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NEW PERSPECTIVES

IN THE PRODUCTION OF ELECTRICITY FROM BIOMASS: ITS SOCIAL IMPACT IN CUBA

IMPACTO SOCIAL DE UNA NUEVA PERSPECTIVA PARA LA PRODUCCIÓN DE ELECTRICIDAD CON BIOMASA EN CUBA

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ABSTRACT

Cuba is putting in place energy and hydrology safety policies in order to mitigate the effects of the current energy and drinking water world crisis. Several alternatives are being implemented aimed at reducing the impact of climate change and the shortage of drinking water, namely the use of renewable energy sources and biomass. The obvious insufficiency of water and the feasibility of using biomass as a suitable source of energy, are issues that support the use of air-cooled condensers (ACC) in biomass power plants (BPPs). The BPP project currently has 25 facilities that respond to the electrical power demand of 1,5 million people while protecting the access and the basic services related to water, which are necessitated by 485840 people. The initial investment cost is 1012 million USD; this represents an annual saving of 119.2 million by reducing diesel fuel imports as well as emissions to the environment. The plateau power consumption level is reduced by a 32% and 1500 new jobs are created in disadvantaged rural areas. This research aims to define the social impact linked to the technical and economic effects of ACC technology use in future BPPs.

Keywords: Energy safety, mitigation, social impact, levelized cost.

RESUMEN

En Cuba se aplican políticas de seguridad energética e hidrológica para disminuir el efecto de la actual crisis mundial de energía y acceso al agua potable. Las fuentes renovables de energía y las alternativas para mitigar el impacto del cambio climático sobre la disponibilidad de agua son aplicadas, entre ellas, el uso de la biomasa. El déficit probado de agua y la posibilidad del uso de la biomasa como fuente propia de energía, son elementos que respaldan el uso de aerocondensadores (ACC) en las centrales eléctricas de biomasa (CEB) previstas. El proyecto de CEB cuenta con 25 instalaciones, que cubrirán con fuentes propias de energía los requerimientos de 1,1 millones de personas, mientras que son protegidos el acceso al agua y los servicios básicos relacionados con esta, requeridos por 485840 personas. El costo de la inversión inicial es igual a 1012 millones de USD, lográndose un ahorro anual de 119,2 millones por reducción de importaciones de combustibles y mitigación de emisiones al medio ambiente. Se logra reducir el costo nivelado de la energía en un 32% y son creados además un total de 1500 nuevos puestos de trabajo en zonas rurales deprimidas. El objetivo del presente trabajo, es definir el impacto social asociado al efecto técnico-económico del uso de la tecnología de condensación ACC en las CEB previstas.

Palabras clave: Seguridad energética, mitigación, impacto social, costo nivelado.

INTRODUCTION

Actions implemented in the field of science and technology always have a direct impact on the society. Both as a political and as methodological problem, the analysis of the implications of this phenomenon, its effect and possible consequences, is a task that approaches and poses great challenges. Today's society is framed in the scenario of two emerging situations, energy sustainability and the global water crisis. At the end of 2019, the International Energy Agency (2020) announced in one of its publications that approximately 87% of the energy resources used globally are of fossil origin, while the availability of drinking water has decreased by approximately 25%. This is due to the high rate of greenhouse gas emissions associated with the use of fossil fuels (Gama, 2019).

Cuba, like all other developing countries, receives the effect of globalization on energy resources and the environmental damage generated by their use. One element that directly affects this effect is the overexploitation of exhaustible sources of water and fuel. In today's world there is an unequal distribution of wealth and goods. The literature on the subject states that *"20% of the inhabitants have 80% of all the world's energy resources, while nearly 1.5 billion human beings lack access to drinking water".* (Castro, 2014, p.10)

Cuba's national energy matrix is made up of approximately 95% of fossil fuel facilities, and the remaining 5% of renewable energy sources. There is heavy dependence on crude oil imports (about 85%), for the national production of hydrocarbons is insufficient to meet the country's energy needs, requiring the import of approximately 7.2 million tons per year of crude oil at an approximate cost of 1.5 billion USD (this work is based on 29.8 USD/barrel average cost).

According to the regulations established in the Kyoto Protocol, one alternative is the progressive introduction of renewable energy sources in electricity generation, which is free of greenhouse gas emissions. Despite the urgency of the protocol's implementation, two major states, the United States of America and Israel, have failed to adhere to the protocol. Both generate 29% of current emissions and consume 18.5% of the energy currently generated and available (International Energy Agency, 2020). In the specialized literature it is stated that "other countries that recognize and signed the Kyoto protocol, are China, Russia, United Kingdom, with 37.6;8.1 and 6.3 percent of total world emissions and 25.2; 11.1 and 12.4% of energy carrier consumption". (Castro, 2014, p.11)

The Cuban state has implemented regulations for the rational use of energy and water. Recently, an investment project has been presented for the use of renewable energy sources in electricity generation (1 650 MW), which includes solar energy (photovoltaic), wind energy (wind turbines) and the use of biomass. In the project, a total of 875 MW correspond to 25 Biomass Power Plant (BPP) installations, which require high volumes of water for their condensation system. This investment will reduce the dependence on fossil fuels in the national energy matrix by 24%, which will, in turn, reduce emissions by nearly 5.5 million tons of CO2. This translates into environmental protection savings of nearly 163.2 million USD.

Although the volume of CO2 that will no longer be emitted as a result of the investment represents only 0.00021% of world emissions, this outcome is consistent with the Marxist principle that states that *"any modest contribution that has an impact in favor of society, based on the rational use of science, constitutes a pillar for great actions".* (Castro, 1999, p.12)

It was recently confirmed that in the past five years the estimated water deficit has grown by 12 percent. According to the hydrological bulletin 03-2020 (Cuba. *Instituto Nacional de Recursos Hidráulicos*, 2020), a total of 37 dams were declared to be in a critical state. Of the planned BPPs, a total of 17 are located in areas of this type. This situation reinforces the compliance with the law 124/2017 on in-land waters, which lays down in article 72 the refusal of the use of reservoirs whose elevations are in critical condition.

According to Deng, et al. (2019), at present, for areas where access to water is restrained, the use of dry condensation (ACC) is an alternative that is gradually finding supporters. This technology is practically unknown in Latin America; at the same time, its use generates reductions in useful power and performance, causing increases in the initial investment and emissions to the environment and the levelized cost of energy.

According to Jin, et al. (2018), given the dilemma of water deficit and the potential use of biomass as an energy source, the use of ACC can be a tentative solution; it has been successfully tested in similar scenarios.

In view of the details that lead to the use of ACCs, it is possible to state that the objective of this work is to define the social impact associated with the technical-economic effects of the use of ACC condensing technology in the planned BPPs.

DISCUSSION

The use of biomass as a source of energy has been known since prehistoric times, as it was used by primitive man. Without receiving a rigorous approach as to its conceptualization, the literature states that "Biomass is considered to be all waste and elements coming from the flora, examples of biomass are firewood, bagasse, agricultural crop waste". (Vizcón, 2019, p.16)

Our country's own agricultural infrastructure makes it an ideal producer of biomass, and its potential can be used in the generation of energy. This is the reason why a total of 25 BPPs projects are under way. They will use biomass for the generation of 850 MW of active power, which is equivalent to 0.98 million tons of oil per year, with an approximate cost of 205 million USD. This project also generates a total of 1,500 employment opportunities in disadvantaged rural areas.

However, the spaces provided for the BPP project face an aggravating element: the water consumption associated with it, which takes average values close to 160 m3/h of water per hour of service. Law 124/2017 establishes that the average human consumption requires a minimum of 0.15 m3/day. This shows that, the water required by the 25 BPPs for one hour of operation is enough to supply the daily needs of a population of 24 800 inhabitants.

Cuba is not exempt from the global water crisis. Recently, 37 critical zones (with an estimated population of approximately 850,000 inhabitants) were identified. In response to this problem, social awareness-raising actions are being carried out by means of the national media, as well as prophylactic actions for the conservation of existing sources that do not present marked deficiencies.

Of the 37 areas that were identified as critical, a total of 19 had been remedied by the end of February 2020 through a costly investment of reverse osmosis systems, with the installation of seawater purification plants. This emergency solution required financing amounting to 72.2 million USD, resulting in a daily consumption of about 310 MWh (approximately the daily consumption of the municipality of Colón, Matanzas province).

Of the areas identified as critical, two of them are located in the province of Matanzas, in the municipalities of Los Arabos and Calimete, with a total of 65,000 affected inhabitants. Coincidentally, two of the planned BPPs are located in these areas. This leads to a problem that science must face: the dilemma of the need for energy independence and the mitigation of the effects of fossil fuels on environmental; an additional challenge is that the water required for this process is not available. According to international practices in countries with similar water situations (including Saudi Arabia, Turkey, South Africa, Russia, etc.), as explained by Mortensen (2020), this problem is partially solved with the use of ACC technology.

BPPs using ACC as a condensing system dispense with water consumption for such purposes, as air is used as the cooling agent. However, its low thermal capacity becomes a serious drawback, which is why ACC has achieved limited used in power plants due to considerable trade-offs in terms of cost and performance. According to Kong, et al. (2018), ACCs require higher capital investment than wet condensers because they incorporate larger heat exchangers with huge fin areas and require additional support structures.

Department of Energy's (2020), puts forward that the installation and operating costs of ACC systems are currently 2.5 to 5 times higher than their wet equivalent. According to Li, et al. (2018), typical levelized cost of energy (average cost of energy production) for plants with ACC range from 40 to 80 USD/MWh, being approximately 15% higher than the costs obtained with the use of a water-cooled technology.

A high ambient temperature causes an increase in the output pressure of the turbine installation coupled to the ACC, thus penalizing the useful power output of the plant. To the detriment of this, the time of higher temperatures coincides with the highest electricity demand.

Another drawback of the planned project is the fixed location of the BPPs; for economic reasons they should be as close as possible to the associated Sugar Agro-industrial Complex (SAC), since the manufacturing process of the latter will be the supplier of the biomass required for the operation of the BPP, coinciding in many cases with areas with critical or unfavorable water availability. This is the case of ***Jesús Rabí*** and ***Mario Muñoz*** SACs in the province of Matanzas.

Faced with the dilemma of the water deficit and the impossibility of putting the planned BPPs into service, the country's top management assigned the task to ***Marta Abreu*** Central University of Las Villas (UCLV). The research mission in question will be that of discerning the most feasible solution from the technical-economic and social point of view without affecting any of the actuators involved.

A study of the initial project developed by Camaraza Medina (2019), was presented to different government's management institutions, including the National Institute of Hydraulic Resources (INRH), the Ministry of Energy and Mines (MINEM), the AZCUBA group and the Sugar Investment Contracting Entity (ECIAZ), all under the observance and guidance of the Ministry of Science, Technology and Environment (CITMA), allowed reaching the consensus that a total of seven BPPs do not have the limitation of water usage, thus requiring the study to focus on the remaining 18 plants. The characterization of the latter indicates that the effective available power totals the 600 MW. A recent report of the Ministry of Energy and Mines of Cuba (2019), states that the supply capacity of these 18 BPPs amounts to 11460 MWh per day, which is approximately the daily energy needs of the provinces of Matanzas, Cienfuegos and Villa Clara.

Camaraza Medina (2019), puts forward that the entry into operation of these 18 BPPs that present difficulties of access to water will make it possible to cover through clean energy sources the energy needs (considering an average consumption of 250 kWh per customer, according to the recommendations of the National Office for the Rational Use of Energy) of a population of approximately 1.8 million people (15.1% of the country's total), eliminating the use of 0.55 million tons of oil (7.6% of current consumption) and eliminating the emission of 1.6 million tons of CO_2 into the environment (1.2% of the current total).

The above shows that the application of this technology would be an appropriate technical decision that would be of great benefit to society; nonetheless, this project is still challenged by an important drawback. The water consumption of these BPPs would put at risk the minimum established consumption rate of the liquid for 483840 people, and not only as a basic service, but also in the complementary services required in the region itself, namely water for agriculture, industry and others.

According to Liang, et al. (2019), given that it is practically impossible to use water in condensing systems in hydrologically depressed areas, a technical-economic assessment of the most feasible alternative is made, and this element becomes a turning point for the use ACC as wet condensation is discarded.

Table 1 lists the 18 BPPs with cooling water supply deficiencies and their respective locations.

Table 1. Planned BPPs in the project that lack cooling water.

BPP	Municipality	Province	Installed Power(MW)	#of People assisted
Jesús Rabí	Calimete	Matanzas	20	23400
Mario Muñoz	Los Arabos	Matanzas	50	41600
Quintín Banderas	Corralillo	Villa Clara	20	24200
George Washington	Santo Domingo	Villa Clara	20	24400
Héctor Rodríguez	Sagua la Grande	Villa Clara	20	24700
Ciro Redondo	Ciro Redondo	Ciego de Ávila	50	44200
Ecuador	Baraguá	Ciego de Ávila	50	44700
Brasil	Esmeralda	Camagüey	20	25200
Panamá	Vertientes	Camagüey	20	25400
Batalla de Guásimas	Vertientes	Camagüey	50	45800
Colombia	Colombia	Tunas	20	16500
Antonio Guiteras	Puerto Padre	Tunas	50	46400
Cristino Naranjo	Cacocum	Holguín	20	25900
Urbano Noris	Urbano Noris	Holguín	20	26000
Julio A Mella	Julio A Mella	Santiago	50	47300
Enidio Días	Campechuela	Granma	50	47500
Antonio Sánchez	Aguada	Cienfuegos	20	17100
5 de Septiembre	Rodas	Cienfuegos	50	43000

As shown above, an ACC is a condenser that does not require cooling water to operate. However, Camaraza Medina (2017), showed that this advantage over its wet equivalent has a major drawback—air has a lower thermal capacity than water (almost 1 500 times lower), so more air than water is required to achieve equal heat exchange rates, which is inevitably accompanied by parasitic energy needs in auxiliary systems.

According to Ataei-Dadavi, et al. (2019), an ACC is an equipment on which the ambient temperature and the incident wind speed exert a marked influence, this coupled with the reduction of the thermal capacity, makes the outlet pressure in a turbine coupled to an ACC higher than that of its wet equivalent, which results in a reduction of power demand.

A review of specialized papers on the field reveals that this power reduction ranges from 2 to 8% of the total power delivered, so that in one day of operation approximately 650 MWh/day are lost in the 18 BPPs that require the use ACC technology. This amount of energy would be sufficient to meet the energy demands of the city of Cienfuegos.

Although currently the ACC geometry has been optimized to minimize the effect of external agents on performance, according to the reports of Huang, et al (2018);and Qu, et al. (2018), when making a comparison with wet capacitors it can be seen that the ACC still performs at lower levels of effectiveness.

At present, ACC technology is mostly marketed, controlled and produced by two large international monopolies: ***SPX Cooler*** and ***Gea Power***, both in North American. Recently, the Chinese company Holtec International has specialized in this type of equipment and has succeeded in displacing its North American competitors in the production of medium power BPPs (P<100 MW).

The delivery power of all the planned CEBs are basically grouped into two power ranges: 20 and 50 MW. ***China Holtec International*** is currently the world leader in the production and commercialization of plants that produce less than 100 MW. Because of the excellent political and commercial relations existing between the People's Republic of China and Cuba, all commercialization of this equipment is contracted with this Chinese consortium.

Once the details of the basic engineering are established, the minimum elements are available to request information from the supplier on the required equipment and its acquisition costs (CIF). At present, due to Cuba's close commercial ties with China, imports from the Asian giant have interest and cost update rates of 5.5% and 10%, respectively. Imports from other European countries (France and Holland) receive interest and cost discount rates of 7.5% and 12% respectively.

A major drawback of the use of ACC technology is that there are no design or selection standards available, and the manufacturers do not usually publish technical information about their products, making it necessary to contact the suppliers directly for the initial analysis—a study that involves outside contractors at an additional cost. In some cases, it is possible to refer to similar experiences of facilities that operate under similar climatic conditions. This makes it possible to purchase an equivalent piece of equipment for the required conditions.

The collaboration between the authors and foreign specialists in the field, facilitated the elaboration of an analysis methodology. This was sent to ***Holtec International*** for review with the help of one of the collaborators, and the method developed received positive criticism. Camaraza Medina, et al. (2019); and Medina, et al. (2018) summarize it.

The aforementioned collaboration allowed establishing communication between the author and the commercial department of HOLTEC INTERNATIONAL, obtaining through this way the acquisition and similar costs for the required ACC, where the CIF cost (product deposited in the commercial port of destination, Havana) amounts to 4.85 million USD per unit (32% more expensive than its wet equivalent) while, the complete equipment of the BPP computes the 55.7 million. Therefore, the ACC equipment required for the 18 BPPs has a total cost of US$87.3 million (the wet technology would have cost US$59.4 million), while the total investment for the BPPs amounts to US$1,002.6 million. The acquisition of the ACC equipment at SPX from a third party (due to the restrictions of the economic blockade) amounts to USD 5.6 million (15% more expensive than the actual retail price), according to a consultation made to ENERGOIMPORT, the Cuban entity in charge of contracting and acquiring equipment for power generation.

A technical-economic study of wet and dry technology was executed by Camaraza Medina (2019), in which the intervals of the opportunity analysis between both technologies was analyzed. Without providing the technicality required by these studies, the present paper provides the main results and their impact on the economic and social environment for a BPP; the results obtained are valid for the remaining 17 facilities.

An average BPP of 20 and 50 MW of power works about 3,810 equivalent hours per year, a value that is determined based on the approximate duration of the sugar cane harvest, for it is the main supplier of biomass for the operation of the BPP. According to the reports of the Ministry of Energy and Mines of Cuba (2019), the real value of the load factor for these facilities was established and set at an average value of 0.72.

The wet technology for the 18 biomass BPPs has an initial cost of USD 59.4 million. With its use, it is possible to generate a volume of energy equal to 2,217.4GWh in the period of operations, which will satisfy the energy requirements of approximately 1.2 million people and other supplementary services linked to these people including, but not limited to, industry, agriculture, sports and recreation, public health and education. This volume of energy generated by biomass (a primary energy source) saves about 0.53 million tons of oil from fossil fuels and eliminates the emission of 1,560 thousand tons of greenhouse gases into the environment. This translates into annual savings of US$119.7 million for the country in terms of eliminating imports and investments not made to protect the atmosphere.

A wet condenser has an estimated service life of 25 years, therefore, the case study carried out is based on a 20-year expectancy, with five years remaining in which the installation has not yet been fully depreciated. The analysis carried out on the pre-set scenario indicates an interest rate of return of 42.6%, a net present value with a discount rate of 15% amounting to USD 5.48 billion, while the investment recovery period covers a total of 7.2 years and the levelized cost of energy (a criterion that takes into account the average cost of generating each kWh) is equal to 0.0685/kWh USD, 45% lower than the levelized cost obtained with the use of fossil fuels.

However, the use of wet condensation puts at risk the access to drinking water of a total of 483 840 inhabitants, as well as all the basic services that involve these, also violating the stipulations of the decree law 124/2017.

The dry ACC technology for the 18 biomass BPPs has an initial cost of 87.3 million USD. With its use it is possible to deliver a volume of energy equal to 2 148.8GWh, or 68.4 GWh less than that obtained with wet systems. This volume of energy satisfies the energy requirements of approximately 1.16 million people and their supplementary services including, but not limited to, industry, agriculture, sports and recreation, public health and education. The energy generated with the use of biomass in this case is equivalent to fossil fuel savings amounting to 0.5 million tons of oil, and 1,460 thousand tons of greenhouse gases are no longer emitted into the environment. This translates into annual savings of US$112.8 million for the country in terms of eliminating imports and investments not made to protect the atmosphere.

The average ACC has a service life of 30 years. In the previous variant, the expectancy analysis was based on a 20-year lifespan, therefore, with the objective of establishing comparisons, this will be the expected service life for the CCA evaluation. The analysis carried out on the pre-set scenario indicates an interest rate of return of 31.6%, a net present value with a discount rate of 15% amounting to 3.12 billion USD, while the investment recovery period covers a total of 8.7 years, and the levelized cost of energy is equal to 0.079 USD/kWh, which is approximately 36% lower than the levelized cost obtained with the use of fossil fuels. This technology does not use water, so it does not affect in any possible way the water supply sources, therefore, it does not constitute a danger for the population that live on the surroundings of the operation area.

Therefore, although the use of the ACC as a condenser in the BPPs shows inferior efficiency rates and technical-economic indicators, they are an alternative solution to the hydrological threat that constitutes the use of its water-cooled equivalent. These elements were presented by the author of this work to competent authorities in the governing body of the country, receiving the approval and acceptance of the parties involved for this purpose, being widely discussed and disseminated.

The ACC uses air as cooling agent, which is delivered by axial flow fans. The large air flow rates required make the dimensions of the fans take considerable proportions (approximately 10 meters in diameter). According to Camaraza Medina, et al. (2019), this type of flow machines creates associated to the air movement a phenomenon known in the engineering technique as air ablation, which consists in an increase of the sound emission levels due to the forced circulation of air flow in the fan blades.

In an ACC, the noise level is an important element, being considered in the specialized literature as an element of local noise pollution, and therefore, it exerts an appreciable influence on the surrounding environment. There are reports from environmentalist institutions that state that in areas where ACCs are used, there is a reduction in the populations of seasonal and migratory birds, as well as other elements of the fauna with a habitat accustomed to the area. Following the Department of Energy's (2020), it would be logical that the level of noise emitted is also harmful and in some cases intolerant for humans who reside permanently in the vicinity of the facility, as well as for those who work there or stay part of the time.

The Cuban Reg. NC 199-1998 ***Noise Emissions and Permissible Levels of Noise Disturbances*** establishes the noise intervals that can be harmful to human health or that can trigger occupational hearing diseases (reduction of hearing capacity by continuous exposure to high intensity sound emitting media); however, it does not include the effect of ACC technology to date in Cuba, so this regulation is disregarded to perform the present study.

O'Neill, et al. (2019) carried out an auditory analysis, which was developed at Stokes Fluid Mechanics, belonging to Oxford University. In this study it is established that the noise level generated by the work of axial fans is solely dependent on the nominal rotational frequency (RF) of these. When this speed is lower than 0.5FR no ecological or auditory damage is generated, when this speed is in the range of 0.5 to 0.8 of the total nominal RF of the fan, the noise level is perceptible and can generate damage to the surrounding ecosystem and to the human ear. Thus, when it exceeds the fraction 0.8 of the total RF then it is harmful to the surrounding environment and therefore to human health. This study complies with the Chinese resolution 10218/2019, which prohibits the use of ACC in projects where the fan speeds has to be set higher than 80% of the nominal speed of the equipment.

If the fan speed is pre-set, the air flow rate to be delivered is limited and, therefore, the heat transfer process and the useful power of the plant is reduced. The analysis of the case studies presented in the doctoral thesis prepared by the author of this paper shows that the peripheral fan speed required by the ACCs to be installed in future biomass BPPs never exceeds 48% (0.48), so that according to international regulations in force, it is classified in the range of permissible values, so it does not cause damage to the surrounding ecosystem or to human health.

The Chinese Reg. 10218/2019 establishes regulatory taxes for amortization of environmental impact, which will be between 1.5 to 3% of the system use value. In the case of the study presented, tax payments amount to 1.9 million USD for environmental impact and sound mitigation of ACC systems, thus benefiting a total of 105 280 people that lives in surrounding areas of the BPPs. The same applies to the endemic flora and fauna of the area, and to the one that temporarily stays in it.

Facing the unknown is very commonly a cause of resistance to change as stated in psychology and sociology theses. In view of this, the author interviewed 376 residents of the surrounding zones of eight BPPs (those located in Matanzas, Villa Clara and Cienfuegos). In addition, a total of 12 professors from the universities of these three provinces, three senior managers of AZCUBA and a total of 20 students in the fourth year of the regular degree program of mechanical engineering at UMCC and UCLV were interviewed. The population sample studied in the surrounding areas of the BPPs are directly linked to the sugar manufacturing process in the CAI. All the professors are senior academics on energy issues and Full Professors, and hold the scientific degree of Doctor in Technical Sciences.

The survey consisted of seven questions, which are as follows:

1- Have you heard about the future installation of biomass plants?

Yes ___ No ___ No comments ___

2- Would you be interested in knowing the principle of operation of a BPP with an ACC, and what benefits it would bring about for you, your family and the country in general?

Yes ___ No ___ No comments ___

3- Do you consider this investment necessary for the common benefit of all Cubans?

Yes ___ No ___ No comments ___

4- Would you like to work in the future bioelectric plant?

Yes ___ No ___ No comments ___

5- Would you be willing to cooperate in the development and installation of bioelectric plants?

Yes ___ No ___ No comments ___

6- Do you consider it an appropriate decision to change from condensing technology to a more expensive and inefficient one in order to protect the access to water of about half a million people?

Yes ___ No ___ No comments ___

7- Do you feel proud and privileged that your area of residence has been chosen for the installation of a bioelectric plant?

Yes ___ No ___ No comments ___

The percentage results of coincidence of the population samples in the survey are shown in Table 2.

Table 2. Percentage computation of the answers received from the interviewees.

Question	CAI Residents			Professors			Managers			Students		
	Yes	No	(Nc)	Yes	No	(Nc)	Yes	No	(Nc)	Yes	No	(Nc)
1	56,4	31,9	11,7	91,7	8,3	0,0	100,0	0,0	0,0	10,0	75,0	15,0
2	98,4	1,6	0,0	100,0	0,0	0,0	100,0	0,0	0,0	100,0	0,0	0,0
3	97,1	0,5	2,4	100,0	0,0	0,0	100,0	0,0	0,0	95,0	0,0	5,0
4	73,9	11,7	14,4	33,3	41,7	25,0	0,0	33,3	66,7	30,0	45,0	25,0
5	87,0	2,9	10,1	83,3	0,0	16,7	100,0	0,0	0,0	80,0	5,0	15,0
6	79,3	19,7	1,0	100,0	0,0	0,0	100,0	0,0	0,0	80,0	5,0	15,0
7	94,1	4,0	1,9	16,7	8,3	75,0	0,0	0,0	100,0	10,0	0,0	90,0

(Nc) No comments

As shown in Table 2, an important group of students and residents are unaware of the future installation and start-up of the BPP, and therefore the informative work to this effect is considered insufficient, as well as the social communication and awareness of the need for their introduction. However, it is interesting that the overwhelming majority agrees with the criterion that they would like to know the principle of operation of a bioelectric plant with an ACC and the benefits it would bring about for society in general, and they also recognize the country's need for energy self-sustainability.

A considerable number of residents assert that they would like to work in the future BPP, but this is not the case in the other three groups. In the case of residents, it can be interpreted as a sense of regional identity. For the other groups, this line of work does not coincide with their research-labor and personal interests, however there is uniformity of criteria in the four groups on the willingness to cooperate if necessary in the construction and start-up actions of the BPP.

An important element of the survey lies in the fact that the absolute majority agrees with the criterion of changing from the condensation technology to another that is more expensive and inefficient but that protects the access to water of about half a million people.

Finally, the sense of belonging of the residents in the area comes to the surface when most of them reach agreement on feeling proud and privileged that the installation of a BPP will take place in their area of residence, which indicates a high rate of acceptance and social impact of the technology, thus fully responding to the objective of this research.

CONCLUSIONS

The research carried out to define the social impact associated with the technical-economic effect of the use of ACC condensing technology in the planned BPPs allows affirming the following:

The Cuban society has an urging need for energy self-sustainability, which can be partially achieved through the use of alternative sources of energy, among which biomass is a fundamental referent.

The start-up of 25 BPPs will guarantee the generation of 850 MW of useful power through the use of primary sources of energy such as biomass; this is equal to annual diesel fuel savings of 0.98 million tons, with an approximate cost of 205 million USD.

The project also creates a total of 1500 employment opportunities in disadvantaged rural areas and guarantees the energy sustainability required by 1.2 million citizens.

The replacement of water-cooled systems by ACCs ensures the hydrogeological sustainability of approximately half a million people, as well as the basic services associated with them.

The project is feasible from the economic point of view, for the initial investment is recovered in the first 8.7 years of the expected 20 years of operation, while accumulating an interest rate of return of 31.6%. The present net value, with a discount rate of 15%, amounts to 3.12 billion USD, as well as the levelized cost of energy is 36% cheaper than that generated with fossil fuels.

The effects of noise pollution, according to current international protocols, are not appreciable on the population groups settled in the vicinity of the BPPs, nor on the region's endemic flora and fauna.

The implementation and development of the project has the endorsement and support of the residents of the BPP's neighboring areas, as evidenced by the survey given to them for that purpose.

More than 94% of the residents in the surrounding areas of the 8 BPPs assert that they would like to have a minimum of technical information about the project, and say that they feel "proud" to have a biomass plant in the vicinity of the CAI in which they work.

The point expounded above is an indicator element that corroborates the fulfillment of the objective of this work, considering the positive social impact expressed by the sense of identity and acceptance of the project of the area's residents.

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