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EXERGETIC ANALYSIS OF A HYDRID SOLAR-BIOMASS COGENERATION POWER PLANT FOR A POULTRY INDUSTRY APPLICATION

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Abstract. *The increasing energetic demand around the world, the depletion of non-renewable energy reserves, as well as the corresponding environment impacts, boosted the search for using renewable sources. However, it is still necessary to overcome the drawbacks regarding the intermittence and high costs of renewable technologies. In this context, a hybrid system can integrate different types of renewable sources in order to mitigate each other technological disadvantages. This work aims to evaluate, on the exergetic perspective, the integration of a Fresnel solar field with a biomass cogeneration power plant considering the feedwater heating and the direct steam generation (DSG) schemes. The cogeneration power plant was designed to supply 12 MWe and 16 t/h of saturated steam at 10 bar for a poultry industry in for two different locations in Brazil (Palotina-PR and Barreiras-BA). Superheated steam feeds a condensing-extraction steam turbine (CEST). A single extraction supplies steam for the process and the deaeration of the working fluid. The hybridized plants save biomass on sunny hours so that, in the design condition, the fuel consumption is reduced by up to 53 % and 8.5 % for the DSG and feedwater heating schemes, respectively. Yet, the found results showed that for each hybrid scheme the exergy destruction was increased if compared to the scenario using biomass only.*

Keywords: *cogeneration, hybrid system, biomass, solar energy, exergetic analysis.*

1. INTRODUCTION

Energy is essential for the management of life and has supported the economic growth and modernization of society, especially in the industrial sector. Coal, oil and related products and natural gas have been playing an important role in this development. According to Kalogirou (2016), the currently consumption rates must exhaust the proven reserves of oil and natural gas by 42 and 54 years, respectively. Coal is on a better situation and could be available for 120 years. According to the International Energy Agency (IEA, 2019), 81 % of the world primary energy demands was supplied by non-renewable energy in 2018. In Brazil, according to the Energy Research Company (EPE, 2020), in 2019 the renewable sources supplied 46.1 % of the intern demand of energy, while oil and related products, natural gas and coal represented 34.4 %, 12.2% and 5.3 % of demand, respectively. Furthermore, the utilization of non-renewable sources has caused environmental impacts due to CO_2, SO_2, NO_x, emissions.

Recently, the energetic challenges are related to better using of energy, due to scarcity of non-renewable fuels, and insertion of renewable sources in the grid. In this regard, multigeneration and hybridized system can be used to archive those objectives (KHALID; DINCER; ROSEN, 2015). Multigeneration can increase the system overall efficiency, while hybridization can integrate different types of renewable sources in order to mitigate each other technological disadvantages. Countries as Australia, Spain, Italy, Greece, Thailand, India and Brazil are prime candidates for the use of solar and biomass energy sources due to the high direct normal irradiance and available lands (PEITERSEIN, 2014).

Thus, several authors reported studies coupling solar and biomass sources in industrial facilities. López, Restrepo and Bazzo (2018) and Burin, Giudice and Bazzo (2018) reported the thermodynamic analysis of using the linear Fresnel solar field technology in the feedwater heating scheme (FWH) in Brazilian industries. These systems increased the feedwater temperature to around 180 °C using solar energy, and saving sugarcane bagasse for using in the off-season period. According to Zhou *et al.* (2015), over 90 % of power plants in the world are using the feedwater heating scheme. Lópes *et. al.* (2021) carried out an exergetic analysis of a cogeneration plant of a sugarcane industry aided by solar energy, located in Colombia. The authors assessed the reduction in the sugarcane bagasse consumption and the exergy destruction using concentrated parabolic trough and Fresnel concentrators to heat the boiler feedwater. The results shown that both solar technologies decreased the exergy destruction and biomass consumption by 8 % and 1.1 %, respectively.

Alternatively, CSP systems have been investigated for the direct steam generation (DSG). Bai *et al.* (2017) studied a solar-biomass hybrid power generation using parabolic trough collectors (PTC). In this work, the solar field is used to superheat the feedwater to 371°C, then the final heating process is realized in a biomass boiler. The annual biomass consumption rate was reduced by 22.5 % in comparison with a typical biomass system. Soares *et al.* (2018) studied two CSP/biomass hybrid power plant with 1 MW_{el} using PTC. One plant for power generation only and the other for combined heat and power (CHP) scheme. An annual analysis was carried out under 16 hours a day of continuous load demand. The power generation scheme had the higher annual average efficiency of about 13.7 %, with a solar share of 27 %. The CHP scheme has a lower annual average efficiency of 11.3 % and solar shar of 28 %.

Thus, in order to assess the hybridization in thermal plants, in this work a biomass-solar cogeneration plant is proposed based in field data of a poultry industry located in Brazil. The power plant proposed by Teixeira Neto (2018) in a previous work use eucalyptus woodchip as fuel, so, in this work, the integration with solar thermal energy is proposed to economize the biomass in an annual operational time. In addition, two locations in Brazil (Palotina-PR and Barreiras-BA) are considered by using TMY data (one-hour time steps resolution) obtained in the Meteonorm® 7.0 data base. As results, the impact on the fuel consumption and on the exergy performance of the system was evaluated, when a linear Fresnel solar concentrating field was coupled in a feedwater heating and a DSG schemes. The fuel consumption, exergy destruction, thermal and solar-to-electricity efficiency were the performance parameters to be analyzed.

2. POWER PLANT DESCRIPTION

The power plant under analysis was proposed by Teixeira Neta (2018), has a capacity to generate 12 MW_e and to produce 16 t/h of saturated steam to supply the process heat demand. The scheme using biomass only is shown in Fig. 1. The boiler produces superheated steam at 520 °C and 68 bar and the steam is expanded throughout the turbine. A steam extraction is performed at 10 bar to supply the industrial process and promote the deaeration. The water prevenient from condenser and the condensate return of the process are pumped to the deaerator, the make-up is added and the water is pumped to the boiler. The design parameters are shown in the Table 1.

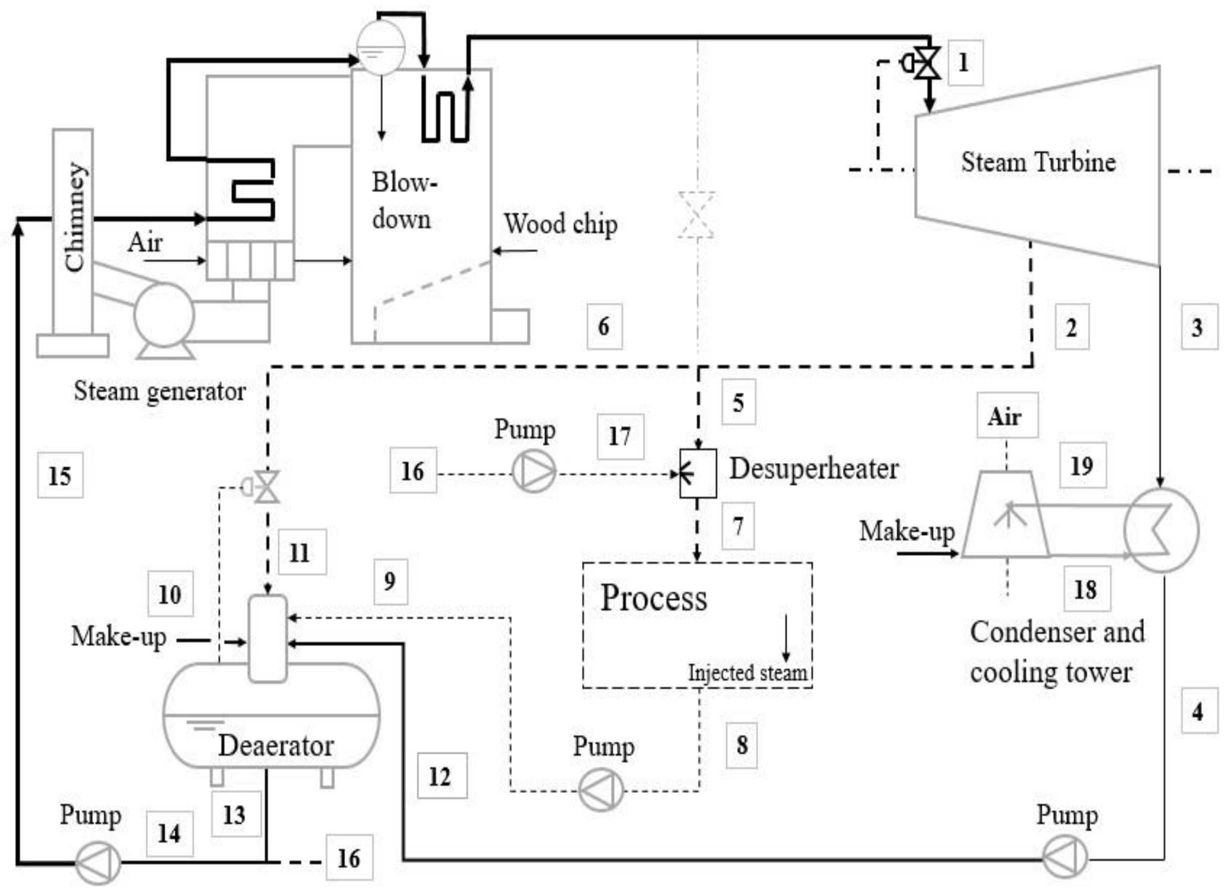

Figure 1. Biomass cogeneration plant, Siqueira Neto (2018).

Table 1. Design conditions

Parameter	**Adopted value**
Plant electricity output capacity, MW_e	12
Process steam mass flow, t/h	16
Steam used directly in process, %	50
Extraction pressure, bar abs.	10
Condensing pressure, bar abs.	0.105
Steam generator efficiency, %	86
LHV (wet basis), kJ/kg	10366
Turbine mechanical efficiency, %	96
Turbine isentropic efficiency 1° stage, %	88.3
Turbine isentropic efficiency 2° stage, %	78.5
Generator electrical efficiency, %	97
Pumps isentropic efficiency, %	78
Pumps electromechanics efficiency, %	96

Source: Siqueira Neto (2018)

3. THERMODYNAMIC ANALYSIS

The thermodynamic analysis is based in mass, energy and exergy balances - Eqs. (1) to (3), respectively. In addition, the thermodynamic modelling was performed for each component of the cogeneration plant. The following assumptions are considered in the analysis:

- Steady state operation;
- Negligible kinetic and potential energy changes;
- Negligible pressure losses;
- Negligible heat losses in pipes and heat exchanges, but the solar field;
- Dead state conditions T_0 = 298.15 K, P_0 = 101.325 kPa.

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}, \tag{1}$$

$$\dot{Q}_{in} + \dot{W}_{in} + \sum \dot{m}_{in} h_{in} = \dot{Q}_{out} + \dot{W}_{out} + \sum \dot{m}_{out} h_{out}, \tag{2}$$

$$\dot{E}_{in} = \dot{E}_{out} + \dot{E}_d, \tag{3}$$

The total exergy is composed by the physical and chemical parts. The specific physical exergy is obtained by the following equation:

$$e_{ph} = h - h_0 - T_0(s - s_0), \tag{4}$$

where *h*, *s* and *T* represent the enthalpy, entropy and temperature, respectively. The subscript *0* represents that the propriety is evaluated in the dead state. The chemical exergy used in this work is evaluated using the simplified model proposed by Szargut, Morris and Steward (1988) as follows:

$$e_{ch} = LHV \cdot \beta, \tag{5}$$

where *LHV* is the low heating value of the fuel (eucalyptus woodchips) and β is calculated by the following equation:

$$\beta = \frac{1.042 + 0.2160\left(\frac{z_{H_2}}{z_C}\right) - 0.2499\left(\frac{z_{O_2}}{z_C}\right)\left[1 + 0.7884\left(\frac{z_{H_2}}{z_C}\right)\right] + 0.0450\left(\frac{z_{N_2}}{z_C}\right)}{1 - 0.3035\left(\frac{z_{O_2}}{z_C}\right)}, \tag{6}$$

where z_{H2}, z_{O2}, z_{N2}, e z_C are the mass fraction of H_2, O_2, N_2 and C, respectively. The equations for exergy destruction for each component and the overall plant are shown in the Table 2. The thermodynamic proprieties and calculations are performed using the software Engineering Equation Solver (EES) (Klein, 2015).

Table 2. Balance and exergy efficiency.

Component	Exergy destruction
Desuperheater	$\dot{E}_{d,Desup.} = \dot{E}_5 + \dot{E}_{17} - \dot{E}_7$
Pump 1	$\dot{E}_{d,P1} = \dot{E}_4 - \dot{E}_{12} - \dot{W}_{P1}$
Pump 2	$\dot{E}_{d,P2} = \dot{E}_8 - \dot{E}_9 - \dot{W}_{P2}$
Pump 3	$\dot{E}_{d,P3} = \dot{E}_{14} - \dot{E}_{15} - \dot{W}_{P3}$
Pump 4	$\dot{E}_{d,P4} = \dot{E}_{17} - \dot{E}_{16} - \dot{W}_{P4}$
Steam Generator	$\dot{E}_{d,Boil.} = \dot{E}_{bio} - \dot{E}_{15} - \dot{E}_1$
Condenser	$\dot{E}_{d,Cond.} = \dot{E}_3 + \dot{E}_{18} - \dot{E}_4 - \dot{E}_{19}$
Deaerator	$\dot{E}_{d,Desae.} = \dot{E}_9 + \dot{E}_{10} + \dot{E}_{11} + \dot{E}_{12} - \dot{E}_{13}$
Process	$\dot{E}_{d,Proc.} = \dot{E}_7 - \dot{E}_8 - \dot{E}_{\dot{Q},Proc}$
Turbine	$\dot{E}_{d,Turb.} = \dot{E}_1 - \dot{E}_2 - \dot{E}_3 - \dot{W}_{Turb.}$
Valve	$\dot{E}_{d,Valv.} = \dot{E}_6 - \dot{E}_{11}$
Cycle	$\dot{E}_{d,Cycle.} = \sum \dot{E}_{d,i.}$

The solar exergy is modeled according to Petela (1964),

$$\dot{E}_{SF} = \dot{Q}_{sun}\left[1 + \frac{1}{3}\left(\frac{T_0}{T_{sun}}\right)^4 - \frac{4}{3}\left(\frac{T_0}{T_{sun}}\right)\right], \tag{7}$$

where T_{sun} is the apparent sun Temperature of 5777 K. Finally, the exergy analysis of the solar field was evaluated by Equation (8),

$$\dot{E}_{SF} + \dot{E}_{in} = \dot{E}_{out} + \dot{E}_{d,SF}, \tag{8}$$

where $\dot{E}_{in}$ and $\dot{E}_{out}$ are the water flux on the inlet and outlet of the solar field, respectively, and $\dot{E}_{d,SF}$ is the exergy destroyed in the solar field.

3.1 Solar feedwater heating scheme

Under this concept, the solar Fresnel field is integrated with the cogeneration cycle in order to preheat the feedwater and to reduce the biomass consumption - Fig. 2 (a). The solar field was sized to heat the boiler feedwater to 180 °C at design point operation. The heat absorbed in receivers, $\dot{Q}_{sf}$ was modeled according to the following equation,

$$\dot{Q}_{sf} = \mathrm{A}_{sf}\left(DNI\eta_{opt} - \dot{Q}''_{loss}\right), \tag{9}$$

where *DNI* [W/m²] is the direct normal radiation, η_{opt} is the solar field optical efficiency, which is evaluated according to Equation (10) and $\dot{Q}''_{loss}$ is the heat loss to ambient [W/m²], that is calculated according the empirical Equation (11) (NOVATEC-SOLAR, 2011),

$$\eta_{opt} = \eta_{0,opt} \cdot K_{\perp} \cdot K_{\parallel}, \tag{10}$$

$$\dot{Q}''_{loss} = u_0 \Delta T + u_1 \Delta T^2, \tag{11}$$

$\eta_{0,opt}$ is the peak of optical efficiency, $K_{\perp}$ and $K_{\parallel}$ are the transversal and longitudinal incidence angle modifiers, respectively, which are calculated according to Novatec-Solar (2011). The parameters u_0 and u_1 are heat loss coefficients and ΔT is the difference between the average temperature in the solar field and the environment temperature.

3.2 Solar direct steam generation scheme

The DSG scheme consists on coupling the solar field side-by-side with the biomass steam generator in order to replace the boiler by 50 % of its capacity, Fig. 2 (b). The solar field in scheme (b) is composed by two sections, the evaporation and superheating sections. The parameters of these sections are presented in Table 3. The modeling of evaporation section is similar to the scheme A. The superheating section, instead, is equipped evacuated tubes (SCHENK, 2014), thus resulting in a different optical efficiency. Evacuated tubes reduce the heat losses. The heat losses of this section are calculated according the empirical Equation (12),

$$\dot{Q}_{loss,super} = u_2 \Delta T + u_3 \Delta T^4, \tag{12}$$

where u_2 and u_3 are heat loss coefficients of the superheating section (NOVATEC-SOLAR, 2011). The parameters of the solar field are presented in Table 3.

Table 3. Parameters of LF collector scheme A

Collector type	**NOVA 1**	**SUPERNOVA**
Module length/width, m	44.8/16.7	44.8/16.7
Net aperture area of module, m²	513.6	513.6
$\eta_{0,opt}$, %	67	65
Heat transfer fluid	Water	Water
Orientation	North-South	North-South

3.3 Annual performance indexes

The annual performance indexes used in this work are presented below. The annual biomass economy is evaluated by Equation (13),

$$\eta_{econ.} = 100 \times \frac{\sum_{i=1}^{8760} \dot{m}_{base(i)} - \dot{m}_{sf(i)}}{\sum_{i=1}^{8760} \dot{m}_{base(i)}}, \tag{13}$$

where $\dot{m}_{base(i)}$ and $\dot{m}_{sf(i)}$ are the biomass used in the base and the solar filed schemes, respectively, at each hour time-step *i* of simulation – hour of the year [1:8760].

The thermal efficiency of solar field along the year is calculated using Equation (14),

$$\eta_{sf} = 100 \times \frac{\sum_{i=1}^{8760} \dot{Q}_{sf(i)}}{\sum_{i=1}^{8760} A_{sf} DNI_{(i)}}, \tag{14}$$

The solar-to-electricity efficiency (η_{STE}) represent the ratio between the electric power generated by the power plant due to solar energy and the total amount of solar thermal energy reaching the solar field, as represented by Equation (15),

$$\eta_{STE} = 100 \times \frac{\sum_{i=1}^{8760} \dot{W}_{solar(i)}}{\sum_{i=1}^{8760} A_{sf} DNI_{(i)}}, \tag{15}$$

where $\dot{W}_{solar}(i)$ is the fraction of electric power generated by the power plant during a Typical Meteorological Year (TMY), calculated according to Equation (16),

$$\dot{W}_{solar} = SF \dot{W}_{generated}, \tag{16}$$

where $\dot{W}_{generated}$ is the total electric power generated by the power plant and SF is the Solar Fraction, that represents the fraction of energy delivered to the working fluid by the solar field. SF is calculated by Equation (17),

$$SF = \frac{\dot{Q}_{solar}}{\dot{Q}_{solar} + \dot{Q}_{SG}}, \tag{17}$$

where $\dot{Q}_{SG}$ is the heat transferred to steam in the biomass steam generator.

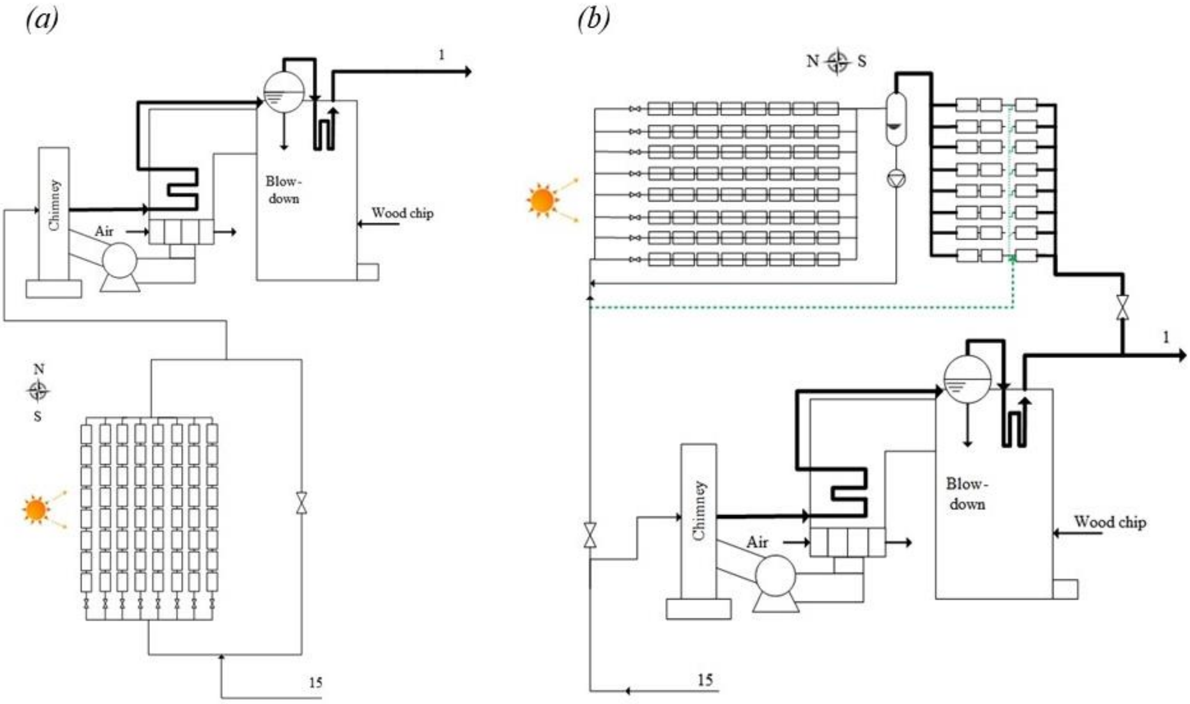

Figure 2. Solar field integration: (a) FWH scheme and (b) DSH scheme.

4. RESULTS AND DISCUSSIONS

The hybrid cogeneration power plant was analyzed for two different sites, considering the design conditions and the annual operation. The meteorological data from Palotina-PR and Barreiras- BA are summarized in Table 4. The design point DNI for each site was evaluated not considering irradiance values smaller than 250 W/m² and calculating the 95 % upper percentile.

Table 4. Meteorological data of Palotina and Barreiras

	Palotina-PR	**Barreiras-BA**
Latitude/longitude, deg	-24.3/-53.8	-12.2/-45
Annual DNI sum, kWh/m²	1534.8	1929.2
Design DNI, W/m²	948	978

4.1 Design point analyses

Table 5 shows exergy analysis results for the cogeneration power plant at design point condition for the city of Palotina – PR. In the base case scheme, the biomass mass flow rate is constant at about 18 t/h in order to assure the energy demands. The results showed that, in this case, the steam generator is the highest exergy destroyer in the cycle (around 89 %) due to the high irreversibility level of the combustion process. Therefore, the steam generator become a key point eligible for improvements. Improving the performance of this equipment or reducing can decrease more significantly the exergy destruction.

The DSG scheme replaced the biomass steam generator load by 57 % using a total solar field aperture area of 46 142 m². In this regard, the fuel consumption was reduced by 53 %, while the exergy destroyed by the steam generator decreased by 51 %. In the other hand, the total exergy destroyed by the power plant increased by 9.3 % due the integration of the solar field. Some authors (López *et. al.*, 2018; Lozano *et. al.*,2014) proposed that solar field exergy destruction doesn't represent negative impacts to the power plant since that solar energy is considered as a free of charge resource. Thus, the increase of exergy destruction by the solar field would not have a negative impact in the system.

The FWH scheme at design point design condition promoted 8.5 % of fuel economy using a total solar field aperture area of 6163 m². The exergy destroyed by the steam generator reduced by 9.8 %, while the overall exergy destruction increased by 0.3 %. In all schemes, just the steam generator and the solar field induced changes in the exergy perspective. The other components don't showed modifications.

The DSG scheme leaded to major benefits in terms of fuel consumption savings and higher reductions of the exergy destruction rates in the steam generator, however it uses a 7.4 times bigger solar field area.

Table 5. Performance parameters of cogeneration power plant schemes located in Palotina-PR

	Base case scheme		DSG scheme		FWH scheme	
Component	**Exergy Destroyed, kW**	**Exergy destruction ratio, %**	**Exergy Destroyed, kW**	**Exergy destruction ratio, %**	**Exergy Destroyed, kW**	**Exergy destruction ratio, %**
Desuperheater	48.6	0.1	48.6	0.1	48.6	0.1
Pump 1	0.9	0.0	0.9	0.0	0.9	0.0
Pump 2	0.1	0.0	0.1	0.0	0.1	0.0
Pump 3	34.6	0.1	34.6	0.1	34.6	0.1
Pump 4	0.1	0.0	0.1	0.0	0.1	0.0
Steam generator	41958.0	89.6	20744.0	40.2	37834.0	80.6
Condenser	535.4	1.1	535.4	1.0	535.4	1.1
Deaerator	486.0	1.0	486.0	0.9	486.0	1.0
Process	533.9	1.1	533.9	1.0	533.9	1.1
Turbine	2857.0	6.1	2857.0	5.5	2857.0	6.1
Valve	348.8	0.7	348.8	0.7	348.8	0.7
Solar Field	-	-	26023.0	50.4	4247.0	9.1
Cycle	46803.4	100.0	51612.4	100.0	46926.4	100.0

4.2 Annual analyses

In the annual analysis of the hybrid cogeneration power plants, TMY data for both Palotina and Barreiras sites were assessed. Besides, the performance of the solar field was evaluated for different Solar Multiple (SM): between 0.8 to 2.3 for the DSG scheme and between 0.9 to 1.3 for the FWH scheme. Operational control aspects of coupling the energy sources were not addressed in this work.

Figure 3 (a) shows the fuel economy as a function of the solar field area for the DSG hybrid power plant scheme for the sites of Palotina and Barreiras. The annual fuel economy design point was 5 % and 6 % in Palotina and Barreiras, respectively. The results show that the location of the solar field installation have an important role on the fuel economy. Using a reflective area 14% smaller in the city of Barreiras it was possible to save 1 % more biomass than in Palotina.

The year-round mean solar field efficiency for the DSG scheme is shown in Figure 3 (b). For design point, η_{sf} was equal to 39.6 % for Palotina a lower value when compared the reference condition due to the intermittency of solar energy. Increasing the solar field aperture area, the solar field efficiency was reduced to 34.5 %. This occurs due to the necessity to keep the load in the steam generator in at least 40 %. Thereby, it is necessary to defocus the solar field mirrors in order to control the steam production on it. A similar behavior was noticed for Barreiras. However, the η_{sf} decreased from 42. 5 % to 35.2 % in a higher rate.

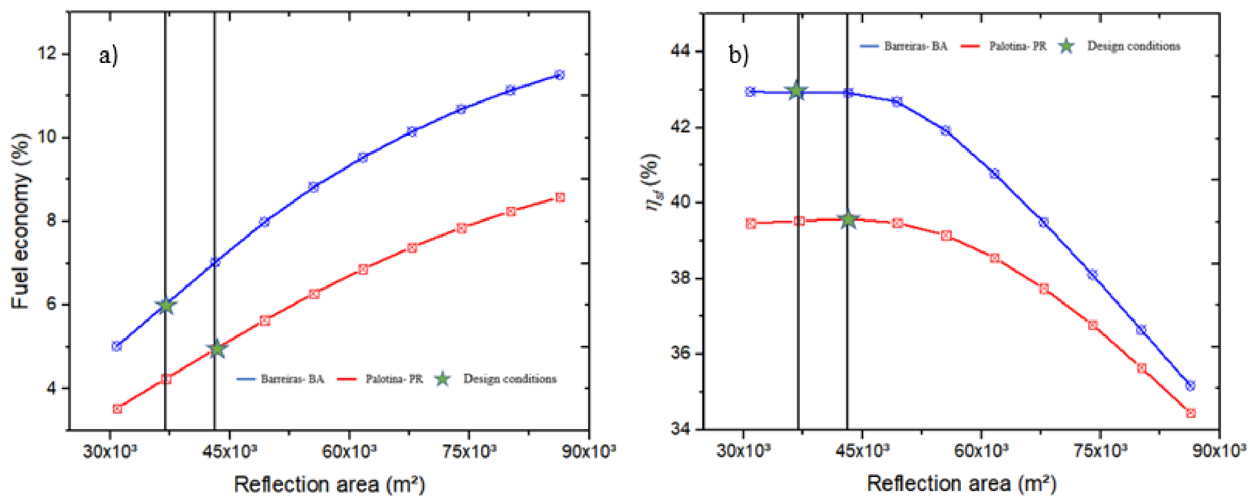

Figure 3. *(a)* Fuel economy versus reflection area, *(b)* η_{sf} versus reflection area for the DSG scheme.

The STE efficiency is used to evaluate the conversion of solar radiation into electricity. Figure 4 shows for the DSG concept the η_{STE} as a function of the solar field aperture area. The annual analyses for design point showed that the hybrid plant located in higher accumulated DNI places has better performance. For higher values of area, the η_{STE} reduces for both locations. Yet, above 75 000 m² of aperture area the η_{STE} for Barreiras became lower than for Palotina. This occurs due to necessity of defocusing the mirrors more often in locations with higher DNI levels.

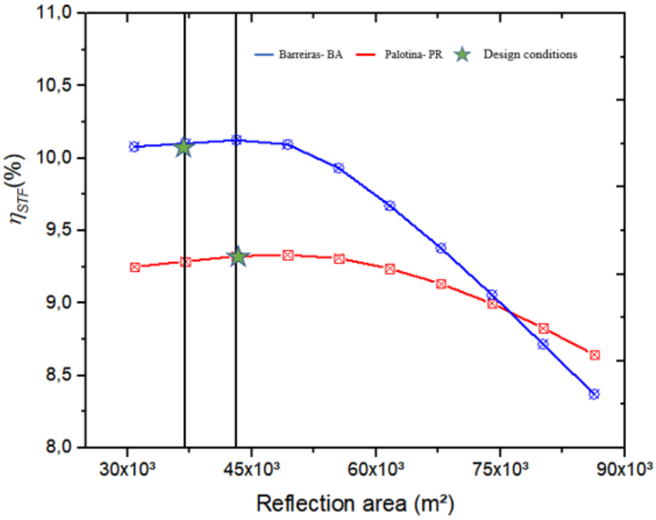

Figure 4. η_{STE} versus reflection area for the DSG scheme.

Figure 5 (a) shows the effect DNI incidence on the exergy destroyed by the cycle, biomass steam generator and solar field, for a period of 72 h, for the DSG scheme in Palotina-PR. The selected interval of operation corresponds to January, between 553 to 624 h of the year. The fluctuations in the exergy destruction occurs in the steam generator, in the solar field and, consequently, in the hybrid cycle. There is an increase of the total exergy destruction when the solar field is performing, but the exergy destroyed in the steam generator is reduced due to the decrease of the boiler load. However, despite of the net increase of total exergy destruction, the replacement of exergy destruction in the steam generator by the exergy destruction in the solar field have a benefit since the solar resource is without cost. Finally, in the first and the last sunny hours of the day there is a higher destruction of exergy due to the lower solar field optical efficiency at these hours.

In Figure 5 (b) it is shown the fluctuations in the exergy destruction on the FWH scheme. As well as for the DSG scheme, the solar field in FWH scheme increase the total exergy destruction of plant, despite of the exergy destruction reduction in the steam generator. However, the impact of integrating the solar field in the FWH scheme is smaller. This is evident due to fuel economy archived in those schemes.

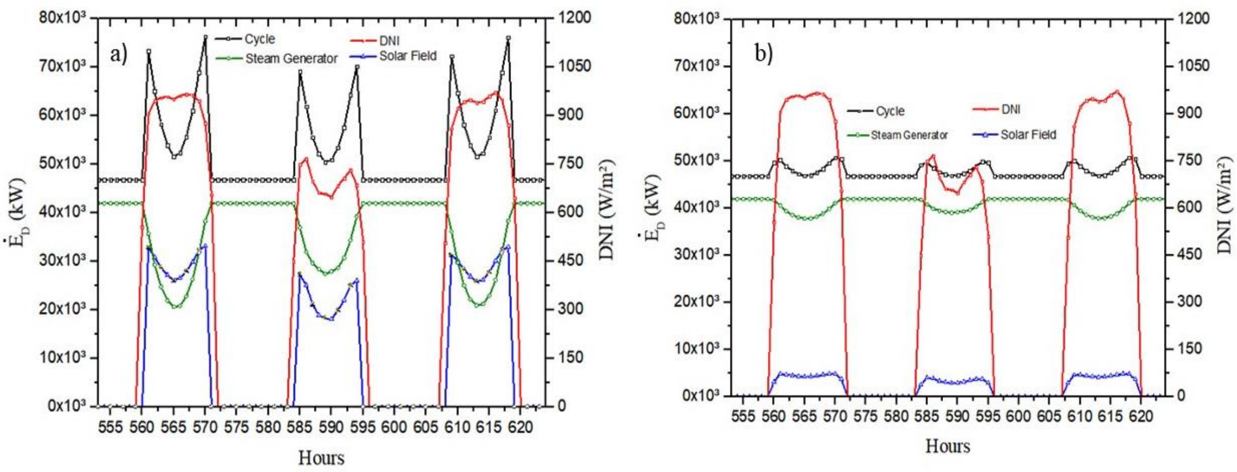

Figure 5. DNI versus exergy destruction.

The results for the FWH scheme are shown in Table 6. In order to assure the constant energetic efficiency of the steam generator, the feedwater was heated by 180 °C. In this regard, the solar mirrors were defocused to ensure that the temperature of 200 ° C was not exceeded. The η_{STE} was about 39 % and 42 % for Palotina and Barreiras, respectively, and η_{STE} did not change more than 1.5 % if solar field area was changed. The annual fuel economy was smaller in comparison to the results with DSG scheme. For the climate conditions of Barreiras, the annual economy archived 1.7 %, while in Palotina it was reached a 1.2 % fuel economy.

Table 6. Annual results for FWH scheme from Palotina-PR/Barreiras-BA

Area, m²	**Annual fuel economy, %**	η_{STE}, %	**Annual fuel economy, %**	η_{STE}, %
	Palotina		Barreiras	
5136.0	0.7	39.5	1.0	42.4
6163.2	0.8	39.4	1.2	42.3
7190.4	1.0	39.4	1.4	42.2
8217.6	1.1	39.2	1.5	41.9
9244.8	1.2	38.7	1.7	41.1

5. CONCLUSIONS

A linear Fresnel solar thermal system coupled to a biomass cogeneration power plant was analyzed for two different configurations at two Brazilian cities. The DSG scheme was coupled in parallel with the biomass steam generator to produce up to 50 % of superheated steam mass flow at 68 bars and 520° C. The FWH scheme was coupled to pre-heat the feedwater of the steam generator up to 180 ° C under design condition. The schemes were analyzed in the design condition and under annual operation. In design condition, the DSG scheme showed greater performance than FWH scheme. The fuel consumptions decreased by 53 % and 8.5 % for the DSG and FWH schemes, respectively, located in Palotina-PR. The annual analyses indicated that the accumulated DNI have an important role in the biomass economy and, consequently, in the viability of the hybrid project.

The components with the bigger impact in the exergy destruction are the steam generator and the solar field. The exergy destruction rates associated with the solar field operation increase the total exergy destroyed but there is a reduction of the exergy destruction rates in the steam generation. The exergy destruction in the solar field do not generate over cost.

The best performance of solar field insertion was attained in Barreiras where the accumulated DNI is higher. In addition, if increasing the solar field aperture area, the biomass economy increases, but it is necessary defocus the solar mirrors in order to assure the minimal load in the steam generator. Finally, the feasibility of the project and the final selection between the DSG and FWH schemes will depend of the economic analysis.

6. ACKNOWLEDGEMENTS

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