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Use of Air Cooled Condenser in Biomass Power Plants: A Case Study in Cuba

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ABSTRACT

A new project of investment developed in Cuba has 25 Biomass Power Plants (BPP) with potencies of 20 and 50 MW. The confirmed lack of water to be used in the condensers is an impediment for the project. The use of dry condensers may be a possible solution, however, the cost of the initial project and the reduction in useful power associated with its use is a limitation to consider. In order to define the feasibility of the use of ACC in these projects, a case study is carried out in which several selection criteria for investment alternatives are considered, with three other types of condensation technologies being evaluated with the objective of comparing costs of investment and operation, as well as the profits generated. The analyses were carried out for a horizon of 20 years, obtaining for the ACC uses, a pay off period of 7.6 and 8.4 years, for the facilities of 20 and 50 MW respectively. With the uses of the selection criteria for investment alternatives, was obtained that for facilities of 20 and 50 MW respectively, the Return Interest Rate (IRR) is 18.2 and 23,8 percent, the Net Present Value (NPV) (with 15% update rate) is equal to 1126.9 and 3024.0 MUSD, the cost of the life cycle is 10682.4 and 24406.1 MUSD, while, the levelized cost of electricity production is 0.062 and 0.071 USD/kWh, with a cost-benefit ratio of 0.1 and 0.13. The results obtained confirm the feasibility of using ACC systems.

1. INTRODUCTION

At the present time, the deficit tried of water and the urgency of the use of the alternative sources of energy, have generated important efforts channeled to solve the existing deficiencies in the used technologies. The use of biomass as an energy source for generating electric power has been one of the most widely accepted alternatives in regions with agricultural and forestry potential [1].

As part of the strategy drawn up by the Cuban state in terms of energy and hydrological sustainability, in the five-year period 2020-2025, an appreciable group of investments are executed in the country, with the purpose of increasing the presence of renewable sources in the national matrix of energy. These include a total of 25 Biomass Power Plants (BPP) that will be associated with the same amount of Sugar Power Plants (SPP) currently in operation, the latter becoming a source of fuel biomass supply (bagasse and cane agricultural waste), being 20 and 50 MW base powers used [2].

However, the current location of the SPP is an aggravating element for the start-up of the BPP, since there are no nearby water sources that are capable of covering the flow rates required by the condensation systems, (approximately 160 m^3/h). In the dry season (2019), 37 water basins in Cuba were declared as critical state, reducing the capacity of delivery to the minimal. This situation evidenced that Cuba is not exempt from the global water crisis [3].

According to the report [4], at the end of 2017, 32% of water withdrawals for industrial purposes were destined for wet condensation systems. In order to reduce the consumption of water in power plants, the use of the so-called dry condensation is gaining ground, because as its name indicates it dispenses with the consumption of water for its operation, achieving savings rates close to 98% with regarding wet condensers [4, 5].

Dry cooling systems have the potential to almost eliminate the use of water in the BPP. Among the dry condensers, one of the most widespread is the so-called air-cooled condenser (ACC), being already known and used in the BPP located in countries such as the United States, Turkey, China, Malaysia, India, South Africa, Germany and Spain, although it has not yet been widely disseminated, since it barely covers 1% of current BPP, as proposed by Huang et al. [6, 7].

However, the ACC have achieved limited penetration in power plants, due to considerable compensation in terms of cost and performance, as they require a capital investment substantially greater than wet condensers because they incorporate larger heat exchangers, with huge fin areas and require additional support structures [8].

In general, the installation and operation costs of the ACC systems are currently 2.5 to 5 times higher than their wet equivalent, while the typical costs of level 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 wet cooling technology [9, 10].

In the existing and available literature, similar experiences are not reported in areas with operational and climatological similarities to national ones, so issuing a judgment on the feasibility of the possible use of ACC would require a case study in which they were simultaneously considered several condensation technologies, in order to establish initial investment cost and life cycle levels. To demonstrate the viability of the use of ACC in the projects of BPP planned in the country is the objective of the present paper.

2. MATERIAL AND METHODS

2.1 Initial considerations for the evaluation of the planned biomass BPP

According to the Sugar Investment Contractor Company [2], the project to be executed in the country consists of 25 BPP, which are detailed in Table 1 [11].

Table 1. Summary of the biomass BPP project

SPP	Location	Province	(1)	(2)	(3)	(4)
30 de Noviembre	San Cristóbal	Artemisa	50	19	1965	1079
Héctor Molina	San Nicolás	Mayabeque	50	32	1629	876
Jesús Rabí	Calimete	Matanzas	20	87	2950	1705
Mario Muñoz	Los Arabos	Matanzas	50			
Quintín Banderas	Corralillo	Villa Clara	20			
George Washington	Santo Domingo	Villa Clara	20	190	338	1346
Héctor Rodríguez	Sagua la Grande	Villa Clara	20			
Uruguay	Jatibonico	Sancti Spíritus	50	108	158	788
Ciro Redondo	Ciro Redondo	Ciego de Ávila	50	152	160	740
Ecuador	Baraguá	Ciego de Ávila	50			
Brasil	Esmeralda	Camagüey	35			
Panamá	Vertientes	Camagüey	20	136	2217	1096
Batalla de Guásimas	Vertientes	Camagüey	50			
Colombia	Colombia	Tunas	20			
Majibacoa	Majibacoa	Tunas	35	163	171	722
Antonio Guiteras	Puerto Padre	Tunas	50			
Cristino Naranjo	Cacocum	Holguín	35			
Urbano Noris	Urbano Noris	Holguín	50	78	2569	1479
Fernando de Dios	Báguanos	Holguín	20			
Julio A Mella	Julio A Mella	Santiago	20	22	1197	1189
Grito de Yara	Rio Cauto	Granma	20	41	153	877
Enidio Días	Campechuela	Granma	20			
Ciudad Caracas	Lajas	Cienfuegos	20			
Antonio Sánchez	Aguada	Cienfuegos	20	125	1832	872
5 de Septiembre	Rodas	Cienfuegos	50			

Notes: **(1)** Power generation of the planned BPP, in MW. **(2)** Energy generated with the use of biomass (year 2019), in GWh. **(3)** Total energy generated (year 2019), in GWh. **(4)** Total energy consumption (year 2019), in GWh.

The period of operation of the BPP is of 240 days/year. The first 150 days, the energetic source is covered with the bagasse produced by the SPP, while, in the remaining time cane agricultural waste (CAW) and forest biomass elements are used. Most of the range of operations is in the drought period, (November-March) reason why the hydrological variables used are referred to these adverse conditions [3].

The possibility of simultaneous work of the BPP and the SPP associated with it, or the shutdown of the latter, as well as the surrounding ambient temperature, generate four basic variants of work, which are:

Variant 1: BPP in operation and SPP out of service, typical day warm seasons.

Variant 2: BPP and SPP in operation, typical day warm seasons.

Variant 3: BPP in operation and SPP out of service, typical day cold seasons.

Variant 4: BPP and SPP in operation, typical day cold seasons.

The simulation of these four operating state variants for each individual preset power of the planned BPP (20 and 50 MW), is carried out by simulating the cycle in the iterative TkSolver manager.

Table 2. Hydrological description of the investment project

SPP	Water basin	Province	(1)	(2)	(3)	(4)
30 de Noviembre	HS-2 N	Artemisa	I	+0.8	+3.1	0.66
Héctor Molina	HS-5	Mayabeque	II	-3.6	-7.3	0.87
Jesús Rabí	M-V	Matanzas	III	-17.2	-32.1	1.41
Mario Muñoz	M-III-Sur	Matanzas	III	-16.4	-1.6	1.03
Quintín Banderas	VC-III-1d	Villa Clara	III	-18.4	-44.1	1.55
George Washington	VC-III-1h	Villa Clara	III	-16.9	+0.2	1.21
Héctor Rodríguez	VC-III-1i	Villa Clara	III	-20.4	-21.3	1.46
Uruguay	SS-18	S. Spíritus	II	-14.8	-25.7	1.16
Ciro Redondo	CA-1-11	Ciego de Ávila	III	-16.2	-0.8	1.29
Ecuador	CA-1-9	Ciego de Ávila	III	-19.3	-12.6	1.39
Brasil	C-I-11	Camagüey	III	-15.6	-44.9	1.56
Panamá	C-I-4	Camagüey	III	-15.4	-9.7	1.24
Batalla de Guásimas	C-I-8	Camagüey	III	-16.1	-9.2	1.26
Colombia	C-I-14-1	Tunas	III	-15.9	-11.8	1.27
Majibacoa	LT-II-2	Tunas	II	-14.9	-60.8	1.36
Antonio Guiteras	LT-II-1	Tunas	III	-15.1	-24.2	1.46
Cristino Naranjo	HG-II-11	Holguín	III	-15.8	-32.8	1.48
Urbano Noris	HG-II-10	Holguín	III	-16.3	-72.8	1.74
Fernando de Dios	HG-II-11	Holguín	II	-13.1	-48.8	1.31
Julio A Mella	SC-II-1	Santiago	III	-22.4	-70.5	1.89
Grito de Yara	G-II-2A	Granma	II	-13.6	-60.1	1.43
Enidio Días	G-II-2B	Granma	III	-17.5	-7.4	1.28
Ciudad Caracas	CF-II	Cienfuegos	II	-13.9	-39.3	1.25
Antonio Sánchez	CF-I	Cienfuegos	III	-17.8	-44.5	1.62
5 de Septiembre	CF-III	Cienfuegos	II	-13.1	-35.1	1.19

Note: **(1)** Classification of the BPP according to water availability. **(2)** Decrease of the dynamic surface level of water basin with respect to the historical average (March/2019), in %. **(3)** Decrease of the rains in relation with the historical average (March/2019), in %. **(4)** Average cost of mitigation required for water use, in USD/m^3 [12].

According to the institutional reports [3], in the dry season period, water sources are classified according to their levels with respect to sea level, having three fundamental classifications, which are:

1- Normal aquifer area.

2- Unfavorable aquifer exploitation area.

3- Critical aquifer exploitation area.

In the first, it is possible to use water rationally. In the second, the use of water is possible only if it complies with expenditure values established by the regulations in force, while in the last zone the continuous extraction of water is prohibited. This point of view, allows grouping conveniently the planned BPP into three groups, based on water availability. This classification is:

Group I- Abundant water availability for condensation

Group II- Acceptable water availability

Group III- Low water availability

Table 2 provides the hydrological description of the place where the planned BPP will be sited. In the 25 BPP, one is located in a water basin with sufficient water for condensation, seven BPP in basins with acceptable availability of water for condensation and 17 BPP in basins with insufficient water volume for condensation

2.2 Comparative criteria of the selection matrix for the initial investment

One method that allows establishing an initial comparison of costs and operating conditions between various condensation technologies is the well-known selection criteria for initial investment developed by Owen and Kröger [5], which is accepted and partially used by HOLTEC, GEA Power, SPX and other firms specialized in the primary selection of condensation technologies [13]. This method examines ten aspects through an expression developed for each case, which generates a punctual value. The sum of these values provides the matrix selection value of the option studied. The option that accumulates the highest score will be that best suits the case studied [14].

The evaluated elements and their corresponding score are:

1- Required cooling water flow (p1). . . . . 15 points
2- Distance to the source of water supply (p2). . . . 15 points
3- Space requirement (p3). . . . . 10 points
4- Period of life of the technology (p4). . . . . 5 points
5- Net power delivered (p5). . . . . 15 points
6- Flexibility of the operation (p6). . . . . 5 points
7- Cost of investment (p7). 15 points
8- Facilities and maintenance costs (p8). . . . . 5 points
9- Flexibility of operation and response to extreme conditions (p9) . . . . 5 points
10- Level of impact on the environment (p10). . . . 10 points

After the evaluation has been carried out, the scores obtained indicate which of the technologies evaluated is the most suitable for the required operation. Generally, the two variants with the highest score index are selected and a comparative case study is carried out between the two, so if there is any type of economic or environmental restriction, then make use of the one with the best opportunity cost indices [14].

The corresponding score for each element is determined separately through the help of linear relationships, as shown below:

$$p1 = 15 - 0.05 \cdot m_{agua} \tag{1}$$

$$p2 = 15 - 0.0038 \cdot L \tag{2}$$

$$p3 = 10 - 0.006 \cdot A \tag{3}$$

$$p4 = 0.1667 \cdot A_{VU} \tag{4}$$

$$p5 = 25 \cdot P_{util} - 10 \tag{5}$$

$$p6 = -0.25 \cdot P_{Back} + 6.25 \tag{6}$$

$$p7 = -0.1 \cdot M_{USD} + 16 \tag{7}$$

$$p8 = -1.66 \cdot M_{Cost} + 6.66 \tag{8}$$

$$p9 = 5 - 0.1 \cdot P_{back} - 0.0125 \cdot V_{SC} - 0.033 \cdot V_E - 0.03 \cdot T_{TBS} \tag{9}$$

$$p10 = 10 - 0.0025 \cdot T_{CO2} \tag{10}$$

Being: m_{agua} is the required cooling water flow rate, in (m^3/h); L is the distance to the source of supply to the installation, in m; A is the area occupied by the condensation system, in m^2, A_{VU} is the period of useful life of the equipment given by the manufacturer, in years; P_{util} is the ratio of the useful power and the real power of the system; P_{Back} is the steam outlet pressure of the turbine, in kPa; MUSD is the unit cost for each MW of installed power, in MUSD; M_{cost} is the value of percent of the total cost assumed for maintenance cost; V_{SC} is the flow of overheated steam supplied to the turbine, in kg/s; V_E is the steam flow taken in intermediate turbine extractions, in kg/s; T_{TBS} is the ambient dry bulb temperature, in °C; T_{CO2} is the mass of CO_2 emitted by the BPP, in Gg/day.

The selection matrix is applied to four condensation technologies, two wet and two dries, in each of the four operational variants previously proposed. The technologies considered are:

Wet condensation technologies:
1- Horizontal wet condenser with one pass (HWC)
2- Wet cooling tower (WCT)

Dry condensation technologies:
1- Air cooled condenser (ACC)
2- Dry cooling tower (DCT)

Table 3 summarizes the final scores of the method for each variant and technology used. In it, it can be verified that of the dry technologies evaluated, in all cases the ACC shows a best index of selection matrix, which becomes a solid confirmation of the hypothesis proposed at the beginning of the present investigation.

Table 3. Summary of scores obtained with the application of the selection matrix method

Variant	Power (MW)	HWC	WCT	DCT	AAC
Warm day,	20	83	81.6	73.2	74.2
SPP out of service	50	78.4	76.1	69.7	70.2
Warm day,	20	85.2	83.7	74.4	75.4
SPP in service	50	81.9	80.6	72.6	74.2
Cold day,	20	86.2	84.6	76.4	77.3
SPP out of service	50	82.7	80.1	73.1	73.5
Cold day,	20	83.1	81.7	75	75.8
SPP in service	50	80.1	77.8	71.8	72.2

3. MOVEMENT OF FUNDS

3.1 Comparative criteria of the selection matrix for the initial investment

The movement of funds of an investment consists in determining in each one of the periods in which the horizon was divided, how many collections and how many payments are made. The analysis is done by balancing inputs and outputs. Without a fund movement, it is not possible to evaluate an investment, so it is necessary to carry out a preliminary market study, which allows including all the possibilities of offers. However, in this work, only one supplier is used, since due to the restrictions imposed on the Cuban state by the economic-commercial blockade, four suppliers consulted only receive a response from HOLTEC INTERNATIONAL. This work complies with the provisions of the current investment resolution in the country (Decree No. 327-2015).

Table 4. Operating costs according to the Kaplan method

Operating cost	HWC	WCT	DCT	AAC
Maintenance	(0.02 - 0.04) V_{uso}	(0.03 – 0.07) V_{uso}	(0.01 – 0.02) V_{uso}	(0.015 – 0.03) V_{uso}
Chemical water treatment	(0.009 – 0.011) V_{uso}	(0.02 – 0.042) V_{uso}	-	-
Mitigation and impact by operation on the environment	(0.01 – 0.025) V_{uso}	(0.02 – 0.032) V_{uso}	(0.037 – 0.047) V_{uso}	(0.038 – 0.048) V_{uso}
Mitigation and impact of gas emissions in the attached cycle	(0.015 – 0.025) V_{uso}	(0.018 – 0.028) V_{uso}	(0.03 – 0.035) V_{uso}	(0.03 – 0.035) V_{uso}
Costs of cooling water use	(0.028 – 1.53) (USD/m^3)	(0.028 – 1.53) (USD/m^3)	-	-

The movements of funds are carried out individually for the 20 and 50 MW BPP, using Kaplan's simplified methodology, which according to the work [15, 16], allows the approximate levels of operating costs based on the updated use value of the equipment examined. This methodology is widely accepted among specialists in the field in North America [17, 18]. The intervals recommended by Kaplan are shown in Table 4. In Table 4, V_{uso} is the use value of the equipment.

All initial equipment costs, (factory inspection, technical assistance, import duty, freight, insurance, basic engineering and inspection at final destination port), were obtained in direct communication with ENERGOIMPORT, the only authorized entity in Cuba for to import facilities destined for the energy industry. The current external financing available to this entity is of Chinese origin, with a bank interest of 5.5% and an update rate of 10%. In the fruitful consultation made [16], the useful life period for the four variants of technologies analyzed is established, being equal to the 25 years for wet technologies and 35 years for dry technologies, taking a 20-year horizon to affect the movement of funds.

3.2 Initial system balance

The average unit costs in USD/kW for various condensation technologies were obtained in the consultation made to HOLTEC, these being considered current when acquired directly from the supplier with update date 03/2019. A summary of these costs is provided in Table 5.

To update equipment costs for periods other than the preparation of this report, you can go to the Marshall & Swift Equipment Cost Index (M&S), the most accepted cost index rate among the main suppliers of condensation systems according to the paper [19]. This rate is described by:

$$V_{MS} = V_{AA} \cdot \left(I_{11} / I_{AA} \right) \quad (11)$$

where, V_{AA} is the value of available equipment cost, in MUSD; I_{11} is the Marshall index on the date it is intended to assess the cost; I_{AA} is the Marshall index of the date that the equipment cost is available.

Table 5. Cost for different condensation technologies

Condensation technology	Unit cost (USD/kW)
Wet tower	88.12
Horizontal wet condenser (one pass)	70.46
ACC (forced throw)	93.21
Dry tower	95.56

Table 6 provides the indexes (M&S) for thermal exchange equipment. Table 7 shows the steam flow to condense in each variant. In the initial basic engineering project presented by the contracting entity [2], an HWC with an outlet vapor pressure of 9 kPa was proposed as a condensation system; however, other alternatives are not contemplated in this project of condensation systems.

The heat flow to be evacuated for each operational situation is detailed in Table 8, while, in the Table 9 are given the water flow required for wet condensers in each variant analyzed. For both powers, the variant considered as critical is variant 1, as it includes the states of maximum operating requirements, and therefore, the case study will be based on its basis.

Table 6. Indexes Marshall & Swift Equipment Cost Index

Year	Index M&S	Year	Index M&S
1920	100	2005	1464.1
1930	152.1	2010	1695.1
1950	285.2	2012	1798.1
1960	382.6	2014	1906.8
1970	516.5	2016	2020.8
1980	697.2	2017	2081.6
1990	941.4	2019	2144.9
2000	1262	2020	2171.6

Table 7. Steam flow to condense in each variant, in kg/s

Variant	BPP 20 MW	BPP 50 MW
Variant 1	19.1	56.1
Variant 2	5.8	24.5
Variant 3	5.7	24.1
Variant 4	18.7	55.0

Table 8. Heat rejected in each variant, in MW

Variant	BPP 20 MW	BPP 50 MW
Variant 1	54.2	131.5
Variant 2	13.6	57.4
Variant 3	53.7	130.1
Variant 4	13.5	57.1

Table 9. Water flow required for wet condensers

Variant	BPP 20 MW		BPP 50 MW	
	HWC	WCT	HWC	WCT
Variant 1	170.6	34.0	209.2	42.7
Variant 2	124.1	24.9	172.9	34.8
Variant 3	169.7	33.8	199.2	40.6
Variant 4	130.6	26.0	182.2	36.4

3.3 Analysis of the main results of the case study

Several selection criteria are used in the evaluation of the four variants of technologies analyzed in this study, these criteria are:

1- Pay off period
2- Interest rate of return (IRR)
3- Net present value (NPV)
4- Life cycle cost

5- Level energy cost
6- Cost benefit ratio.

Due to the volume of information and variables involved, the results obtained for the BPP of 20 MW and 50 MW are summarized and presented in Tables 10 and 11. Here, load factors and losses equal to 0.72 and 0.58 are taken respectively, an average cost of energy sales of 0.127 USD/ kWh, as well as 19.1 equivalent hours of charging, as stipulated by the research [11]. The mitigation costs are equal to the sum of costs of emissions, operational pollution and cooling water consumption. Previously it was given the criteria of several authors in which they establish the levelized cost of energy for ACC between 40 to 80 USD/MW. The results obtained in this work are located in this range [20-23].

Table 10. Summary of the case study for a 20 MW BPP

Elements	HWC	WCT	ACC	DCT
FOB cost equipment (MUSD)	1350.9	1760.7	1909.4	1988.8
Initial Ticket Balance				
Active power delivered (MW)	19.6	19.4	18.5	18.3
Electrical consumption (MWh)	945.9	1037.6	1431.7	1479.2
Electrical losses (MWh)	61.3	60.6	57.8	57.2
Total energy sold (GWh)	71.3	70.2	65.2	64.1
Revenue from energy sales (MUSD)	2055.5	2022.5	1879.6	1846.5
Initial balance of outputs				
Bagasse consumption (t/h)	37.0	37.4	39.2	39.6
CO_2emissions (t/h)	11.8	12.0	12.5	12.7
Cost of power not served (MUSD)	0.0	22.0	133.1	157.3
Maintenance costs (MUSD/year)	27.0	52.8	15.3	35.8
Water chemical treatment costs (MUSD/year)	14.2	44.0	0.0	0.0
Mitigation cost (MUSD/year)	183.8	131	175.7	183
Partial operating costs (MUSD/year)	225.0	239.5	252.7	286.5
Linear depreciation (MUSD/year)	76.7	98.8	76.2	79.2
Utilities				
Utilities (MUSD/year) (with taxes paid)	1198.3	1150.1	1058.7	1010.2
Selection criteria for investment alternatives				
Pay off Period, 10% update rate. (years)	6.2	7.5	8.4	10.3
IRR (%)	28.1	20.8	18.2	15.5
NPV (15%)	2113.9	1229.8	1126.9	121.8
Life cycle cost, (MUSD)	7547.8	10426.8	10682.4	10957.8
Level energy cost, (USD/kWh)	0.057	0.065	0.071	0.073
Cost benefit relation	0.28	0.118	0.105	0.01

Note: In Table 10 and 11, are used the recommendations given by US. Department of Energy for selection of the best investment alternatives.

Table 11. Summary of the case study for a 50 MW BPP

Elements	HWC	WCT	ACC	DCT
FOB cost equipment (MUSD)	2522.9	3318.7	4255.9	4732.1
Initial Ticket Balance				
Active power delivered (MW)	48.5	47.6	46.2	45.9
Electrical consumption (MWh)	2077.2	2328.2	3115.2	3173.2
Electrical losses (MWh)	151.6	148.8	144.4	143.5
Total energy sold (GWh)	177.1	172.9	164.5	163.0
Revenue from energy sales (MUSD)	5100.4	4979.4	4737.5	4693.6
Initial balance of outputs				
Bagasse consumption (t/h)	90.9	92.6	95.4	96.0
CO_2emissions (t/h)	29.1	29.6	30.5	30.7
Cost of power not served (MUSD)	0.0	31.9	131.9	139.3
Maintenance costs (MUSD/year)	53.3	99.9	29.8	68.0
Water chemical treatment costs (MUSD/year)	28.0	76.6	0.0	0.0
Mitigation cost (MUSD/year)	323.3	240.1	370.2	380.6
Partial operating costs (MUSD/year)	404.5	448.3	532.0	574.4
Linear depreciation (MUSD/year)	142.9	177.9	160.8	170.9
Utilities				
Utilities (MUSD/year) (with taxes paid)	3114.2	2976.1	2763.7	2696.8
Selection criteria for investment alternatives				
Pay off Period, 10% update rate. (years)	4.4	5.6	7.6	9.2
IRR (%)	41.5	31.1	23.8	19.3
NPV (15%)	8034.1	5953.3	3024.0	2026.4
Life cycle cost, (MUSD)	16283.7	21327.9	24406.1	25407.3
Level energy cost, (USD/kWh)	0.05	0.055	0.062	0.065
Cost benefit relation	0.493	0.279	0.124	0.08

4. CONCLUSIONS

The analysis of the results obtained in the evaluation process of the operation of an ACC in each study variant confirms that its use is possible. In the case study, the behavior of four variants of condensation technologies in two base powers (20 and 50 MW) is examined, applying the rapid Kaplan methodology.

In both powers the most critical variant is considered to be the one with the highest volume of heat to be rejected and the highest associated cooling water consumption. Although the case study shows that wet technology has more favorable indicators, its use requires about 160 m^3/h of water, a value higher than the levels currently available.

The analyses were carried out for a horizon of 20 years, obtaining for the ACC uses, a pay off period of 7.6 and 8.4 years, for the facilities of 20 and 50 MW respectively. With the uses of the selection criteria for investment alternatives, was obtained that for facilities of 20 and 50 MW respectively, the Return Interest Rate (IRR) is 18.2 and 23,8 percent, the Net Present Value (NPV) (with 15% update rate) is equal to 1126.9 and 3024.0 MUSD, the cost of the life cycle is 10682.4 and 24406.1 MUSD, while, the levelized cost of electricity production is 0.062 and 0.071 USD/kWh, with a cost-benefit ratio of 0.1 and 0.13. The results obtained confirm the feasibility of using ACC systems

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