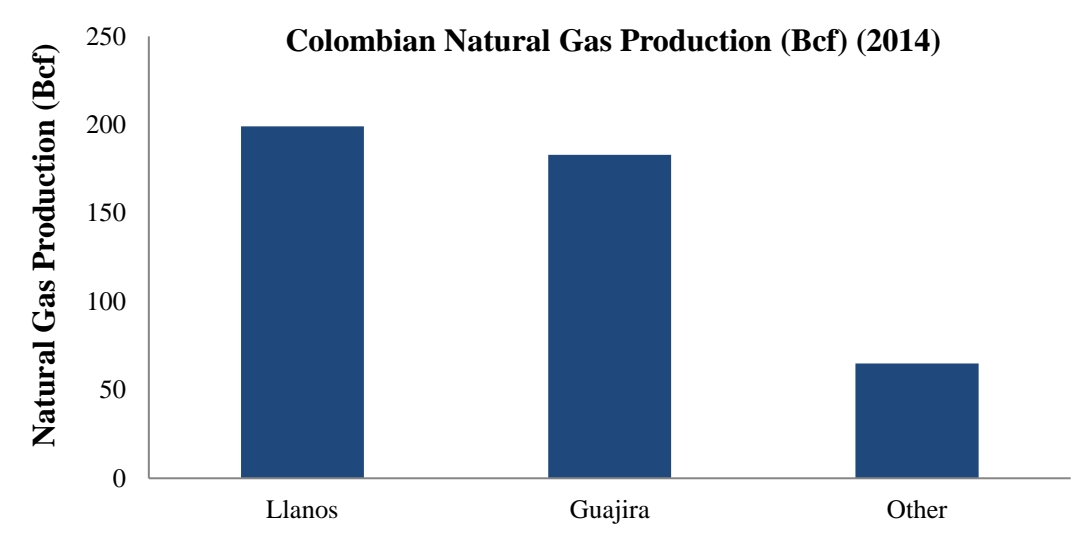


Figure 18: Figure showing Colombian natural gas production (Bcf) by geologic basin. Total natural gas production in 2014 was 448 Bcf (ARI COGSM).

Of Colombia's two major natural gas producing basins, the Guajira Basin is far more mature. Conventional Guajira Basin natural gas production is already beginning to decline, with production estimates falling from 0.37 Bcfd in 2016 to 0.19 Bcfd by 2020. On the other hand, Llanos Basin production is expected to increase until 2022. Production estimates for the Llanos in 2016 are 0.63 Bcfd, while production estimates for 2022 are 1.01 Bcfd. Increasing Llanos Basin production is expected to offset Guajira Basin declines, with total Colombian natural gas production increasing until 2022. However, unless unconventional gas (CBM/CMM, shale gas, etc.) comes online by 2022, gas production will start to decline and Colombia will eventually be a net importer of gas.

4.3.2 Midstream Infrastructure

Due to Colombia's geography with high peaks and dense jungles, natural gas infrastructure and transportation have always proved challenging. Furthermore, attacks on oil and gas infrastructure often disrupt natural gas transport. Colombia boasts 4,991km of natural gas pipeline, and several companies have committed to investing in midstream projects (CIA, 2013). The three major natural gas pipeline systems are the Ballena-Barrancabermeja, linking Chevron's northeast Ballena field to central Colombia; the Barrancabermeja-Nevia-Bogotá line, integrating Colombia's capital city; and the Mariquita-Cali line, which connects the western Andean foothills (Figure 19) (Oxford, 2014). Transportadora de Gas Internacional (TGI), a subsidiary of Grupo Energia de Bogotá, is the largest pipeline operator in Colombia, overseeing approximately 3,700km of pipe (EIA, 2016).



Figure 19: Figure showing oil and gas midstream infrastructure throughout Colombia (Platts, 2014).

In 2007, the Trans-Caribbean Gas Pipeline, also known as the Antonio Ricaurte Pipeline, was opened, linking Chevron's Ballena field in the northeast portion of the Guajira Basin to western Venezuela (EIA, 2016). Venezuela's Petróleos de Venezuela (PdVSA) financed the \$335 million pipeline and, in 2011, the pipeline was extended across Colombia to Panama and Ecuador (EIA, 2016). Pipeline throughput peaked at 250 MMcf/d in 2014, but has averaged 91 MMcf/day since 2014 (EIA, 2016).

Pipeline expansion has been a catalyst for Colombia's growing natural gas demand. As of 2016, 670 out of the total 1,123 Colombian municipalities have access to natural gas via pipeline (AAPG, 2016). Colombia's largest cities, Bogotá, Medellín, Cali, and Barranquilla are all included in these natural gas-connected areas. Eight million households, about 81 percent of Colombia's total, currently have natural gas access, with an additional one million to come online by 2018 (AAPG, 2016).

4.3.3 Liquefied Natural Gas (LNG)

Colombia is well-positioned to take advantage of the emerging LNG industry. In November of 2016, Colombia will begin importing LNG from Mitsui & Co. at a terminal in northeastern Cartagena. The Höegh Grace import terminal at Cartagena is estimated to have capacity for 400 MMSCFD. The import terminal expects to unload between six to twelve tankers a year, depending on power plant demand (Bloomberg, 2016).

4.3.4 Unconventional Shale Gas

Colombia is thought to hold world-class shale source rocks, offering significant opportunities for unconventional shale oil and gas developments. The Middle Magdalena Valley (MMV), Eastern Cordillera, Llanos, and Catatumbo Basins appear to show the most promising geology for shale gas development (Figure 20). ExxonMobil, ConocoPhillips, Ecopetrol, and Royal Dutch Shell all own shale oil and gas lease blocks in the MMV Basin. While many of these lease blocks are oil-focused, large amounts of associated gas are expected to be produced (ARI, 2014.1). A number of exploration wells were set to be drilled in 2015, but ExxonMobil, ConocoPhillips, and Royal Dutch Shell were forced to cut Colombian spending amid declining oil prices. Commercial shale production has not yet been realized.

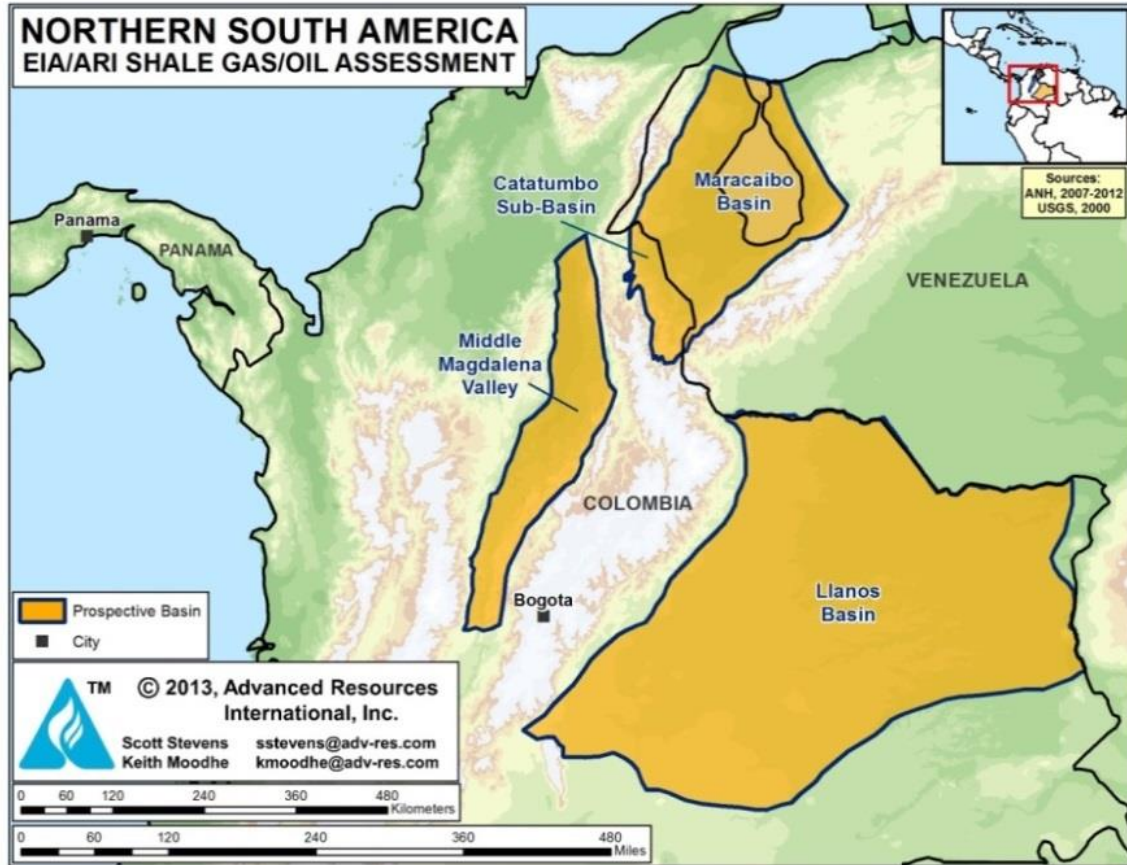


Figure 20: Shale oil and gas basins in Northern South America (figure adapted from ARI, 2014).

4.4 Structure of Colombia's Natural Gas Industry

Colombia's natural gas demand is dominated by two major draws: reinjection gas and pipeline gas (Figure 21). About half of Colombia's natural gas is reinjected into producing oil fields in order to increase reservoir pressure, offset declining oil well production, and to mitigate low energy prices (EIA, 2016). Pipeline gas is delivered to various parts of Colombia, to be used by the power sector, as an industrial fuel, and in the transportation sector. The proportion of Colombia's natural gas committed to reinjection and pipeline projects is expected to grow. As Colombia's aging oil fields produce fewer hydrocarbons, greater amounts of natural gas will be needed for reinjection to maintain reservoir pressure and stem the decline of oil production. Likewise, as Colombia's demand for industrial and vehicle fuel increases, more natural gas will be required to meet this demand. Colombia's fleet of 530,000 natural gas-powered vehicles is already the 7th largest in the world (AAPG, 2016). This figure, accounting for an estimated 14 percent of Colombia's total vehicles, is expected to grow, however, as industrial vehicles such as garbage trucks and bus rapid transit (BRT) systems convert to run on natural gas (AAPG, 2016).

Colombia's 2015 Natural Gas Balance

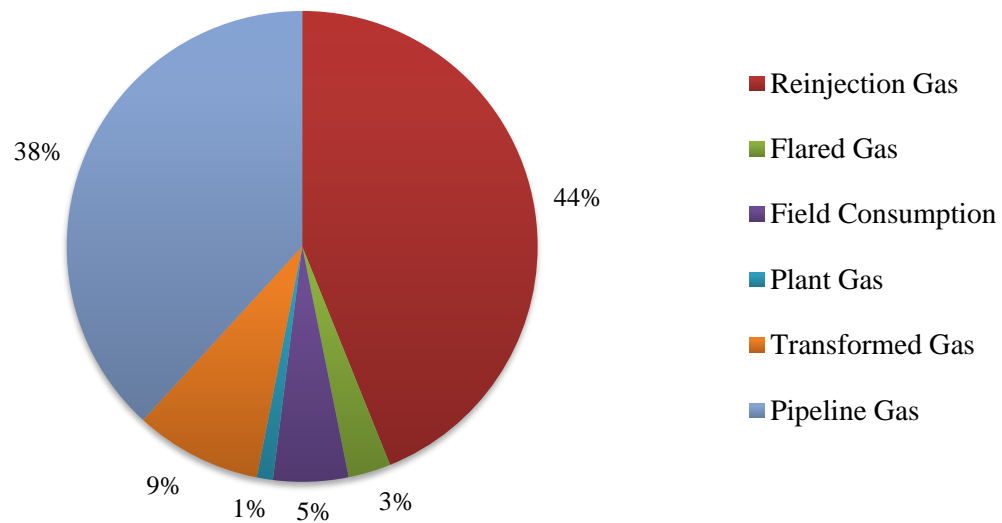


Figure 21: Figure depicting Colombia's 2015 natural gas balance, with the majority of natural gas being utilized as reinjection gas (44 percent). Figure adapted from (ANH, 2015) data.

4.5 Natural Gas Market Policy and Pricing

4.5.1 Policy and Reforms

Colombia historically offered attractive regulations in order to encourage both domestic exploration and to attract foreign investment. When the National Hydrocarbons Agency (ANH) was formed in 2003, it took over the regulatory role previously held by state-owned Ecopetrol. In addition, following the creation of the ANH, it was made possible for private companies to own 100 percent stakes in oil and gas fields with less than 60 million barrels of reserves (Open Oil, 2012).

In March of 2011, the Colombian government published a decree outlining plans to increase domestic natural gas production, specifically production from shale and CMM/CBM fields (EIA, 2016). These policies, combined with increasing natural gas demand in several sectors, have made natural gas a priority for the Colombian government.

4.5.2 Foreign Direct Investment (FDI)

According to a 2010 report by the US-based *Council of the Americas*, Colombia has developed its energy sector over the last decade into one of Latin America's foremost destinations for foreign investment in the oil and gas sector (Open Oil, 2012). From 2005-

2013, Colombia's FDI grew at a compound annual growth rate (CAGR) of 22 percent (Figure 22) (Ecopetrol, 2013). While 2003 marked the modernization of Colombian oil and gas policy, auctions for Colombian onshore and offshore blocks in 2008, 2010, 2012, and 2014 were turning points for Foreign Direct Investment (FDI). The four auctions resulted in over 200 onshore and offshore block contracts signed, as well as close to \$8 billion in FDI (pwc, 2014).

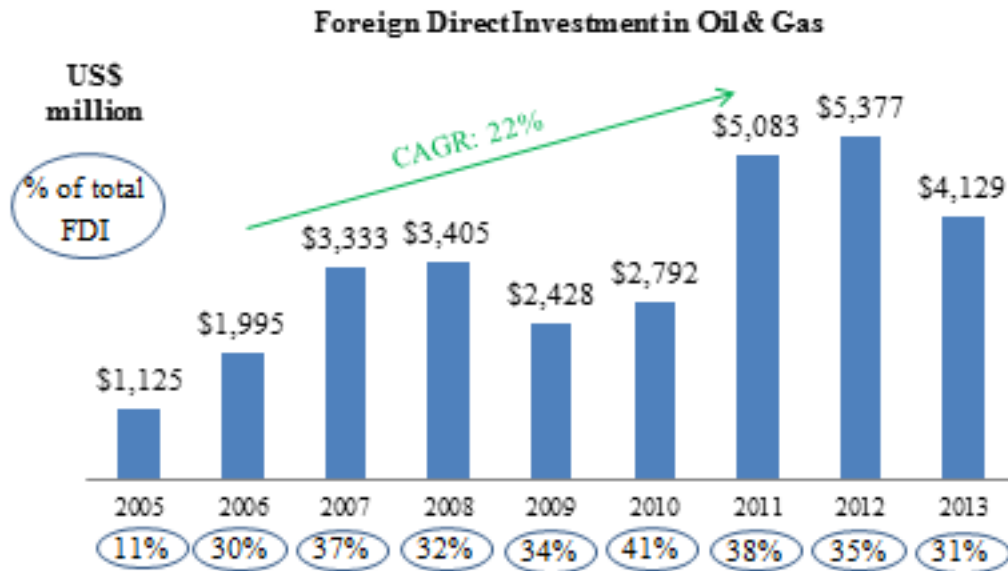


Figure 22: Figure depicting increasing FDI in Colombian oil and gas projects from 2005-2013, with a 22 percent CAGR. Figure adapted from (Ecopetrol, 2013).

Additionally, in 2012, Colombia started a sovereign wealth fund, focused on stability and savings, using royalties from extractive industries (USDOS, 2015). The fund is administered by the Central Bank, is able to administrate up to 30 percent of annual royalties, and, as of December 2014, the fund had saved approximately \$2.5 billion (USDOS, 2015).

4.5.3 Natural Gas Market Pricing

Colombia's Regulatory Commission of Energy and Gas (CREG) was created by Article 74 of Law 142 of 1994 in order to regulate public services, including electricity and natural gas prices (CREG, 2016). Urban areas in Colombia are classified as one of six socioeconomic strata. The two lowest natural gas prices are available to citizens who do not use much electricity. These citizens receive natural gas at a subsidized price, with the subsidies financed by citizens in the two uppermost socioeconomic strata (CREG, 2016). Citizens who are in the middle two socioeconomic tiers receive natural gas at market prices (Figure 23).

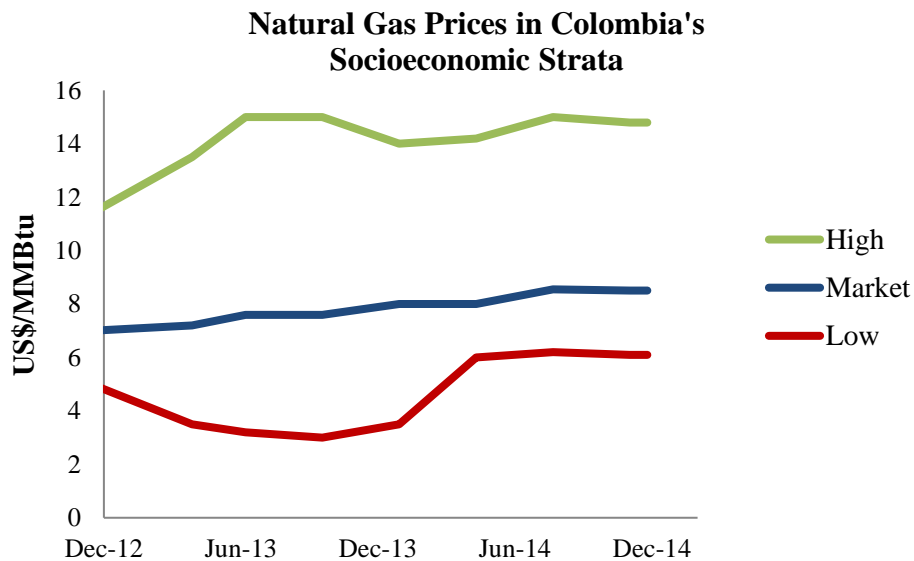


Figure 23: Approximated natural gas prices (US\$/MMBtu) in Colombia's various socioeconomic strata. Figure adapted from data via (NATURGAS, 2014).

Due to the remote nature of certain regions of Colombia, access to natural gas, whether subsidized or not, can be expensive. Average market prices, consequently, remain significantly higher than those in the U.S. Average market prices for Colombian citizens purchasing natural gas at the end of 2014 were \$8.2/MMBtu (NATURGAS, 2014). The highest two socioeconomic tiers, however, pay large contributions in order to ensure affordable natural gas reaches the lowermost socioeconomic strata.

5.0 Coal Mine Methane (CMM) Market

5.1 Overview

Colombia has extensive coal reserves and, by extension, is thought to hold significant coal mine and coalbed methane (CMM and CBM) as well. National studies currently estimate its methane reserves to be between 11-35 Tcf, although not all of the gas is considered economically recoverable (ANH, 2011). U.S.-based Drummond Company operates two lease blocks, one in Guajira and one in Cesar, where they are conducting CMM/CBM exploration programs. Additionally, in 2017, the USTDA published the results of a CMM/CBM feasibility project in Córdoba (USTDA, 2015). The objective of the study was to inform GECELCA of the project's potential before the company makes a drilling decision. GECELCA hopes the project will increase regional methane utilization, help supply the Colombian natural gas market, and reduce the area's greenhouse gas emissions (USTDA, 2015). The results of the study estimate that the project could be developed in such a way that between 30.9 MMtCO_{2e} and 34.7 MMtCO_{2e} will not be emitted to the atmosphere, if best practices are used to reduce GHG emissions during the entire life cycle of the project (GECELCA, 2017).

Characteristics that typically indicate promise for developing a CMM project are identified in Table 3.

Table 3: Table showing the most important parameters in determining a CMM prospect's Gas in Place and Economic Gas Deliverability (ANH 2011).

Characteristics Determining Gas in Place	Characteristics Determining Economic Gas Deliverability
<ul style="list-style-type: none"> • Gas Content <ul style="list-style-type: none"> – Coal Rank – Coal Composition – Maturation Process • Total Coal in Place <ul style="list-style-type: none"> – Areal Coal Extent – Net Coal Seam Thickness • Storage Capacity <ul style="list-style-type: none"> – Isotherm Evaluation – Saturation 	<ul style="list-style-type: none"> • Coal Seam Thickness • Permeability • Coal Seam Spacing • Coal Seam Depth • Hydrology • Depositional Environment • Saturation • Geologic Structure • Reservoir Pressure

There are a number of challenges currently facing Colombian CMM project development, including limited data on reservoir properties (e.g., gas content, permeability) and a lack of infrastructure to utilize the gas, especially for mines located in remote areas. Nevertheless, CMM production and utilization presents Colombia with an opportunity to increase mine safety, reduce its greenhouse gas emissions, and help meet the country's increasing natural gas demand.

5.2 Current CMM and CBM Projects and Coal Mine Methane Emissions

Colombia's CMM/CBM industry is in its infancy. Despite the nation's large CMM/CBM reserves, significant commercial utilization has yet to be realized (Table 4). In 2004, U.S.-based Drummond Company, Inc. purchased a lease block for CBM exploration in Cesar (Figure 24). The lease block, near Drummond's La Loma and El Descanso mines, encompasses 392,515 acres and lies in close proximity to Drummond's current coal production and infrastructure (Drummond, 2016; GMI, 2015). Additionally, in 2006, Drummond acquired a second CBM exploration block in Guajira. The second block totals 77,833 acres and holds an estimated 2.2 Tcf of CBM reserves (Drummond, 2016; GMI, 2015). Development of the second block is currently on hold due to a dispute between ANM and ANH regarding overlapping concessions.

Table 4: Comparison estimated quantities of Mineable Coal in Place (Gmt) and Potential Total Gas in Place (Tcf) throughout Colombia (ANH 2011).

Region	Mineable Coal in Place (Gmt)	Potential Total Gas in Place (Tcf)
Cesar	6.6	2.3-6.3
Guajira	4.5	2.5-10
Boyacá	1.7	2.1-5
Cundinamarca	1.5	2-5
Valle del Santander	0.2	0.1-6.2
Norte de Santander	0.8	0.9-1.2
Córdoba	0.7	0.4-0.5
Antioquia	0.5	0.3-0.4
Santander	0.8	0.5-0.7
Total Recovery Potential	17.3	11.1-35.3

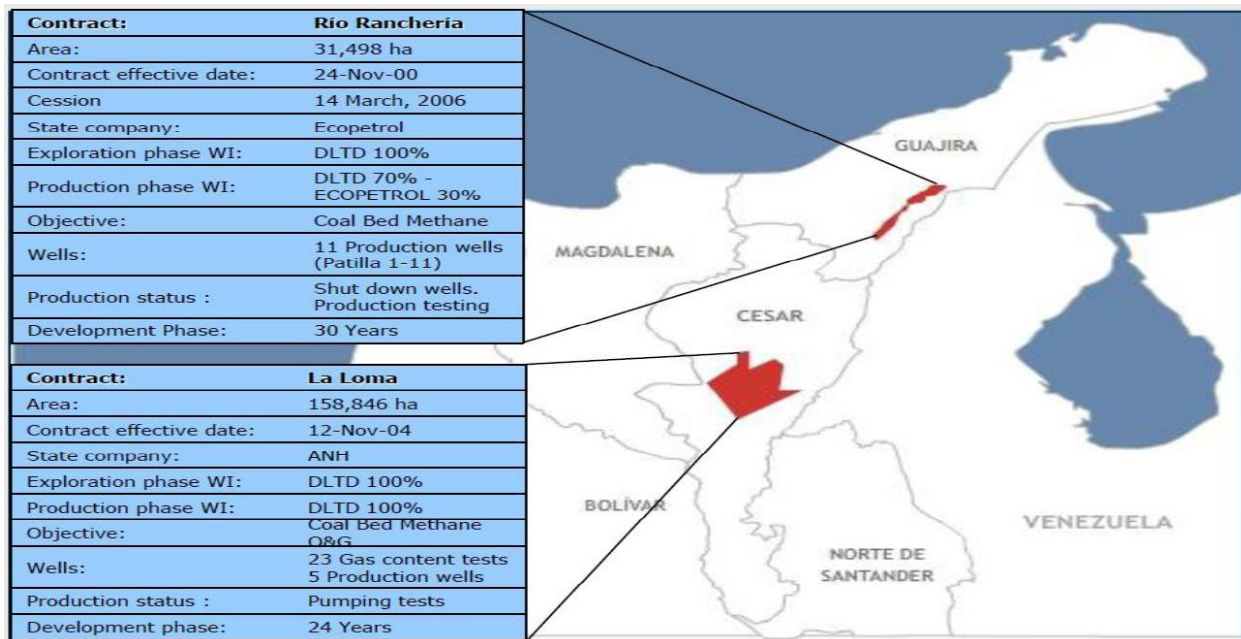


Figure 24: Drummond Company, Inc.’s two CBM exploration lease blocks. These two blocks are Colombia’s current major CMM/CBM plays. Figure adapted from ANH, 2011.1.

The only company actively pursuing a CBM project in Colombia is Drummond Coal at the La Loma block, where they operate their pilot project (ANH, 2011; GMI, 2015). The pilot project is meant to measure methane emissions at Drummond's La Loma/Pribbenow Mine, and Drummond has signed a contract with Ecopetrol to extract CBM from the area (GMI, 2015). Details on when CBM will begin to be extracted are not available. Because there are no commercial CMM/CBM utilization projects in Colombia, coal mines continue to produce significant annual emissions, which have been rising at a rate of 40-50 percent per year over the last two decades, as shown in Table 5.

Table 5: Table showing Colombia's coal mine methane (CMM) emissions (GMI, 2015).

	2000	2005	2010	2015 [•]
Mm³	231	357	511	651
MtCo₂e*	3.9	6.1	8.7	11.1

*Global Warming Potential (100-year) used is 25, [•]Projected.

5.3 Regulatory and Legislative Environment

Currently, there is no regulation or law preventing a project developer from applying for a license to explore or produce CMM/CBM; an unconventional license issued by ANH provides the rights to explore for unconventional hydrocarbons. Furthermore, if exploration of CMM/CBM was not the target of the original hydrocarbon license application, a petition can be submitted to the ANH for permission to include coal associated gas contained by the coalbeds during the exploration phase (GMI, 2017). Therefore, if owners of existing coal licenses wish to sell CMM/CBM gas or electricity, they must acquire an unconventional hydrocarbon license covering the coal lease.

Once a hydrocarbon license is secured, the National Code of Natural Renewable Resources, or Decree 2811 of 1974, requires that the developer first obtain an environmental permit. Decree 1220 of 2005 issued by the Ministry of Environment and Sustainable Development (MADS) establishes the basic procedures and requirements to obtain an environmental license for hydrocarbon exploration and production (GMI, 2017).

Colombia's National Development Plan (NDP) 2010-2014 identified the mining sector as a national locomotive for economic growth, specifically mentioning CMM/CBM projects as an avenue for expansion (MinMinas, 2010). One of NDP 2010-2014's major

objectives was to develop more sustainable mining practices and to better utilize previously wasted natural resources (MinMinas, 2010). In regards to CMM/CBM, NDP² 2010-2014 aimed to allow drainage and utilization of:

- 1) Methane from open-pit and underground coal mines;
- 2) Methane by means of ventilation systems (VAM) in underground coal mines;
- 3) Methane in abandoned underground coal mines (AMM);
- 4) Burning methane through ventilation systems (VAM) in underground coal mines.

As a result of NDP 2010-2014 and increasing natural gas demand, the Colombian government published a decree in 2011 describing its plan to increase domestic natural gas production, particularly from gassy coal mines (EIA, 2016). Decree 4923 set forth a 40 percent reduction in government royalties applicable to unconventional hydrocarbons, which includes CBM (GMI, 2017). Additionally, 2015 and 2016 witnessed favorable regulatory developments regarding Colombia's CMM/CBM industry's future. Article 59 of Decree 1886 (2015) grants that the mine owner may extract gas to improve mine safety and utilize the gas on site. However, for a large-scale, commercial CMM projects, developers still must obtain the requisite licenses.

In 2015, as party to the Kyoto Protocol, Colombia committed to working towards reducing its carbon emissions by 20 percent by 2030, although CMM was left out of Colombia's Kyoto commitment and is not part of their NDC. One issue that could affect CMM development is a 2016 Colombian court ruling that empowers local and regional governments to block mining activities within their jurisdictions (Stratfor, 2016). Given this recent legislation, it remains to be seen what the net impact on CMM/CBM investment will be.

5.4 Challenges to CMM Projects

One of the biggest issues facing Colombian CMM development is that Colombia's largest coal mines are surface mines. CMM potential at surface mines is limited to pre-mine drainage. However, there are an estimated 3,000 underground coal mines that annually produce 6 Mt, according to the Colombian National University (GMI, 2011). Many

² Adapted from MinMinas, 2010.

of these mines reach depths no greater than 600m and are dangerously gassy (GMI, 2011). These mines may provide opportunities for methane utilization, as many of them only have basic ventilation systems in place. Unfortunately, these small mines have limited technical and financial capability to conduct a CMM project.

Lastly, Colombian coal projects have been scrutinized and protested in recent years, with Colombian citizens resisting relocation and development. Drummond and Cerrejón Coal Company both came under criticism in 2016 for pollution and displacement charges (London Mining Network, 2016). With recent legislation empowering local and regional governments, CMM project developers may face the challenge of meeting local peoples' demands.

5.5 Benefits of Implementing CMM and CBM Projects in Colombia

If Colombia is able to economically implement widespread CMM/CBM utilization, significant benefits would accrue. CMM/CBM utilization increases mine safety. Colombia has experienced a number of tragic coal mine explosions since 2010, and increasing CMM/CBM utilization will help mitigate this risk. Secondly, reducing the amount of methane escaping into the atmosphere will help Colombia to meet its 20 percent carbon emissions reduction goal by 2030. In the absence of CMM/CBM utilization projects, GHG emissions from coal mines can be expected to continue increasing annually. Third, CMM/CBM utilization can supplement Colombia's growing natural gas demand. Colombia's demand for natural gas is projected to increase from 450 Bcf/yr. in 2015 to almost 500 Bcf/yr. by 2020 (ARI COGSM). Lastly, CMM/CBM project implementation will increase Colombian coal producers' revenue and ensure that the nation's mining sector remains an engine for national economic growth.

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7.0 Appendix A



Figure 25: Figure showing a detailed map of Colombia’s coal mines and Colombia’s coal mine operators. Over 90% of Colombia’s coal production comes from the northern departments of Guajira and Cesar (GMI, 2015; Cerejón, 2013; Mining Atlas, 2016). El Cerrejón, La Jagua, and La Loma (Mina Pribbenow) are Colombia’s three largest mines. Figure adapted from Peace (2016).

Table 6: These three mines account for over 90% of Colombian coal production (GMI, 2015; Cerejón, 2013; Mining Atlas, 2016).

Mine	Type	Location	Mine Owner	Production	Reserves
				(Mt per year)	(Mt)
Cerrejón Zona Norte	Surface	Guajira	Cerrejón Coal Company	33.2	4,874 (2013)
Carbones del Cerrejón	Surface	Guajira	Cerrejón Coal Company	3.7 (2010)	-
El Cerrejón Corte	Surface	Guajira	Cerrejón Coal Company	5.6 (2010)	-
Mina Pribbenow/La Loma	Surface	Cesar	Drummond	21	485
La Jagua	Surface	Cesar	Glencore/ Prodeco	7	260
La Jagua	Underground	Cesar	Glencore/ Prodeco	0.9 (1994)	-