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Renewable Energies in the Electricity System of Valle del Cauca (Colombia)

Odnawialne źródła energii w systemie elektroenergetycznym Valle del Cauca (Kolumbia)

Abstrakt: W artykule opisano obecną sytuację i udział odnawialnych źródeł energii w systemie elektroenergetycznym jednego z departamentów Kolumbii – Valle del Cauca. W ramach badania dokonano interpretacji ram instytucjonalnych dotyczących energii odnawialnej w Kolumbii oraz ogólnej analizy światowego i kolumbijskiego systemu elektroenergetycznego. Kolejna kwestia to udział odnawialnych źródeł energii w wytwarzaniu energii elektrycznej w Valle del Cauca, głównie w zakresie produkcji i infrastruktury energii hydroelektrycznej, bioenergii i energii fotowoltaicznej. W dalszej części autorzy skoncentrowali się na kwestii potencjału elektrycznego energii odnawialnej w omawianym regionie. Ponadto przedstawiono szereg dyskusji na temat tego, jak omawiany departament skorzystał z ram instytucjonalnych dotyczących wykorzystania energii odnawialnej.

Słowa kluczowe: energia odnawialna; energia fotowoltaiczna; bioenergia; kogeneracja; *Sistema Interconectado Nacional* (SIN); Valle del Cauca

Abstract: The article describes the current situation and the share of the renewable energy sources in the electricity system of Valle del Cauca Department in Colombia. The research involves an interpretation of the institutional framework regarding renewable energies in this country, a general presentation of the worldwide energy system, and the Colombian electricity system. The next issue refers to the share of renewable sources in electricity generation developed in Valle del Cauca. It mainly refers to the production and infrastructure of hydroelectric power, bioenergy, and photovoltaic energy. Then, the article focuses on the electric potential of renewable energies held in the Department. Finally, there is a set of discussions on how Valle del Cauca has taken advantage of the institutional framework regarding the exploitation and use of renewable energies.

Keywords: renewable energy; photovoltaic energy; bioenergy; cogeneration; *Sistema Interconectado Nacional* (SIN); Valle del Cauca

INTRODUCTION

Global economic growth goes together with energy consumption. This phenomenon has led to the massive use of both renewable and non-renewable resources, and, therefore, the deterioration and depletion of many of these resources. In this scenario, the energy system is said to be responsible for this situation. The system is characterized by being unsustainable, polluting, and wasteful. Additionally, it mostly uses limited fossil resources. If the current consumption continues at this speed, oil, natural gas, and coal reserves on the planet are thought to last for no more than 41, 65 and 205 years, respectively (Morales 2007). Given this situation, a growing concern has emerged in order to promote initiatives and policies that mitigate the harmful effects on the energy system and the electricity sector. It is precisely at this point that renewable energies appear to be a serious alternative to meet the energy requirements of the population.

The effort around the world to achieve a sustainable energy matrix has led to renewable energy to have a valuable growth in recent years, therefore, a significant share in world electricity production. At the end of 2017, it accounted for 26.5% of the global electricity production. Wind and photovoltaic generation initiatives are leading in the world in terms of growth, which has increased by 227% and 145%, respectively between 2014 and 2017 – even electricity from wind accounted for 5.6% of total world electricity production in 2017 (REN21 2016; 2017; 2018).

Although Colombia's electricity matrix mainly depends on hydraulic power generation, the country is behind the implementation of renewable energies, especially non-conventional ones, since the indicators show that other countries in the region stay ahead of Colombia in the use of solar, wind, and other energy sources. This is the reason why it is important to study this situation and progress of this electric energy issue in Colombia. It is also worth paying attention to the initiatives to study the contribution of renewable energies to the electric system of Valle del Cauca Department and its potential. Valle del Cauca is a region crossed by the Cauca River and surrounded by the central and western mountain ranges. It is famous for its sugar industry, which has become the driving force of initiatives for power generation from residual biomass. It is also a very sunny region that has become a solar energy source for the country as well.

MATERIALS AND METHODS

The main objective of the study is to characterize the current situation of renewable energies in the electric system in the region of Valle del Cauca, in southwest of Colombia, as well as its renewable energy potential. The type of study is descriptive. A documentary analysis and a case study method are used, the information is mainly provided by different national and international entities specialized in the subject. Some of the documents which should be highlighted are annual reports of SIN operation and market administration of energy in Colombia provided by XM, the national atlas of solar radiation, ultraviolet and ozone (IDEAM, UPME 2017a), the atlas of wind (IDEAM, UPME 2017a), and the atlas of energy potential of biomass wastes in Colombia (Ministry of Mines and Energy [Ministerio de Minas y Energía] 2010), and the *Identification of the Electric Generation Potential with Unconventional Sources of Renewable Energy for Small-Scale Exploitation in Valle Del Cauca* supplied by CIAT, DESOLCON, CVC (2015). The research also analyzed articles by Morales (2007) or Peñaranda, Montenegro, and Giraldo (2017). Additionally, the current Colombian legislation on the topic under discussion was investigated.

LITERATURE REVIEW

The definition of renewable energy can vary depending on the legislation of each country. Hernández (2011) defines them as all those that are extracted from sources that regenerate naturally, which guarantees that they are not exhausted. These are considered clean or green initially, because they pollute very little, and do not emit the gases that produce the greenhouse effect. Regarding the relationship between energy consumption and economic development there is no absolute theory. Studies indicate that the results depend on the countries analyzed, measurement models, time and variables analyzed. Caraballo and García (2017) collect information on the causality relationship between energy consumption and economic growth. In the first hypothesis, it indicates that economic growth depends on energy consumption, a unidirectional causal relationship is established in which lower energy consumption leads to a negative impact on economic growth. In the second case, economic growth and energy consumption depend on each other, the feedback hypothesis raises a two-way causal relationship between energy consumption and economic growth, supporting the idea that an active policy by the tax governmentor subsidies can have a positive effect on economic growth, which, in turn, will lead to a consequence on energy consumption. Some studies, for example, those conducted by Salim, Hassan and Shafiei (after Loaiza 2018) indicate that

> [...] the results showed a positive long-term relationship between renewable and non-renewable energy sources, industrial production and economic growth. There is unidirectional causality between GDP growth and renewable energy consumption. These results indicate that OECD countries are still dependent on energy primarily for their industrial production. In this sense, the expansion of renewable energy sources is a viable solution to address energy security and cope with the problems of climate change, and the gradual replacement of renewable energy sources with non-renewable energy sources, this could improve the economic growth of a country.

Other studies in Latin America such as those carried out by Nachane, Nadkarni and Karnik (after Vera, Kristjanpoller 2017) find bidirectional causality between real GDP *per capita* and commercial energy consumption in countries such as Brazil, Venezuela and Colombia for the period 1950–1985. On the other hand, Murry and Nan verify unidirectional causality between the real GDP towards the consumption of electricity in Colombia (after Vera, Kristjanpoller 2017).

According to the above, economies such as Colombia depend on their energy consumption, so it is essential for the state to guarantee the energetic supply it demands. The Colombian energy matrix depends on fossil fuels partially, thus, renewable energies appear in the process of energy transition, additionally, from the environmental perspective, these are considered less polluting and more environmentally friendly. Hernández (2011) affirms that

> […] the main benefit that renewable energies produce compared to traditional energies is that they reduce their dependence, replace them gradually and contribute to maintaining the quality of life of current people, guaranteeing a friendly environment and more balanced, which allows to preserve the healthy environment of future generations and contribute to the reduction of global warming.

INSTITUTIONAL FRAMEWORK

The Congress of the Republic of Colombia established Law 143 of 1994 which provides a set of rules for electricity generation, interconnection, transmission, distribution, and marketing in the national territory (Congress of Colombia [Congreso de la República de Colombia] 1994). Law 1715 of 2014 promotes the use of such recognized non-conventional renewable energies as bioenergy, energy from the seas, small hydroelectric power plants, as well as wind, geothermal, and solar energies. This law also regulates their integration into the National Energy System (Congress of Colombia [Congreso de la República de Colombia]

2014). Law 697 of 2001 promotes the rational and efficient use of energy and the use of alternative energies (congress of Colombia [Congreso de la República de Colombia] 2001). Article 18 (tax reform) of Law 788 of 2002 establishes, as tax-exempt income, the sale of electric power that has been generated based on wind resources, biomass, or agricultural waste, in accordance with the other requirements established by the said law (Congress of Colombia [Congreso de la República de Colombia] 2002). Finally, Law 1215 of 2008 is worth mentioning, which supports the sale of surplus electricity obtained through cogeneration to electricity distribution companies (Congress of Colombia [Congreso de la República de Colombia] 2008). Under these measures the sugar mills of Valle del Cauca have been able to sell their surpluses of electric energy generated from cane bagasse to SIN. It is also a favorable scenario for the development of new uses of renewable energy and its easy commercial integration into the national network.

THE ELECTRIC NATIONAL AND INTERNATIONAL CONTEXT

In general terms, the global supply of primary energy in 2015 exceeded 13,647 Mtoe, of which 81% corresponds to fossil fuels (oil, coal, and natural gas). This same trend is due to the global electricity sector, which in 2015 reached a generation of over 24,255 TWh, of which 77% comes from fossil or nuclear resources and the remaining 23% corresponds to renewable energy, mainly hydraulic power (see Fig. 1). Electricity consumption stood at 22,386 TWh.

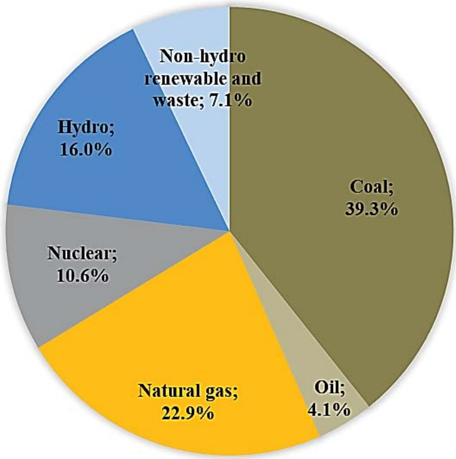


Fig. 1. World electricity generation according to supplying source in 2015 (on the basis of International Energy Agency 2017)

The energy context in Colombia shows significant differences compared to the global energy context – in 2015, internal energy production was equivalent to 124.7 Mtoe, and electricity consumption reached 59.4 TWh, which in *per capita* terms is lower than global consumption. In Colombia, each inhabitant represented a consumption of 1,231 Kwh, while the annual world average was 3,052 Kwh (International Energy Agency 2017). Unlike the global electric system dependent on non-renewable resources, the national electricity production mainly depends on renewable resources. In 2015, over 67% was generated in hydroelectric power plants (*Unidad de Planeación Minero Energética* [UPME] 2016) (see Fig. 2). In 2016, electricity generation in Colombia reached 65,940 GWh (XM 2016) and in 2017 – 66,667 GWh (XM 2017).

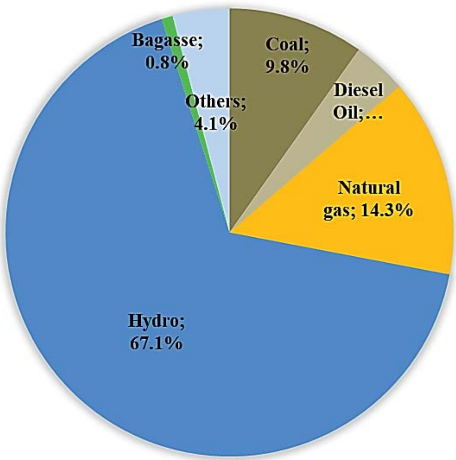


Fig. 2. SIN electricity generation in Colombia according to supplying source in 2015 (on the basis of UPME 2016)

SOURCES OF ELECTRICITY IN VALLE DEL CAUCA

According to UPME (2016) in Valle del Cauca Department, 3,138 GWh of electricity was generated in 2015, which is equivalent to 4.7% of the energy generated from the SIN. In the same year, the department consumed 5,981 GWh, equivalent to 11.3% of the total electric power of the SIN consumed in Colombia (see Tab. 1).

As of July 2016, Valle del Cauca registered an electric power generating capacity of 1,103 MW, representing 6.7% of the effective SIN generation capacity in Colombia; 37.2% of the generation capacity comes from Diesel fuel. In terms of renewable energies, it can be seen that 58.3% of the capacity is hydraulic power and 3.5% biomass (UPME 2016) (see Fig. 3).

Tab. 1. Electric energy generation and consumption in Valle del Cauca between 2012 and 2015 (on the basis of UPME 2016)

Year	SIN electric energy generation in GWh	Share in the national electric energy generation	Total electric energy consumption in GWh
2012	2,342	3.9%	5,289
2013	2,914	4.7%	–
2014	2,854	4.4%	–
2015	3,138	4.7%	5,981

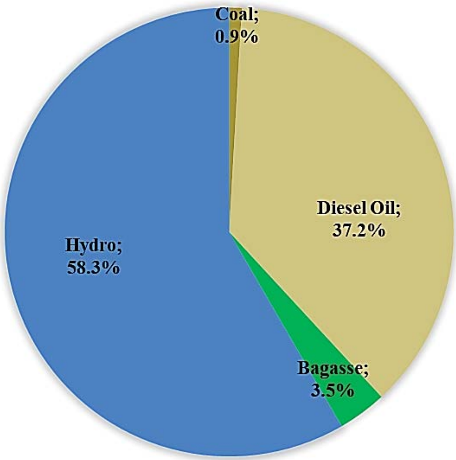


Fig. 3. Effective electricity generating capacity in Valle del Cauca as of July of 2016 (on the basis of UPME 2016)

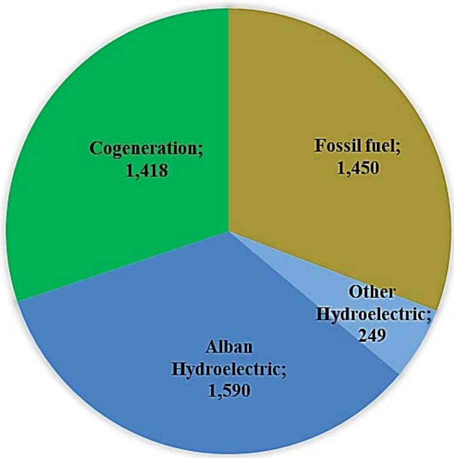


Fig. 4. Electricity generation in Valle del Cauca according to supplying source in 2016 (MW) (on the basis of Asocaña 2017)

Hydropower generation is relevant for Valle del Cauca. In 2016, it reached 39% of the total generation. On the other hand, in recent years, bionergy has achieved a fundamental role generating 30% of the department's electricity (see Fig. 4). In Valle del Cauca, in addition to innovating in bionergy and being an absolute leader at the national level, it has been recently decided to experiment with photovoltaic energy as a pioneer in solar energy projects in Colombia.

HYDROPOWER – CONTEXT AND CONTRIBUTION

Hydroelectricity prevails in the Department with an installed generating capacity exceeding 643 MW. The power plants with the highest installed capacity are Alto and Bajo Anchicayá and Calima – they have 88% of the hydraulic generating capacity. In 2013, over 90% of the hydroelectric-type electric power supplied by the Valle del Cauca to the SIN was generated in the aforementioned hydroelectric power plants. The energy inventory in Valle del Cauca also includes 10 other mini-hydroelectric[1] power plants connected to the SIN (CELSIA n.d.). The complete list is provided in Tab. 2.

Tab. 2. Hydropower plants and mini hydropower plants in Valle del Cauca: Installed capacity and SIN share (on the basis of XM 2016; 2017; CELSIA n.d.)

Power plant	Installed capacity MW	SIN percentage share		SIN share in GWh	
		2012	2013	2015	2016
Alto Tuluá	20	0.05%	0.09%	53.8	48.0
Alto y Bajo Anchicayá	429	2.61%	2.89%	1.246,0	1.590,0
Amaime	19.9	0.09%	0.07%	37.4	30.0
Bajo Tuluá	20	–	–	53.6	55.0
Calima	132	0.36%	0.25%	246.0	57.0
El Rumor	2.5	0.02%	0.02%	–	–
Nima I y II	6.7	0.05%	0.05%	22.9	29.4
Río Cali I y II	1.8	0.02%	0.02%	9.3	11.0
Río Frío I	1.7	0.02%	0.01%	5.8	6.0
Río Frío II	10.0	0.08%	0.07%	11.9	13.0
Total	643.6	3.30%	3.47%	–	–

[1] In this text it refers to hydroenergy use with nominal power less than 20 MW.

BIOENERGY – CONTEXT AND CONTRIBUTION

In the Department, the electricity generation from sugarcane bagasse has shown dynamism during the last years. As of 2013, this energy accounted for about 0.6% of the total electric power produced in Colombia. Over 90% was produced by Valle del Cauca's sugar mills (*Cámara de Comercio de Cali* n.d.). The total national bioenergy transmitted to the SIN in 2015 and 2016 reached 526 GWh and 600 GWh, respectively (XM 2016). The Department is the national leader in terms of cogeneration. Sugar mills are currently capable of self-supplying the demand for electricity. In 2016, they had a production capacity of 253 MW, of which a surplus of 94 MW was obtained and sold to the national network, and total electricity generation was equivalent to 1,418 GWh, which would be enough to supply electricity to over one million people. The installed cogenerating capacity from bagasse has grown at an average rate of over 7% per year. Surplus capacity has doubled between 2010 and 2016. By 2018, the installed capacity is expected to reach 284 MW, a surplus of 123 MW is projected, which will surely be sold to the National Network (Asocaña 2017) (see Tab. 3).

Tab. 3. Cogenerating installed capacity and net surplus effective capacity (MW) in Valle del Cauca (on the basis of Asocaña 2017)

Year	Installed capacity	Surplus
2010	174	46
2011	180	53
2012	182	53
2013	187	51
2014	215	68
2015	237	78
2016	253	94
2017*	274	116
2018*	284	123

*projected capacity

El País.com.co (2018) points out that bioelectricity has played a leading role in the total electricity generation in Valle del Cauca. In 2016, the sucro-energy sector contributed 29.9% of the total electricity generated in the Department. However, the report including the generation of the Salvajina hydroelectric power plant in Valle del Cauca total electricity production is to be taken into account. This hydroelectric power plant is located in the neighboring Department of Cauca. If the contributions of the Salvajina reservoir are not taken into account, it could be concluded that 34% of the electricity generated comes from sugarcane bagasse in Valle del Cauca.

According to figures from XM (2015; 2016), in Valle del Cauca, sugar mills with the highest contribution to the SIN are La Cabaña (Proenca), Providencia 2, Mayagüez I and Rio Paila I. It is also necessary to note that some of the energy generation plants use other fuels besides bagasse. Tab. 4 shows the electrical contribution of some sugar mills to the SIN as well as the primary energy contribution of bagasse and other fuels to the electric generation of sugar mills in Valle del Cauca.

Tab. 4. Electricity contribution of sugar mills in Valle del Cauca to the SIN (on the basis of XM 2015; 2016; 2018)

Sugar mill	Contribution to SIN GWh 2015	Contribution to SIN GWh 2016	Electric generation (Gwh) between Sept. 2017 and Sept. 2018.	Contribution of primary energy between Sept. 2017 and Sept. 2018.	
				Bagasse	Coal
Proenca 1	144.9	143.2	217.6	52.08%	47.92%
Providencia 2	112.9	120.0	259.5	100%	–
Mayagüez I	138.3	113.4	156.4	71.46%	28.54%
Río Paila I	17.2	47.1	213.1	100%	–
Central Castilla I	8.4	10.4	78.9	100%	–
Manuelita	–	4.7	54.4	100%	–
San Carlos	3.6	3.7	49.1	100%	–
Pichichi	3.6	2.5	42.6	100%	–
Central Tumaco	1.0	0.3	–	–	–
Carmelita	0.1	0.0	28.2	100%	–

PHOTOVOLTAIC ENERGY – CONTEXT AND CONTRIBUTION

The Department is a pioneer in the advance towards the use of solar energy. In September 2017, the first photovoltaic plant in Colombia, which has 35,000 photovoltaic modules, came into operation. It is located in the municipality of Yumbo. It has an installed capacity of 9.8 MW and a generating capacity of 16.5 GW per year, equivalent to the consumption of approximately 8,000 households (CELSIA 2017). Other projects of this type being conducted in the Department include the sustainable campus of Universidad Autónoma de Occidente that has a system of 638 photovoltaic modules, the police station in the municipality of Florida that has become the first station of the country operating with photovoltaic energy and the educational institution, Gabriel García

Márquez, Panorama satellite campus, that has 20 photovoltaic installed modules (El País.com.co 2017).

POTENTIAL OF RENEWABLE ENERGIES IN VALLE DEL CAUCA

Hydroenergy potential

To evaluate the power generating potential from a water source, it is necessary to have data related to the flow and the height difference between the intake point of said flow and the suction axis of the turbines (CIAT, DESOLCON, CVC 2015). Such information is limited in the Department. However, according to the Regional Autonomus Corporation of Valle del Cauca (*Corporación Autónoma Regional del Valle del Cauca*, CVC) and the Group of Management and Agricultural Engineering Support of Colombia (*Gaiacolis Grupo de Gestión y Apoyo a la Ingeniería Agrícola de Colombia*, GAIACOL) (CVC GAIACOL 2007), 12 basins of first order are recognized, which correspond to the Pacific watershed, and 35 basins of third order are tributaries of the Cauca River. Some basins such as Anchicayá, Calima, or Amaime are used in electricity generation, and others, despite not being used for electricity generation, have flows with an outstanding annual average, among them, the basins of the Bugalagrande River (15,230 l/s), Claro River (7,240 l/s), Timba River (21,171 l/s) and La Vieja River in the north of the Department (90,000 l/s).

Bioenergy potential

In Colombia, less than 17% of wastes generation are used in energy production, a figure that is far below compared with 67% of energy use by the countries of the European Union (Peñaranda, Montenegro, Giraldo 2017). According to the Ministry of Mines and Energy (Ministerio de Minas y Energía 2010), Valle del Cauca has over 168,000 ha of sugarcane-growing fields, and the usable waste from bagasse, stem, and leaf exceeds 12 million tons, whose energy potential is estimated at 96,000 TJ/year. According to recent data (Asocaña n.d.), states that there are over 220,000 sugarcane-growing hectares in the 47 municipalities located in the Cauca River valley. It should be noted that around 25% of the clean sugarcane corresponds to green leaves waste, dry leaves, and remaining sugarcane that is mostly left in the field and burnt (Peñaranda, Montenegro, Giraldo 2017). The sugar mills have taken important steps in the use of sugarcane waste through energy cogeneration. This potential is beginning to materialize and even more with the cogeneration projects that the sugar mills intend to implement. Despite sugarcane has by far the highest potential, there are other agribusiness crops that generate waste with potential energy use (see Tab. 5). In terms of livestock waste (poultry, bovine, and pig manure) and they thought to be just over 3,153,000 tons every year, whose energy potential reaches 5,956 TJ/year. Map 1 shows the energy potential of residual biomass of sugarcane crop in Valle del Cauca in 2013 (CIAT, DESOLCON, CVC 2015).

Tab. 5. Energy potential in Valle del Cauca according to type of organic waste in 2013 (on the basis of the Ministry of Mines and Energy 2010)

Product	Grown area ha	Production t product/year	Amount of waste t/year	Energy potential TJ/year
Rice	5,970	40,031	102,079	452
Banana	6,202	65,015	399,844	228
Coffee	72,563	63,523	340,509	3,310
Sugarcane	168,033	2,132,596	12,667,620	96,695
Brown sugarcane	6,216	35,228	221,234	1,885
Corn	31,568	157,931	223,472	2,400
Plantain	15,650	147,073	904,497	516

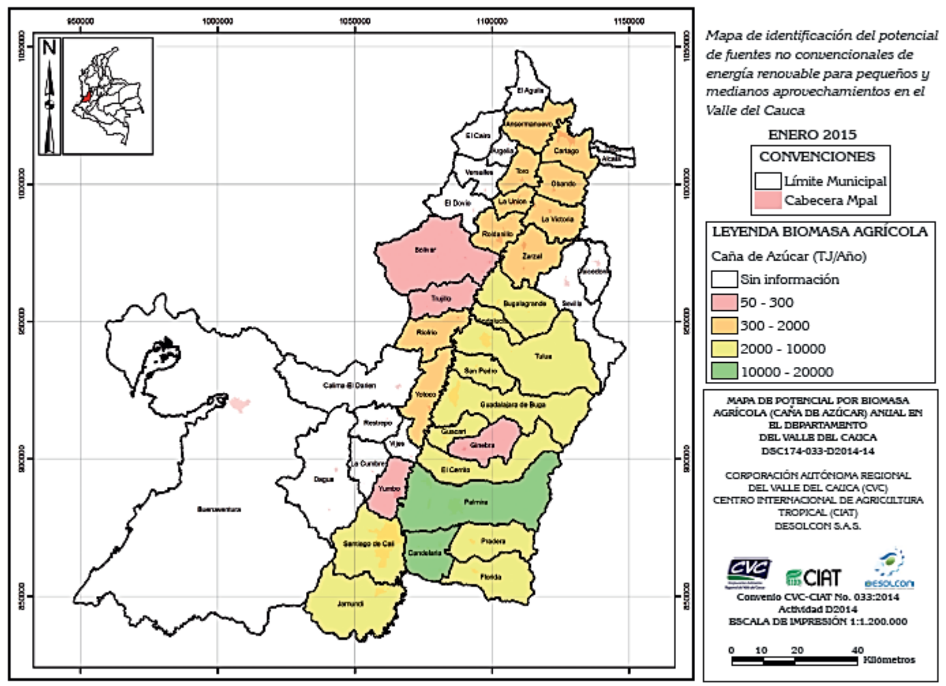
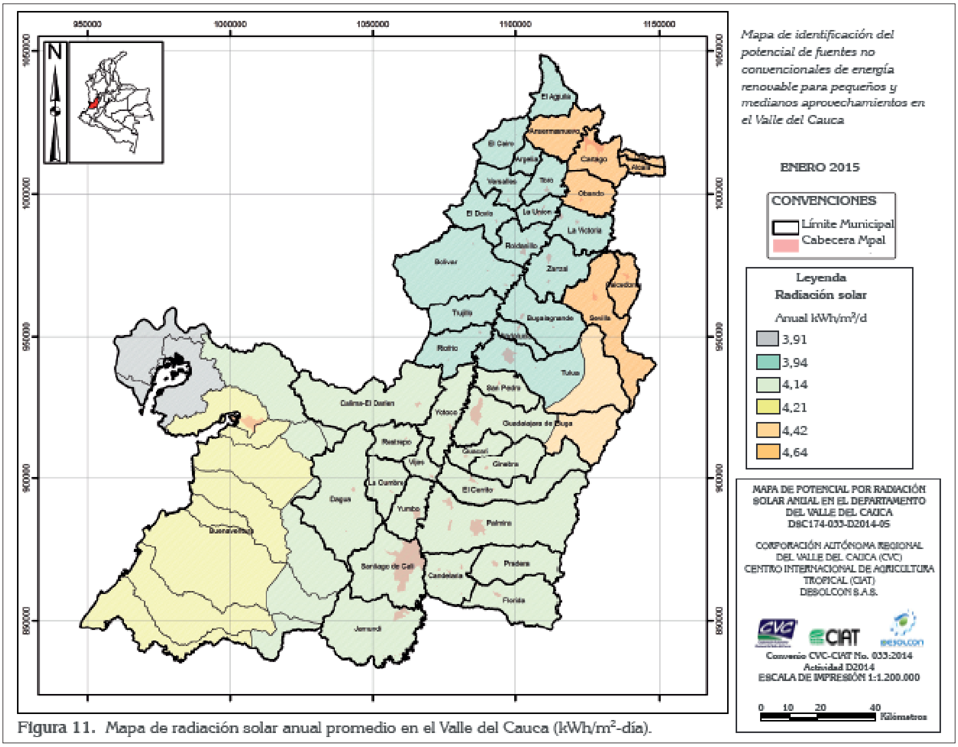


Figura 18. Mapa de potencial energético biomasa residual cultivo caña de azúcar (TJ/año).

Map 1. Energy potential of residual biomass sugarcane crop in Valle del Cauca (on the basis of CIAT, DESOLCON, CVC 2015)

Solar potential

Colombia has positive indicators in terms of solar resource availability due to its geographical location close to the Equator. Valle del Cauca is one of the regions with the highest solar energy potential in the country. As stated by the Institute of Hydrology, Meteorology and Environmental Studies (*Instituto de Hidrología, Meteorología y Estudios Ambientales*) (IDEAM, UPME 2017a), "[…] the highest averages are highlighted in large sectors of the Caribbean region, the Orinoquia and the inter-Andean valleys, while minor averages occur in large sectors of the Pacific region, the western Amazon, and in some isolated sectors of the three mountain ranges". The global radiation intensity exceeds 4.5 kWh/m2 per day in the area that crosses the Department from northern Cauca to the coffee-growing area. The global solar irradiation is bimodal, which means that during the periods January–March and July–September, the highest solar irradiation levels are recorded, and during the periods April–June and November–December, lower levels of global solar irradiation are reported. The national map of global solar irradiation is provided by IDEAM, UPME (2017a). Map 2 shows solar



Map 2. Solar irradiation annual average in Valle del Cauca (on the basis of CIAT, DESOLCON, CVC 2015)

irradiation in Valle del Cauca according to data reported by the NASA Research Center between 1983 and 2005 (CIAT, DESOLCON, CVC 2015).

In terms of solar brightness, extensive areas of Valle del Cauca show averages between 5 and 6 DSH (daily sun hours). According to the specific data of the city of Cali, the highest levels of solar brightness are recorded in the periods December–January and July–August, and the lowest levels of solar brightness are recorded in the periods April–May and October–November. Most of the Department area registers between 4 and 5 hours of solar brightness, and some other places register between 5 and 6 hours; the coastal area of the Pacific registers an insolation between 3 and 4 hours. The inter-Andean valleys next to the Caribbean region and large sectors of the Orinoquia are the regions with the highest potential for the use of solar energy in the country.

Wind potential

According to International Center for Tropical Agriculture (*Centro Internacional de Agricultura Tropical*) (CIAT, DESOLCON, CVC 2015), the

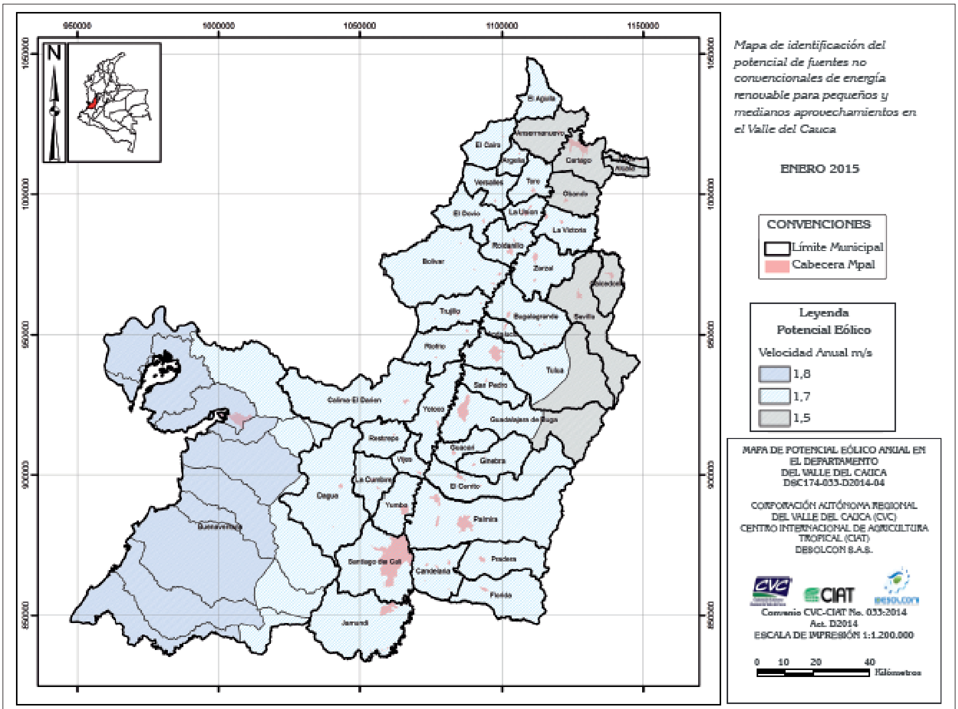


Figura 12. Mapa del potencial de generación con fuente eólica en el departamento del Valle del Cauca (m/s).

Map 3. Wind power generation potential in Valle del Cauca (on the basis of CIAT, DESOLCON, CVC 2015)

Department has a low potential in terms of wind power generation; wind speeds are between 1.5 and 1.8 m/s; however, it is necessary to deeply study the case of some municipalities such as Dagua, Calima-El Darién, Vijes and Roldanillo, where wind speeds over the minimum required have occasionally been recorded. Map 3 shows electric potential for wind power generation in Valle del Cauca (CIAT, DESOLCON, CVC 2015).

According to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM, UPME 2017b), the conventional IDEAM stations in Valle del Cauca have low levels of wind speed recorded at 10 m high. These do not exceed 1.6 m/s; however, it is clear that due to the complex orography of Colombia, it is difficult to obtain accurate calculations of areas far from the reference stations.

CONCLUSIONS

The electricity system of Valle del Cauca mainly depends on hydropower, but the use of fossil resources also has a significant share in the Department electrical matrix. The use of non-conventional renewable energies has played a fundamental role. In recent years, the use of agribusiness waste from the sugar sector in the bioenergy generation has significantly grown. This type of energy accounts for about a third of the electricity produced in the Department – it has even contributed its surplus to the SIN. Several mini-hydropower projects have also been conducted and the first advances have been made in the photovoltaic energy production. It currently has the largest photovoltaic plant in the country. Given the progress in the production of conventional and non-conventional renewable energies, it seems that the Department has made its first approaches towards understanding and taking advantage of legal issues that regulate and encourage the use of these types of energies.

As regards the future of renewable energy in the Valle del Cauca, its integration into the SIN and the boom that seems to wake up in the process of energy transition, the forecast seems to be promising in the growth of these uses in the coming years. Regarding the renewable energy potential, the possibilities of growth in the bioenergy production should be highlighted, thanks to the large volumes of waste from sugarcane crops in the Department. There are also possibilities of development in the field of solar energy. Several areas of Valle del Cauca show some of the most positive levels of global solar irradiation in Colombia.

From the perspective of economic development, it seems that countries such as Colombia or regions such as Valle del Cauca are facing certain questionable development standards. Traditional economic development and quality of life imply high energy consumption and, therefore, the expenditure of renewable and non-renewable natural resources, a situation that becomes more complicated when the energy matrix depends on fossil resources that generate pollution and environmental deterioration. Finally, taking into account that in some way renewable energies seek to mitigate environmental effects and at first glance they are considered clean energies, it is necessary to leave the investigation open in regard to bioenergy and hydropower in the Department. Regarding the first one, there is a wide discussion because it depends on the monoculture of sugarcane, whose processes of crop harvesting and energy production can bring collateral environmental effects. On the other hand, hydroelectric energy is considered by some authors as non-renewable energy. Its effects can lead to the displacement of communities, deterioration of the landscape and a negative influence on biological diversity.

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