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VISIÓN ELECTRÓNICA

A RESEARCH VISION

Use of wastewater and waste from Colombian pacific for electrical generation

Aprovechamiento de aguas residuales y residuos del pacifico colombiano para la generación eléctrica

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Abstract: The Colombian Pacific region has 36 municipalities corresponding to areas not interconnected to the National Interconnected System [1], and a population of 1,332,082 inhabitants [2]. The region's electricity supply is made partially from diesel plants with coverage of 6 to 8 hours a day, [3]. Currently, neither solid waste nor wastewater generated has adequate disposal, which generates great environmental and health impacts. The present study estimated the energy potentials that can be obtained from these wastes produced in the region. The calculated theoretical energy potential was 30 MWh / year and the technical energy potential was 20,589 kWh / year, considering an energy conversion efficiency of 50 % and an effective collection of 70%. These potentials cover 5.2% of the total energy demand in the region for 24 hours a day. To solve a total coverage, we can think about the implementation of

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hybrid systems of distributed generation using the current diesel plants with the supplement of clean energy sources (other biomass residues, water resources or photovoltaic solar systems).
Keywords: Biogas, Clean energies, Electric generation, Sewage, Urban solid waste.

Resumen*:* La región pacifica colombiana cuenta con 36 municipios correspondientes a zonas no interconectadas al Sistema Interconectado Nacional [1], y una población de 1.332.082 habitantes [2]. El suministro eléctrico de la región se hace de manera parcial a partir de plantas diésel con cubrimiento de 6 a 8 horas diarias, [3] Actualmente, ni los residuos sólidos ni las aguas residuales generadas tienen disposición adecuada, lo que genera impactos ambientales y de salubridad; el presente estudio estimó los potenciales energéticos que pueden obtenerse a partir de estos residuos producidos en la región. El potencial energético teórico calculado fue de 30 MWh/año y el potencial energético técnico, fue de 20.589 kWh/año, al considera una eficiencia de conversión energética de 50% y una recolección efectiva del 70%. Estos potenciales permiten cubrir el 5,2% de la demanda energética total de la región durante 24 horas al día. Para garantizar un cubrimiento total, se pueden pensar en la implementación de sistemas híbridos de generación distribuida usando las plantas diésel actuales con el suplemento de fuentes de energía limpias (otros residuos de biomasa, recursos hídricos o sistemas solares fotovoltaicos).
Palabras clave: Biogás, Energías limpias, Generación eléctrica, Aguas residuales, Residuos sólidos urbanos.

1. Introduction

The Colombian Pacific has no planning for the management of Urban Solid Waste (USW) and Wastewater (WW), a situation that generates a negative impact on ecosystems. At the national level, some policies have been proposed to discourage the single use of some products, such as green taxes, plastic bags and carbon tax; these, beyond the economic collection, seek to generate ecological awareness and promote the development of new environmentally friendly products, ensuring the reforestation and protection of forests, initiatives with great potential in the Colombian Pacific. [4].

In the electricity sector, it is paradoxical that the Pacific region is one of the regions with the highest annual rainfall worldwide, does not have hydroelectric power plants that could cover the current and future energy demand of the region, and is forced to have 36 municipalities considered as non-interconnected zones (NIZ), to the national interconnected system (NIS), a situation that leaves it as one of the most vulnerable regions of Colombia [5]. This situation makes it one of the most vulnerable regions in Colombia.

On the other hand, instead of becoming an environmental problem, USW and WW can be seen as an energy resource that could be used for electricity generation. For this to become a reality, it is necessary, first, to evaluate the energy potential of these resources.

2. Development of the topic

The Colombian Pacific region is composed of 174 municipalities divided between four departments: Cauca, Chocó, Nariño and Valle del Cauca, according to the Ministry of Environment and Sustainable Development (2012), in this region more than 1,208 tons of solid waste are produced daily, most of them correspond to organic waste that cause pollution problems to rivers, streams and the sea [6]. The use of biodegradable waste can produce biogas, which can be used in cogeneration systems for electricity generation plants for the 36 municipalities in the Pacific zone that are part of the NIZ.

In this work, an energy evaluation of USW and WW for the 36 municipalities belonging to the Colombian Pacific NIZ is carried out, calculating their theoretical and technical potentials. Theoretical potential is understood as the amount of energy that can be supplied by biomass;

on the other hand, technical potential is understood as the evaluation of energy production from WW and USW.

USW comes from different activities and is made up of a wide variety of substances (paper, wood, cardboard, plastics, etc.); when its fraction decomposes, it generates volatile compounds such as methane and carbon dioxide that contribute to the greenhouse effect.

The WW are formed by liquid effluents generated by human beings in their daily activity, It is a waste of a very high water content, reason why its evacuation is done in rivers and the sea, this process is obtained a waste called sewage sludge, where most of the organic matter present in the wastewater remains; This waste can be processed to obtain biogas, which in turn, can be used as fuel. [7].

2.1 Residual biomass

Currently, the most advanced and common systems in anaerobic digestion of biomass are continuous systems, which are characterized by a regular feeding of the digester, the same amount of substrate is added and extracted daily. The result is a constant and controlled biogas production that can be stored in a gasometer. Before being used as fuel gas, the biogas is purified through a series of filters. The biogas produced can be used in cogeneration systems where it is burned in internal combustion engines to generate electricity and simultaneously recover waste heat. It can also be used in boilers to generate steam or heat water for thermal energy production.

2.2 Biogas from USW and WW

One of the main alternative energies in which Colombia has great potential but is not exploited is the residual biomass, such as USW and WW, knowing this perspective was published "Atlas of the energetic potential of residual biomass in Colombia". [8].

Table 1. Municipalities of the departments of the Colombian Pacific Region belonging to the NIZ. Source: Institute for planning and promotion of energy solutions for non-interconnected zones. [9]

Non-interconnected municipalities in the pacific zone of Colombia		
Department	**Municipality**	**N° inhabitants**
Cauca	Timbiquí	21.738
Cauca	Guapi	29.797
Cauca	López de micay	12.950
Chocó	Acandí	9.584
Chocó	Alto Baudó	36.773
Chocó	Bahía Solano	9.327
Chocó	Bajo Baudó	17.402
Chocó	Bojayá	10.099
Chocó	Carmen Del Darién	5.462
Chocó	Condoto	14.660
Chocó	Cantón de San Pablo	7.970
Chocó	Medio San Juan	15.945
Chocó	Istmina	25.351
Chocó	Juradó	3.319
Chocó	Lloró	11.197
Chocó	Medio Atrato	29.487
Chocó	Medio Baudó	13.560
Chocó	Nóvita	7.957
Chocó	Nuquí	8.576
Chocó	Quibdó	116.087
Chocó	Río Iro	9.695
Chocó	Rio Quito	8.961
Chocó	Litorial de san juan	15.251
Chocó	Rio sucio	28.832
Chocó	Sipi	4.048
Chocó	Unguía	15.126
Nariño	Barbacoas	38.708
Nariño	El Charco	38.207
Nariño	Pizarro	15.497
Nariño	La Tola	19.112
Nariño	Magüi (Payán)	23.136
Nariño	Mosquera	16.769
Nariño	Olaya Herrera	31.593
Nariño	Roberto Payán	23.287
Nariño	Tumaco	212.692
Valle	Buenaventura	423.927
Total inhabitants		**1.332.082**

Table 1 shows the 36 municipalities of the NIZ of the Colombian Pacific region; it is made up of 23 municipalities of Chocó with a population of 424,669, 9 municipalities of Nariño with a population of 419,001, 3 municipalities of Cauca with a population of 64,485 and municipality of Buenaventura with a population of 423,927.485, the number of inhabitants of the 36 municipalities of the Colombian Pacific NIZ is 1,332,082 inhabitants that do not have adequate water, electricity and basic education services for their inhabitants.

Through the inhabitants of the NIZ of the Colombian Pacific, the energy potential of residual biomass is evaluated, for the use of USW and WW, considering a planning to meet the needs of the lack of electricity, using the resources generated by each of the inhabitants when they waste or do not recycle organic waste.

2.2.1 Energy evaluation from USW and WW in the NIZ municipalities of the Colombian Pacific region

To calculate the energy potential of residual biomass, mathematical models are developed to obtain theoretical potentials and technical potentials for energy production in the Colombian Pacific using USW and WW, these equations are extracted from the "Biomass Atlas of the Brazilian state of Minas Gerais". [10].

2.2.1.1 Calculation of theoretical and technical energy potential of MSW

STEP 1

Equation (1) estimates the per capital generation of solid waste (kg/inhabitant-day).

$$PCG = \frac{Pw}{Np} \qquad (1)$$

Where:

- PCG= per capita solid waste generation (Kg/inhabitant-day)
- Pw: weight of solid waste generated (Kg/day)
- Np: number of people per municipality

STEP 2

Equation (2) estimates the calculation of the theoretical potential of methane generation from USW:

$$Methane\ \left(\frac{Ton\ CH4}{year}\right) = USW_t \times MCF\ \times DOC_f \times \frac{4}{3} - R \times (1 - O_x) \qquad (2)$$

Where:

- USWt : Total USW collected (t/year)
- MCF: Methane correction factor 1
- DOC: fraction of degradable organic carbon in MSW (0 a 1)
- DOCf : fraction of DOC that is actually degraded 0,5
- F: fraction of methane in biogas (0 a 1)
- R: CH4 recovered (t/year)
- OX: oxidation factor (0 a 1)

STEP 3

Equation (3) stimulates the calculation of the technical potential of USW

$$Potential\ USW\left(\frac{MW}{year}\right) = \frac{tmethane*1000*LHV*n}{\rho*8322*860} \qquad (3)$$

Where:

- tmethane: amount of methane generated in the year (obtained in equation 2)
- 1000: conversion from ton to kilogram
- LHV: lower heating value 8,604 Kcal/m3 (36,023.23kJ/ m3)
- η: conversion efficiency 0,28
- ρ: density of methane 0.74 kg/m3
- 8760: 24-hour operation is considered year-round

- 860: conversion factor from kcal/kg to kWh/kg.

2.2.1.2 Calculation of theoretical and technical energy potential of WW

STEP 1

Equation (4) estimates the calculation of methane gas generation from WW

$$Methane\left(\frac{t\ CH_4}{year}\right) = (Pop \times TE \times BOD_5 \times \eta_r \times MMEF) - R \qquad (4)$$

Where:

- Pop: population (number of inhabitants of the place to be evaluated)
- TE: treated effluent (m^3 /inhabitant/year) a value of 0.150 m^3 /inhabitant/year was considered according to data from the aforementioned Atlas of Minas Gerais. [10].
- BOD_5: biochemical oxygen demand generation rate (ton BOD_5 /m^3). As in the previous case, data from the Brazilian atlas are used, since the Colombian biomass atlas does not have sufficient data (0.000312 ton BOD_5 /m^3).
- η_r : biodigester efficiency. A 50% efficiency is assumed for anaerobic biodigesters.
- MMEF: maximum methane emission factor. The value taken into account as maximum methane emission is the one suggested by the IPCC [11] 0.25 tCH_4 per ton of BOD_5.
- R: amount of methane recovered (kg CH_4 / year)

Once this value (t of methane per year) is obtained, the value of this sewage sludge can be calculated.

STEP 2

Equation (5) stimulates the calculation of the Technical Potential of Generation

$$Sewage\ sludge\ potential\ \left(\frac{MW}{year}\right) = \frac{t_{methane} \times 1000 \times LHV \times \eta_c}{\rho \times 8760} (5)$$

Where:

- tmethane: amount of methane generated in the year (data obtained in equation 4).
- 1000: conversion from ton to kilogram
- LHV: lower heating value of methane gas (8,604 Kcal/m3) (36,023.23 kJ/m3)
- ηc: Conversion efficiency 0,28
- ρ: density of methane (0.74 Kg/m3)
- 8760: considering an operation of all hours per year
- 860: conversion factor from Kcal/Kg to kWh/Kg (1kW= 1kJ).

3. Results

The electricity generation potential for the Colombian Pacific was calculated by means of the theoretical and technical potential of USW and WW based on data obtained from reliable entities such as: FAO, IPCC, World Bank, Banco de la República de Colombia, DANE, biomass atlas of the Brazilian state of Minas Gerais.

Table 2. Theoretical and technical potential of energy generation from WW by departments with municipalities in NIZ in the Pacific region. Source: own.

Department	Number of municipalities NIZ	Total inhabitants municipalities NIZ	Theoretical energy production potential (MJ/year)	Technical energy production potential (kWh/year)
CAUCA	3	64.485	0,184	223,74
CHOCÓ	23	424.669	1,211	1473,43
NARIÑO	9	419.001	1,195	1453,77
VALLE DEL CAUCA	1	423.927	1,209	1470,86
TOTAL	**36**	**1.332.082**	**3,799**	**4.622**

Table 2 shows the theoretical and technical potential of the WW of the NIZ municipalities of the Colombian Pacific.

Table 3. Theoretical and technical potential of energy generation from USW by departments with municipalities in NIZ in the Pacific region Source: own.

Department	**Number of municipalities NIZ**	**Total inhabitants municipalities NIZ**	**Theoretical energy production potential (MJ/year)**	**Technical energy production potential (kWh/year)**
CAUCA	3	64.485	1,26	1531,36
CHOCÓ	23	424.669	8,29	10084,82
NARIÑO	9	419.001	8,18	9950,22
VALLE DEL CAUCA	1	423.927	8,27	10067,20
TOTAL	**36**	**1.332.082**	**26**	**31.634**

Table 3 shows the theoretical and technical potential of USW from the NIZ municipalities of the Colombian Pacific.

By means of the total number of inhabitants that make up the Colombian Pacific region of the four departments that make up this region, the total theoretical WW potential is 3,799 (MJ/year), in the case of USW it is 26 (MJ/year), adding the two results together we obtain 29,799 (MJ/year).

The technical potential obtained from the WW is 4,622 (kWh/year), in the case of USW the results obtained are 31,634 (kWh/year), adding the two results we obtain 36,256 (kWh/year) of its technical potential for energy production, the average consumption of the Colombian Pacific housing is 24,170 (kWh/month), the percentage of the benefited population is 9.20724% of its total population which is 1,332,082 inhabitants of the pacific zone of Colombia.

4. CONCLUSIONS

Through the study of the technical potential, the amount of energy produced by the inhabitants of the Colombian Pacific zone was determined by evaluating the amount of USW and WW where a potential energy production of 31,634 (kWh/year) was stipulated, which can be used to solve the energy problems of the 36 municipalities of the Colombian Pacific NIZ.

USW and WW can be used to produce goods and services for society that require the physical and chemical transformation of matter and in some cases involving residual biomass for energy production.

Through energy conversion and harvesting, the energy potentials can cover an energy demand of 5.2% for 24 hours.

The inhabitants of the Colombian Pacific should be aware of creating, caring for and managing future power plants for the use of biomass. The use of renewable energies is becoming more and more important, because they are clean and inexhaustible resources provided by nature. Their use provides endless advantages, the most important of which is to reduce the greenhouse effect and protect the planet.

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