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# APPLICATION OF COGENERATION AND TRIGENERATION SYSTEMS

# APLICACIÓN DE SISTEMAS DE COGENERACIÓN Y TRIGENERACIÓN

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## ABSTRACT

The improvement in the energy efficiency of a thermoelectric power station and the implementation of cogeneration and trigeneration plants have great potential to mitigate the effects of energy consumption and its impact on the global problem of climate change. Public environmental policies in the Latin American context implement the use of unconventional energy sources through different mechanisms. This research identifies environmental policies focusing on the application of alternative cogeneration and trigeneration systems. To promote the application of these systems, each country presents tax incentives and the generation of programs. In Latin America, the country with the highest participation in cogeneration plants in Brazil, due to government support to eliminate barriers to the sale of surplus energy, and the strengthening of programs such as PROINFA. On the other hand, we have Chile, Peru, and Colombia, in which it shows government barriers to be able to sell the energy surpluses that are generated in cogeneration plants and so far maintain little participation in the generation of electrical energy from unconventional sources. In Colombia, it presents regulatory conditions for the electricity grid, which restricts the participation of "small energy generators." However, in recent years, there has been

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greater participation in the energy matrix based on clean energy. The foregoing will allow recognizing the progress of the use of renewable energies in Colombia, specifically of the cogeneration plants, which is an estimated expansion of installed capacity of 314 MW

**KEYWORDS:** Energy, cogeneration, trigeneration, non-conventional renewable energy, environmental policies

## INTRODUCTION

Energy problems are increasing worldwide due to population growth and rising living standards (Ibrahim et al., 2014). Therefore, the transformation of the current unsustainable energy system into a sustainable system faces new challenges to ensure accessible and safe energy supply. New strategies and measures that may affect energy consumers are needed. In particular, improving energy efficiency and renewable supply is considered fundamental in the transformation process (European Commission, 2018).

Renewable energy can respond to the energy crisis caused by inexorable depletion of hydrocarbons, serious regional and global environmental problems, problems of expanding access to energy resources and are also offered as new opportunities for economic development (Garrido et al., 2013). Therefore, energy use should be optimized by improving the efficiency of energy systems. In addition to improving building and home appliance designs, saving energy, and promoting renewable energy sources (Ibrahim et al., 2013).

It is necessary to highlight where the highest energy consumption occurs; this belongs to the construction, residential, public, or commercial sector, representing 32% of the total energy consumption. In terms of primary energy consumption, they account for about 40% in most IEA countries (IEA "Energy Efficiency," 2017).

This consumption is mainly divided into the consumption of appliances, heating, cooling, and the use of hot water. Typically, these loads are supplied by electricity from the electricity grid and/or heat generated separately in boilers when natural gas or oil is burned (Al Moussawi et al., 2017). However, thermal power plants are characterized by relatively low overall efficiency, where the average efficiency for electricity generation is less than 40% (Martínez and Ballester, 2010; Al-Sulaiman et al., 2010). Even with fuel cells, overall efficiency varies from 30 to 60% (Wu and Wang, 2006; Alanne and Saari, 2004).

In the same context, the use of fossil fuels on which the most conventional power generation systems are based is the result of a large number of greenhouse gas emissions (Al Moussawi et al., 2017). Itis estimated that global oil reserves would peak, then start to decline and will never rise again. Therefore, according to Al Moussawi, it is vitally important to optimize the use of limited fuel resources, specifically for the urban sector. Therefore, the separate production of thermal energy and electricity would be environmentally and energetically inefficient. It will be more cost-effective to produce both forms of energy in a single energy production process. The use of low-quality waste heat from the power generation process, to produce heating and/or cooling will be one of the solutions to save energy, for this reason, the use of cogeneration and trigeneration technologies is the most appropriate (Wang et al., 2011; Mago and Chamra, 2009).

This research presents environmentally friendly public policies in the Latin American and national context, which favors the application of cogeneration and trigeneration systems to generate electrical and thermal energy. Therefore, tax incentives are applied to generate greater participation of generators. In addition, the projections presented by these Latin American countries are shown. Specifically, we will focus on Colombia, and it is expected that by 2028 there will be a significant increase in power generation from implementation to cogeneration and trigeneration systems.

## 2. METHOD

Cogeneration is a simultaneous or sequential production process of electrical energy and heat, based on the use of different renewable and fossil energy sources, which can also be used in different applications. Cogeneration technologies are often economically very cost-effective as combined energy production occurs very close to the endpoint of consumption and with high efficiency, combining electricity and heat generation (Rios, 2016). In addition to cogeneration, another electrical and thermal power generation system is trigeneration. Trigeneration is defined as combined cooling, heating, and power (CCHP) synchronously from the same power source. CCHP is a term used to refer to a thermal trigeneration system (Sulaiman et al., 2011a).

Over the years, numerous studies have been carried out in the field of solar and biomass trigeneration (Karellas & Braimakis, 2016). In 2011, Sulaiman et al. analyzed a trigeneration system using a biomass combustion chamber and an ORC. In their research, they showed that the efficiency of the trigeneration exercise is increased to 27% compared to the energy efficiency of the electric energy case, which is approximately 11% (Sulaiman et al., 2011b).

In addition, Sulaiman et al. simulated a solar PTC trigeneration system coupled to an ORC and an absorption cooler. The maximum efficiency of the trigeneration exercise was estimated at 20% (Sulaiman et al., 2011c). For its part, Rentizelas et al. investigated the economic potential of using two trigeneration systems, where one is based on an ORC and the other on a gasification subsystem. The gasification option was determined to be the most optimal because it has higher electrical efficiency (Rentizelas et al., 2009).

On the other hand, Braimakis & Karellas proposed thermodynamic modeling and economic analysis of a microscale tri/cogeneration system, capable of combining production based on the joint operation of an organic Rankine cycle (ORC) and a steam compression cycle (VCC) (Braimakis & Karellas, 2018). In addition, Sulaiman et al. stated that: "A potentially efficient thermal system that has not received the attention of researchers is a thermal trigeneration system that uses ORC as the main engine." Emphasizing the great usefulness of the ORC cycle in cogeneration systems (Sulaiman et al., 2013).

In 2019, Valencia et al. presented a thermoeconomic analysis for a trigeneration system consisting of; an absorption cooling cooler, a gas microturbine, and the generation of heat recovery steam from the subsystem (Valencia et al., 2019). On the other hand, Wang et al. developed a trigeneration system based on biomass gasification. The system presented the highest energy efficiency during the summer, reaching 37%, while the average annual energy efficiency was around 28% (Wang et al., 2015). Similarly, a study was conducted in which Wang et al. analyzed the performance and efficiency of a trigeneration system powered by pure diesel and jatropha crude oils using ECLIPSE software (Wang et al., 2010).

In addition, Lants et al. carried out an assessment of the economic viability of various technologies, also at different scales, for the combined production of heat and energy from manure-based biogas in Sweden (Lantz, 2012). Finally, Topal et al. developed a study showing the importance of a trigeneration system, which, using a single fuel source produces three useful energy products (electricity, heating, and cooling), and emphasizes the simulation of a trigeneration system with direct co-combustion of poultry waste (Topal et al.,2018).

## 3. RESULTS AND DISCUSSION

According to the World Energy Council (2014), cogeneration accounted for approximately 7.3% of the total installed capacity for electricity generation worldwide. By geographical area, the participation of cogeneration in the member countries of the Commonwealth of Independent States (CIS) is around 45%; in the European Union, about 14.5%; in North America, approximately 6.2%; Asia-Pacific 4.9% and Latin America only about 3%. In absolute terms, installed cogeneration capacity globally rose from 437.4 GW in 2006 to 733.7 GW in 2015, representing an annual growth rate of 5.9%.

Brazil is the largest country in Latin America, occupying almost half of the continent's surface area, as well as being among the ten countries with the highest energy consumption, producing about 2.2% of electricity worldwide. Brazil is the largest producer of oil and natural gas in Latin America.

However, electricity production in the country is largely dominated by hydropower, which produces about 80% of the gross generation and maintains a similar fraction of installed generation capacity. This low-cost electricity scenario, in addition to regulatory barriers that did not guarantee the interconnection and sale of surpluses to the public grid, led for many years to slow the growth of installed capacity in cogeneration, a situation that begins to change from 2001, thanks to the introduction of regulatory changes that removed some of the barriers to which the expansion of natural gas networks was added and the search for security of supply

In Brazil, in relation to the use of alternative energy, in the last decade, reforms have been made in the regulation and strengthening of incentive programs for the generation of electricity through alternative energy sources with which it intends to generate 3300 MW in 20 years, of which 2010 and 2011, 2802 MW will have entered into operation in the SIN, of which 18.3% (514 MW) originated at the biomass-based cogeneration plant and the rest of the mini-hydro electric plants and wind farms. Therefore, strong growth in installed capacity is expected in distributed generation and, in particular, in cogeneration systems.

Public environmental policies promote the penetration of cogeneration in Brazil, the rulers have relied mainly on mechanisms known and implemented internationally, within which we highlight the following:

➢ Law No. 9074 (1995). This law introduces the concepts of Self Producer and Independent Producer while establishing its right to sell the electricity produced to both free customers (not subject to price regulation) and distribution dealers (regulated by the State).

➢ Law No. 10848, (2004). This law establishes the obligation of distribution companies to acquire a quota equivalent to 10% of their demand for distributed generation sources, a position that is transferred to consumers.

➢ Alternative Electricity Source Incentive Program (PROINFA). This program seeks to promote the diversification of the Brazilian energy matrix through the promotion of a total of 3,300 MW of installed capacity in new power generation plants considered alternative or non-conventional, specifically wind, biomass thermoelectric (and therefore cogeneration) and small-scale hydroelectric plants. The program guarantees the award of supply contracts with the company Centrales Eléctricas Brasileiras (Electrobás SA) for a period of 20 years and at a regulated preferential price.

Sponsored by the Brazilian government, the expansion of Brazil's electricity system, including the modification of the long-term contracts of PPA (Energy Purchase Agreement), has been achieved by annexing the financing mechanism to diversify energy sources, and thus stimulate the creation of reduction projects. GHG under the CDM agreement.

In a 2017 study, 57.4% of chile's electricity production was based on fossil fuels, mainly imported coal. This not only generates large amounts of CO2 that contribute to the concentration of greenhouse gases in the atmosphere and local air and soil pollution but also makes Chile dependent on the import of primary energy sources (Ministry of Energy of the Government of Chile, 2018). Due to environmental problems that have been observed in the country due to conventional energy sources, a containment plan has been undertaken to improve the use of renewable energy.

Chile's main objective for better use of its natural resources such as sun, wind, hydropower, and biomass is to diversify the energy matrix and provide the economy with sustainable energy and heat supply. For this, together with the NCRE, Cogeneration (Combined Heat and Power-CHP) has been one of the pillars of the country's energy revolution, based on the search for greater energy efficiency, decarbonization, and flexibility of the electrical system (Poque et al., 2018). Chile's energy policy is making great efforts to promote the efficient development of energy, and it is in this field that cogeneration technologies are presented as an ideal alternative to convene power generation.

According to Energiza (2017), the cogeneration potential in the country reaches 832 MW, with the metropolitan region with the highest capacity, with 468 MW. The food, oil, and mining sectors are the sectors that offer the greatest potential for this technology. In addition, the presence of biomass collection facilities is of vital importance in the country.

On the other hand, Chile's electricity system is characterized by being a system in which electricity generation, transmission, and distribution activities depend on private companies. The State only exercises functions of regulation, control, and direction of investment in generation and transmission, essentially through the CNE and the SEC. In Chile, three independent electrical interconnection systems are presented: the Norte Grande SIconected System (SING), the Central Interconnected System (SIC), and the Aysén System.

Electricity generation activities through alternative methods such as cogeneration plants have been greatly affected in the regulatory framework. However, the measures of Law 20.257 and the exemption from payments provided for in the Regulations (Electrical Regulations 1997) may benefit these facilities provided that they use a fuel belonging to the ERNC are:

- Law No. 20257, (2008). Law 20.257 was enacted in April 2008, and the LGSE was amended with respect to the generation of electricity from NCRE sources, which states that power companies that market power in electrical systems with an installed capacity of more than 200 MW must demonstrate annually that a percentage of the total energy they market has been injected into electrical systems by unconventional renewable generation, either own or contracted. This percentage is 5% between 2010 and 2014. As of 2015, the obligation gradually increased by 0.5% per annum to 10% in 2024.

In addition, co-generators will be able to integrate an Economic Cargo Dispatch Center (DEC) and, consequently, market their energy, only if they have an installed capacity of more than 9 MW. This restricts the entry of these actors into the system as the vast majority of possible cogenerators are in the range of 0.1 - 5 MW.

In Peru, the discovery and subsequent exploitation of the Camisea natural gas field allowed access to an economical fossil resource, which guarantees the continuity of supply and the low cost of raw material for cogeneration systems. In addition, the massive penetration of cogeneration systems into electricity distribution systems would lay the groundwork for a new concept of electricity supply: distributed generation in large residential and commercial areas, as well as in industrial areas, which would result in significant energy savings in conventional electricity. Generation system and in the electrical transport and distribution system. Therefore, the use of natural gas in cogeneration systems is considered a tool for the optimal use of energy efficiency of fossil resources.

The national regulatory framework related to the production of electricity and heat in cogeneration systems is defined in the following documents:

- Law 28832 to ensure the efficient development of electricity generation 2006. Among the most important points related to cogeneration technology are: Cogeneration is defined as the process of combined production of electrical energy and thermal energy as an integral part of productive activity. Therefore, thermal and electrical energy is intended for own or third-party consumption. The generator is defined as the holder of a generation grant or authorization. Generation systems include cogeneration and distributed generation. Measures are proposed to promote the distributed generation and the implementation of efficient cogeneration systems connected to the SEIN. For example, the use of distribution networks is allowed, paying only the incremental cost incurred.

- Supreme Decree No. 064-2005-EM, called the Cogeneration Regulation, which states: The technical criteria to be taken into account by cogeneration systems, as well as the requirements and conditions for cogeneration plants to participating in the electricity market. Some of the main provisions are: Definitions of self-consumption of energy and energy are established for the consumption of the cogeneration production process. The process will be independently measured and recorded for the purposes of COES valuations. The steps to be taken to obtain the qualification as a cogeneration system are determined. Minimum effective electrical performance (REE) values are set, as well as the relationship between electrical energy and heat.

The price of natural gas applicable to cogeneration systems is set, which will be at the same price as for electric generators. Qualified cogeneration systems will take precedence in the office when operating in cogeneration mode, but will not be considered for short-term marginal cost determination.

Cogeneration systems will pay the connection fee only according to the surplus, contracted with third parties or cash. The cogeneration system that is integrated into COES will be able to market its energy and energy delivered to the system with distributors, generators, and/or free customers.

Transfers resulting from the economic operation of the system will be settled in accordance with THE procedures of COES, the cogeneration system that is not integrated into the COES must have contracted the sale of all its energy and energy.

### 3.1 NATIONAL STUDY

The global market has defined environmental policies that ensure improvements in energy efficiency by helping to mitigate environmental impact and reducing pollutant emissions into the atmosphere.

In Colombia, Law 697 of 2001, which promotes the rational and efficient use (URE) of energy, establishes the legal parameters for the development of energy efficiency regulations, on the other hand, we have Law 788 of 2002, which established an exemption from income tax on income derived from the sale of electricity generated from agricultural waste, wind sources, and biomass. This law requires compliance with 2 requirements: to process CO2 issuance certificates and that at least 50.0% of the resources obtained from the sale of such certificates are invested in socially beneficial works in the region where it operates.

According to a study by the UPME (energy mining planning unit), the sale of surplus electrical cogeneration in Colombia was 526.2 million kWh in 2015 (11.5% more than in 2014) and recorded an average annual growth of 28.2% between 1998 (the year cogeneration initiated in Colombia) and 2015. The resolution of Creg-085, Creg -085 of 1996 and Creg -107 of 1998, defined the regulations for co-generators and generation with plants with a capacity of less than 20MW, in the National Interconnected System (SIN).

The 2008 measure of Law 1215 exempted co-generators from paying the 20.0% contribution to the energy they generate for consumption. In addition, the Creg was ordered to define the technical aspects that determine a cogeneration process, the Creg 005 of 2010, regulates measurement systems, energy audits, the sale of surpluses, and equivalent electrical performance (REE).

### 3.1.1 Cogeneration applied in the economic sector

This section presents cogeneration in the economic sectors. However, the largest stake, according to the UPME study in 2014, is in the industrial sector. Therefore, our study will only focus on this specific sector as it has an installed cogeneration capacity of 597MWe greater than in the oil sector.

In addition, sales of surplus electricity to SIN are only generated in the industrial sector, as the oil sector is not interested in selling its surplus energy. Even in the public and commercial sectors, they do not have cogeneration capacity.

The results of cogeneration plants with the use of a primary energy source are shown below in figure 1.

It can be seen that the energy sources used in cogeneration systems are mainly: oil, dry residual biomass, and natural gas. It highlights the fact that biomass is 38% even though its calorific value is lower than that of coal.

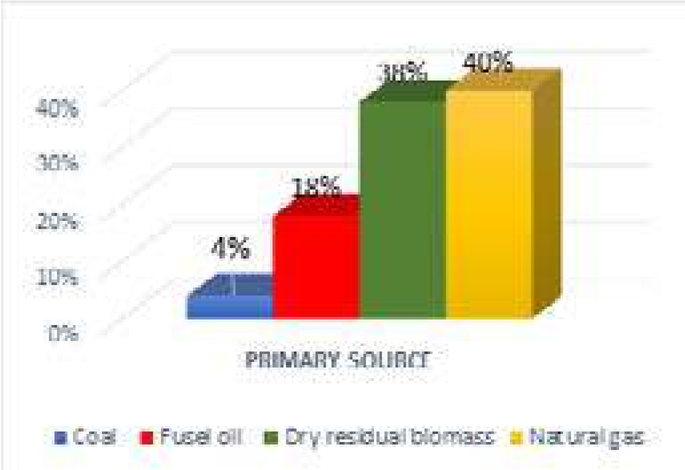


Figure 1: Primary source for the application of cogeneration systems in Colombia. Prepared by the authors from the data obtained (UPME, 2014).

At the sample level, it is possible to see an almost equal proportion of a difference of only 2% between the main sources of primary energy, natural gas (40%) biomass (38%). The rest of the percentage is divided into coal (18%) crude (4%).

It can be concluded, according to the statistical study showing that one of the main contributions of co-generated electricity is the industrial sector, specifically sugar mills. In Colombia, the technologies available in installed capacity for the application of cogeneration systems are as follows:

**Table 1**: Equipment implemented in generating co-generated electrical power Source of data: Prepared by the authors based on data from (UPME, 2014)

| abbreviations | Signification |
|---|---|
| MCI | Internal combustion engines |
| TG | Gas turbine |
| Boiler - Steam Turbine | Boiler - steam turbine |
| CC1(TG+ TV) | Combined cycle (turbine gas + steam turbine) |
| CC2(MCI + TV) | Combined cycle(Internal combustion engines + steam turbine)) |

Finally, the available technological results are shown, which are: MCI (internal combustion engines), TG (gas turbine), boiler steam turbine, used in cogeneration plants in Figure 2.

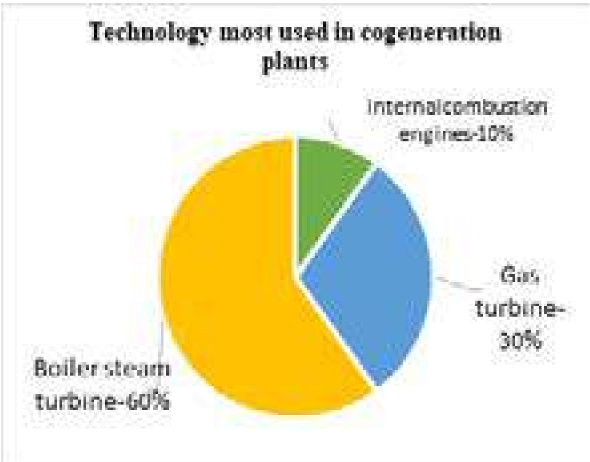


**Figure 2:** Technologies mostly used in cogeneration plants. Prepared by the authors, the data was obtained (UPME, 2014).

In the technologies used for cogeneration, you can see that the highest percentage is found in boiler and steam turbine cycles with 60%, followed by gas turbines with 30% and finally internal combustion engines with 10%. These proportions are stability according to installed capacity.

### 3.1.2 Public policies for the promotion of unconventional applications of renewable energy

In Colombia, it is more common to apply cogeneration systems compared to trigeneration systems, due to the legislative favor found in Colombia, as there are no current regulations to support trigeneration systems.

Therefore, our approach is directed to cogeneration systems applied to renewable energy. Law 1715 of 2014 aims to promote the integration of non-renewable energies into Colombia's electricity system, and thus to comply with international agreements such as the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Law 629 of 2000, which aims to reduce greenhouse gas (GHG) emissions).

Within this law, certain mechanisms (beyond the tax incentives mentioned above) are provided that seek to encourage small-scale local generation. In the first instance, local small-scale car generators and co-generators are authorized.

This law includes the use of the energy potential of agricultural biomass. In addition, the development of hybrid solutions to minimize the use of diesel. Law 142 of 19947 defines that co-generators may transfer the energy they produce, in whole or in part, to a clientele that may be composed of partners or persons economically linked to the company (Law 142, 1994). The incentives defined in this act reduce 50% of the value of an investment in FNCE (unconventional energy sources) over total income for five years after investment. In addition, equipment, machinery, and services to produce energy from FNCER (unconventional renewable energy sources) will be excluded from VAT and tariffs (for new projects and non-country-manufactured machinery/equipment).

### 3.2. PROJECTIONS IN THE FUTURE

Cogeneration projects are considered an alternative that contributes to environmental impact mitigation by reducing emissions generated in energy transformation. In addition, they reduce vulnerability to the eventual disconnection of the electricity grid and contribute to the development of distributed generation, making electrical systems more efficient. In recent years they have witnessed a considerable increase in energy efficiency measures, those that seek to promote smart energy consumption without reducing people's quality of life. These range from policy-making and economic process optimization to implementing technologies that increase production capacity with less energy.

Among the technologies that have been adopted to increase energy efficiency, cogeneration stands out for its benefits. According to CAF (2017), countries such as Brazil and Nicaragua have managed to make sugarcane bagasse a very important source for their cogeneration processes. Brazil, the world's largest producer of sugar cane, has approximately 3 GW of installed biomass-based cogeneration capacity, and it is estimated that its cogeneration potential of this type could be sufficient to supply half of the generation capacity required by the country over the next ten years.

So far, we can see that this technology represents an important option for Latin America in its advances in energy efficiency and in consolidating a clean and sustainable energy matrix over time. However, there are still significant challenges for the region to take the top places in energy efficiency worldwide, which, according to the American Council for an Energy-Efficient Economy (ACEEE), are now led by Germany, Italy, Chile, and France.

For this reason, CAF (Latin American Development Bank), formerly known as the Andean Development Corporation, has been supporting Latin American countries to move in this direction. In this way, USD 240,000 was planned to support the National Fuel, Alcohol, and Portland Administration (ANCAP) to find cogeneration solutions at its La Teja refinery in Montevideo, Uruguay (Rios, 2017).

In December 2019, Latin American and Caribbean countries announced the 70% renewable energy target by 2030, equivalent to 312 GW of installed capacity. The agreement was launched by Colombia and Chile as conventional energy accounts for 75% of global CO2 emissions and 56% of Latin American emissions. The agreement is to promote regulatory frameworks that are related to and consistent with environmental policies and therefore encourage the use of alternative sources of power generation.

Below are forecasted for 2020, countries such as Brazil, Chile, Peru, and Colombia present plans to expand electricity production from unconventional sources, the generation of electricity from residual biomass occurs mostly in cogeneration plants in Table 2 shows the implementation of biomass energy in each country, showing a total of 9863 MW by 2020.

Table 2: Installed biomass capacity in MW
Source of data: Prepared by the authors based on data from (Copper, 2010)

| Latin America (2020) | Energy source (Biomass) |
|---|---|
| Brazil | 8521 |
| Chile | 1061 |
| Peru | 101 |
| Colombia | 180 |
| Total | 9863 |

### 3.3. PROJECTION OF THE IMPLEMENTATION OF COGENERATION PROJECTS IN COLOMBIA

The sale of energy surpluses from Law 788 of 2002 has introduced little by little since 2000, the application of unconventional power generation with cogeneration systems in the energy matrix.

Figure 3 shows the sale of cogeneration energy in Colombia with a study range of 1998-2015.

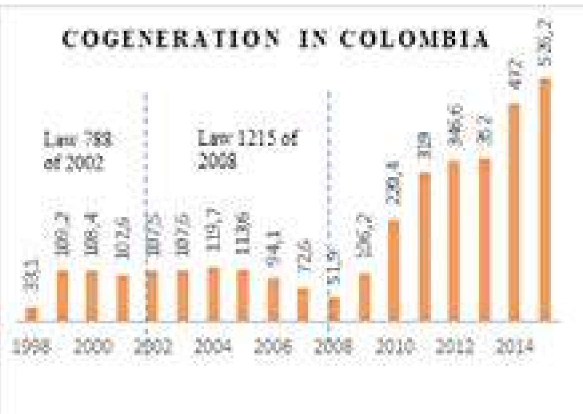


**Figure 3:** Sale of cogeneration energy in Colombia (kWh) 1998-2015. Source of data: Prepared by the authors based on data from (Cali Chamber of Commerce, 2016).

To meet the supply of electricity demand, UPME conducts an annual control of the plan to expand generation resources and electricity transmission networks. The approach study carried out has a long-term projection and is based on information on current electricity infrastructure and energy demand projections.

For the long-term period 2019-2028, an increase in installed capacity is required. Therefore, an optimal mixture of all conventional and unconventional sources is made in Colombia, and it is planned to incorporate 248 MW of cogeneration

Figure 4 shows the timeline of technology expansion used in each hydraulic, gas, coal, and cogeneration plant. The results show greater participation in the implementation of technology in hydroelectric plants. On the other hand, conventional thermal power plants are located, and finally, we have the contribution of unconventional renewable generation from the application of cogeneration systems.

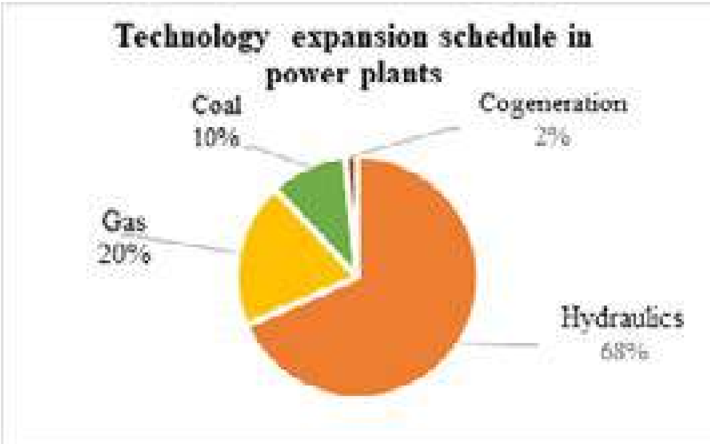


**Figure 4:** technology expansion chronogram in power generation plants. Source of data: Prepared by the authors based on data from (UPME, 2014-2028).

To increase the use of cogeneration systems, the 2014-2028 Reference Expansion Plan was carried out, UPME considers several renewable energy scenarios based on the potential identified in these sources. It should be borne in mind that law697 of 2001 created the national URE program (PROURE), in which it promotes energy efficiency and the use of unconventional renewable energies. The long-term projections in 2014-2028 are:

- FNCE (unconventional energy sources) can account for 6% of the electric power basket, which would correspond to an installed capacity of 1,207 MW by 2028. In addition to the 474 MW of wind power in the pessimistic scenario, the installation of 143 MW of solar energy, 275 geothermal, and 314 MW of cogeneration with biomass (UPME, 2015) is considered possible.
- According to the UPME study, it envisages the possibility of the installation of up to 1370 MW of wind power, 122 MW of cogeneration from cane, 558 MW of cogeneration from palm, 750 MW from geothermal plants and finally, 448 MW of solar energy.

## 4. CONCLUSIONS

Cogeneration reduces fuel consumption by taking advantage of some of the waste heat of thermal machines. In addition, the advancement in equipment and the integration of different disciplines have made possible the existence of systems that, in addition to heat and electricity, are able to generate cold, this system is known as trigeneration. Hotels, hospitals, and airports are being configured as the sectors most likely to benefit from these schemes in the design of conditioning systems, in addition, and the use of cogeneration and trigeneration allows the reduction of greenhouse gas (GHG) emissions as fossil fuels move.

In Latin America, the use of renewable energy is on track, with Brazil being the country that uses renewable energy the most in Latin America, in other countries in the region, the implementation of these systems is still in development, governments are creating measures to provide a higher priority to the use of renewable energies and systems such as cogeneration and trigeneration.

Brazil is one of the Most renewable global energy countries, in 2017 80% of the electricity used by Brazil came from the productivity of renewable sources, even though most of the electricity comes from hydroelectric plants, in the same year Brazil reached 18.2 GW from cogeneration.

In Chile, although 57.4% of Chile's electricity production was based on fossil fuels in 2017, a containment plan has been undertaken to improve the use of renewable energy. Chile's commitment to better use of its natural resources makes cogeneration one of the pillars of the country's energy revolution in seeking to obtain energy efficiently. To this end, the measures of Law 20.257 and the exemption from payments laid down in the Regulations provide that; Cogeneration plants may benefit from using a fuel belonging to NCRE (non-conventional renewable energy).

Peru, for its part, opened its first cogeneration plant in 2009, since then, Peru's progress has not been so hasty, the small number of natural gas cogeneration facilities is associated with a lack of planning and long-term vision of Camisea's natural gas use, and a weak energy efficiency policy in the industrial sector. In Peru, an adequate medium- and long-term strategy for the implementation of energy plans related to the promotion and incentives of cogeneration technologies in the industrial, commercial, and residential sectors has not been developed.

Finally, it is evident that Colombia has made great progress in the implementation of renewable energies, highlighting that hydroelectric energy is the main producer of electrical energy in the country, representing 69.9% in 2017, in addition, according to a recent study by UPME in 2014, the industrial sector reached an installed capacity of 596.7 MW, while the oil sector of 95 MW.

Colombia must continue the path to the economy of the future, a path in which government intervention is key to continuing to promote the development, implementation, and use of renewable energy since energy demand grows throughout the years, so also the pollution of the environment due to GHG emissions. Therefore, the most efficient solution is the implementation of these energies and the use of cogeneration and trigeneration systems. Thus, GHG emissions can be considerably reduced.

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