THERMOECONOMIC APPLICATION FOR COST ALLOCATION IN A DUAL-PURPOSE POWER AND DESALINATION PLANT

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Abstract: *Aiming at a evaluating which is the best way to value internal flows in order to define a dual-purpose power and desalination plant productive structure, this work compares three thermoeconomic methodologies that can be applied for cost allocation for water and electricity in an extraction-condensing steam turbine cogeneration plant, where the steam is extracted for a thermal desalination process. The compared methodologies value the internal flows in three different ways: a) exergy (E Model), b) combining exergy and entropy (E&S Model) and c) a new model that combines enthalpy and entropy (H&S Model). The analysis questions the thermodynamic application by the methodology represented by E&S Model, and the results prove that this methodology overcharges the cost of the electricity in the detriment of the cost of the desalted water. The other two methodologies present more coherent results, with small differences in the unit costs of the two products.*

Keywords*: Cost Allocation, Cogeneration, Desalination, Thermoeconomy, Neguentropy*

1. Introduction

Desalination is the most important way to provide drinking water for the populations in the arid regions of the planet. Allied to the fact that the main way to generate electricity in these regions is the use of thermal power plants, it is, then, possible to create a favorable environment for the implementation of dual-purpose power and desalination plants making use of the energetic, economic and environmental advantages of cogeneration. A dual-purpose power and desalination plant is an important application of cogeneration technologies where the produced heat is used as the main energy source of a thermal desalination unit using distillation processes.

Because the plant produces both electricity and desalted water, a method to split total cost is necessary to determine the unit cost of each product. Several methods of cost allocation have been in use for a number of years, but, recently many authors have shown that thermoeconomy is the best one as far as cost allocation in cogeneration and dual-purpose plants. Thermoeconomy is a discipline that combines thermodynamic and economic concepts in modeling thermal systems and it represents whole cost distribution process in the plant (Uche, 2000).

Thermoeconomy is also applied to thermal plants diagnosis and optimization, but its most important application is to calculate the physical costs of their flows and products. For a number of years thermoeconomic modeling was developed by formulating costs equations on the physical structure of the plant, but this procedure faced difficulties due the necessity of interpretation of the cost attributing rules for the attainment of auxiliary equations that made the mathematical solution of the equation set possible. Recently it was shown that the best way to overcome this obstacle is to formulate equation set based on the productive structure of the plant, defined on the basis of the function of each physical plant productive unit (Serra, 1994). This way the system of equations is always determined, which facilitates its solution. In this work, the thermoeconomic models are solved using Steam Table Software for Microsoft Excel.

The productive structure is a diagram formed by real productive units (equipment) and fictitious units (junctions and bifurcations) linked by internal flows. There are also external flows, which represent the fuel, equipment and services costs. Although there are no more doubts that the internal flows of the productive structure must be valued according to the second law of thermodynamics, an aspect that still remains unanswered is the best criterion or magnitude to express them. Some authors use only exergy (exergoeconomic modeling) to value the internal flows, here called E Model. Others use a methodology represented here by the E&S Model, which values part of the internal flows by using their exergy and the other part by using their entropy. By the questioning the thermodynamic application by the E&S Model, a new model is here presented. This new model, here called H&S Model, values part of the internal flows based on their enthalpy and the other part on their entropy.

In order to evaluate the best way to value the internal flows of the productive structure, the three models are applied to determine the unit cost of electricity and the unit cost of water in a dual-purpose power and desalination plant, and the results are compared and assessed based on the energetic advantage of the cogeneration technology application.

2. Plant Description

The plant consists of the extraction-condensing steam turbine cogeneration technology associated with multiple effect distillation with thermal vapor compression desalination technology (MED-TVC). The physical structure of the plant is shown in Figure 1. The plant has the capacity of producing 27.78 kg/s (2400 m^3/day) of desalted water and 4375 kW of electricity, which 298 kW are consumed by the auxiliary equipment of the plant. The largest electricity consumer of the plant is the desalination units (200 kW), but the boiler fan consumes 53.47 kW and the remaining power is used for feed pump, condenser pump and two circulating pumps (39.47 kW, 4.02 kW, 0.75 kW and 0.30 kW, respectively). The cogeneration plant scheme (thermodynamic design only) is simulated using the Thermoflex Software.

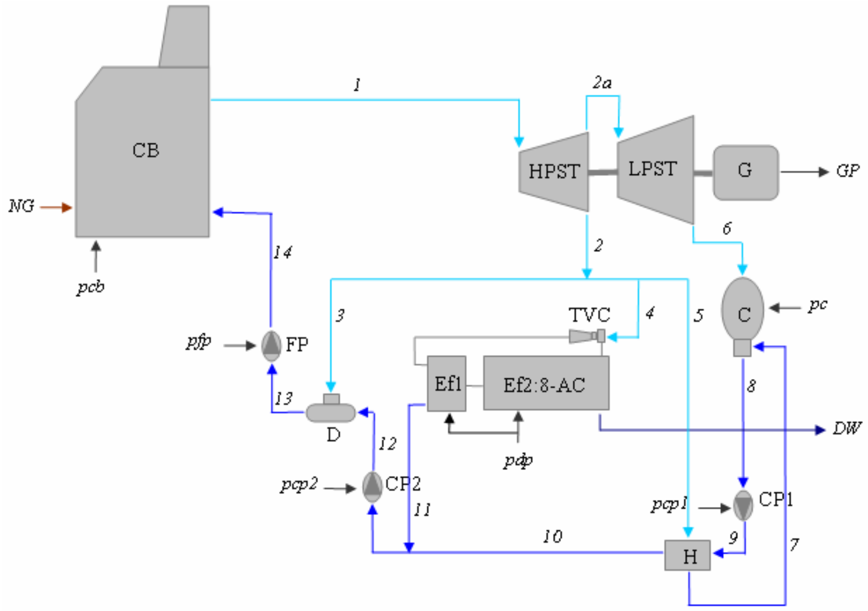

Figure 1: Physical Structure of the Dual-Purpose Power and Desalination Plant

At 2500 kPa (25 bar) and 330°C, the boiler generates 8.61 kg/s (31 t/h) of steam, which 4.55 kg/s (16.4 t/h) are completely expanded through the steam turbine down to the condenser pressure of 5.6 kPa (0.056 bar) and 4.05 kg/s (14.6 t/h) are extracted from the intermediate stage of the turbine at 200 kPa (2 bar) and 136°C. The extracted steam is used in the desalination process (3.19 kg/s), deaerator (0.67 kg/s) and heater (0.19 kg/s). The condenser is cooled by sea water, which enters at 25°C and leaves at 32°C. The quality of steam at the outlet of the low pressure steam turbine is 92.6 %. The temperature of the feeding water is 106°C. Natural gas consumption in the boiler is 23852 kW. The desalination unit has 8 effects and it returns condensate at 60.2°C (Santos, 2005). The process steam passes through the thermal vapor compressor, where it gets mixed with the steam generated by the last effect and gets condensed in the first effect (Ef1) by transferring heat to continue the distillation process in the remaining effects and in the auxiliary condenser (Ef2:8-AC). The plant can also operate in pure condensing mode (MED-TVC desalination unit is off) producing 5328 kW (net electric power).

3. Thermoeconomic Modeling

The objective of the thermoeconomic modeling is to obtain a set of cost equations which describes mathematically the cost process formation in the plant. The equations are formulated based on the productive structure. The real productive units (rectangle) represent real pieces of equipment or real equipment groups and have their own monetary costs due to the respective capital cost (including civil works), operation and maintenance. The bifurcations (circles) do not have costs because they are fictitious units, but they serve to distribute the cost of the product of a productive unit to other subsequent ones. The junctions (leangles) are also fictitious productive units that convert products of previous productive units into fuel to another unit. The productive structure depends on the function that is given to each piece of equipment of the plant and on the desired isolation level. The cost allocation, whose purpose is to determine the unit costs of the products, only demands an appropriate level of isolation that does not compromise the results.

3.1. E Model

This model is based on a thermoeconomic methodology called exergoeconomy because it values the internal flows according to the respective exergy value (Serra, 1994 and Santos, 2005). It does not permit the total isolation of the plant because exergoeconomy does not define a product for the dissipative equipment (the condenser, for example). The productive structure of the dual plant using the E Model is shown in Figure 2 and it is defined with only 4 real productive units (SGS, FWS, EGS and DP), 2 bifurcations (B1 and B2) and 5 junctions (J1, J2, J3, J4 and J5).

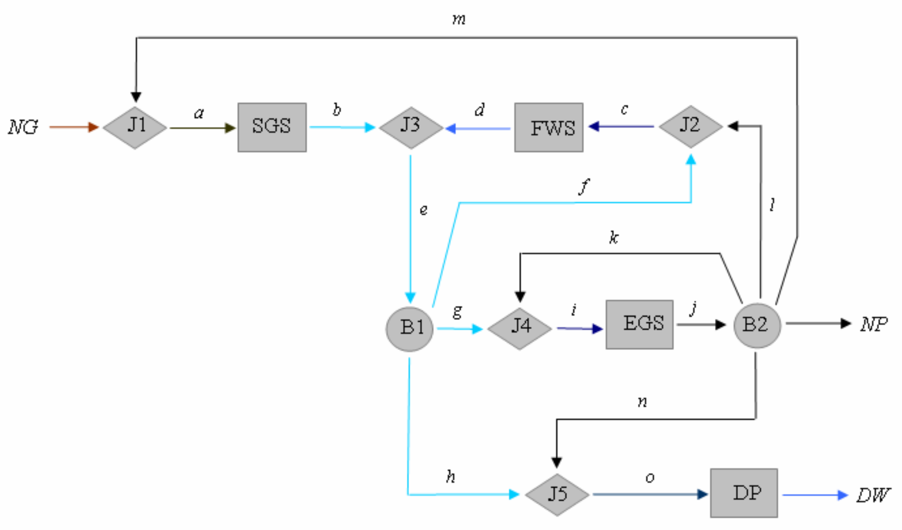

Figure 2: Productive Structure of the Dual-Purpose Power and Desalination Plant using E Model

The physical equipment (or unit) that composes each of the real productive units is shown in the Table 1, where the equations that compose the E Model are also displayed. The equipment is defined and grouped according to its function of production: electricity, water or both. The equations is a cost balance set, expressed in terms of unit cost (*c*) and exergy (*E*) of the internal flows, and the values of the external flows that represent the costs of the equipments (*Z*) and also the one that represent the fuel cost (C_{NG}). The value of the desalted water production is a volumetric flow (V_{DW}).

Table 1: Definition of the Productive Units and the Equations of E Model

PRODUCTIVE UNITS	EQUATIONS
J1	$c_a \cdot E_a - c_{NP} \cdot E_m = C_{NG}$
SGS (= CB)	$c_b \cdot E_b - c_a \cdot E_a = Z_{SGS}$
J2	$c_c \cdot E_c - c_Q \cdot E_f - c_{NP} \cdot E_l = 0$
FWS (= FP + D + CP2)	$c_d \cdot E_d - c_c \cdot E_c = Z_{FWS}$
J3	$c_e \cdot E_e - c_b \cdot E_b - c_d \cdot E_d = 0$
B1	$c_Q \cdot (E_f + E_g + E_h) - c_e \cdot E_e = 0$
J4	$c_i \cdot E_i - c_Q \cdot E_g - c_{NP} \cdot E_k = 0$
EGS (= HPST + LPST + G + C + CP1 + H)	$c_j \cdot E_j - c_i \cdot E_i = Z_{EGS}$
B2	$c_{NP} \cdot (E_m + E_l + E_k + E_n + E_{NP}) - c_j \cdot E_j = 0$
J5	$c_o \cdot E_o - c_Q \cdot E_h - c_{NP} \cdot E_n = 0$
DP (= Ef1 + Ef2:8-AC + TVC)	$c_{DW} \cdot V_{DW} - c_o \cdot E_o = Z_{DP}$

The DP productive unit is defined as the equipment that consumes exergy from the cycle to produce desalted water. In a similar way the EGS unit is composed by equipment that only contributes to electricity generation, including the condenser and the heater. Although the condenser does not have a defined product, (in exergoeconomy) it assists the low pressure steam turbine, once the steam leaving the turbine must be condensed. On the other hand, the heater also contributes to electricity generation because it only works with the flow that leaves the low pressure steam turbine. The productive structure of the plant could be defined with only three real units without any variation in the result, joining the two units (SGS and FWS) that have pair function of supplying fuels to the EGS and to the DP. For cost allocation using the exergoeconomy (E Model), the value of some flows is irrelevant because the objective is the attainment of the unit cost of the final products. This way, besides the flows that represent the final products it is important to quantify the value of all the flows that leave the bifurcations because the costs are distributed to the final products proportionally to the exergy of the flows that leave the bifurcations. The relevant productive flows and the equations that determine them (as function of the physical flows) are in Table 2. The desalted water is a volumetric flow (V_{DW}) and de others relevant productive flows are exergy flows (*E*), in terms of electric power (*P*) or mass flow (*m*) and specific exergy flow (*e*).

Table 2: Valuation of the Relevant Flows of the E Model

FLOW	VALUATION
NP	$E_{NP} = P_{GP} - P_{pc} - P_{pcp1} - P_{pfp} - P_{pcp2} - P_{pcb} - P_{pdp}$
k	$E_k = P_{pc} + P_{pcp1}$
l	$E_l = P_{pfp} + P_{pcp2}$
m	$E_m = P_{pcb}$
n	$E_n = P_{pdp}$
f	$E_f = m_3 \cdot (e_3 - e_{13})$
g	$E_g = E_1 - E_3 - E_4 - E_{10}$
h	$E_h = E_4 - E_{11}$
DW	V_{DW}

The solution of the set of equations that represents the E Model (Table 1) provides the unit costs of each one of the productive structure internal flows as results, including the flows that also represent the final products and the unit cost of the irrelevant flows. The flows that leave the same bifurcation have the same unit cost.

3.2. E&S Model

The recent trend of thermoeconomic modeling is to value part of the flows of the productive structure according to their entropy (Cerqueira, 1999 and Uche *et al.*,2001). This procedure, called neguentropy internalization, allows the definition of a productive structure detailing each piece of equipment of the plant, as it is shown in Figure 3. This E&S Model considers that the function of some of the equipment of the plant (CB, D, H, FP, CP1 and CP2) is to increase the working fluid exergy and consequently inject exergy in the cycle. The injected exergy is used as fuel to generate electricity in the turbo-generator (HPST, LPST and G) and also to produce drinking water in the desalination unit (Ef1, Ef2:8-AC and TVC).

The injection of exergy and the generation of electricity also generate entropy (by increasing the working fluid entropy). The work fluid entropy decreases during the condensation in the condenser (C), in the heater (H), in the desaerador (D) and in the first effect of the desalination unit (Ef1). Then the condenser is an exergy consumer and its function is to return part of the entropy generated in the plant. The product of the condenser is the neguentropy (NS_C), which must be redistributed to the other productive units at the same rate as their contribution to the generation of the total entropy of the plant. This way the desaerador and the heater have double function in the plant because they inject exergy in the cycle (on the water side), but, they have also the neguentropy as product (NS_D and NS_H) on the steam side. The first effect of the desalination unit (Ef1) also has a double function: to absorb the useful heat (Q_U) initiating the process and to supply neguentropy (NS_{Ef1}) to the cogeneration steam cycle.

A piece of equipment is considered to be an entropy generator if it increases the working fluid entropy. If the working fluid entropy is reduced, the equipment is a neguentropy generator. The entropy multiplied by the reference temperature (T_0) has the same unit as the exergy, which is shown in Equations 1 and 2.

$$S_{CB} = \dot{m}_{14} \cdot T_0 \cdot (s_1 - s_{14}) \quad (1)$$

$$NS_C = \dot{m}_6 \cdot T_0 \cdot (s_6 - s_8) \quad (2)$$

Equation 1 represents the entropy generated in the boiler, which is the equipment that generates the most entropy in the cycle. Equation 2 represents the only product of the condenser: the neguentropy. The productive structure of the Figure 3 has entropy flows (S), neguentropy flows (NS), exergy flows (E) and electricity flows (P) which is pure exergy too. All the neguentropy flows are joined in a junction (J_S) and are distributed through the bifurcation (B_S) to the real productive units that generate entropy. All the exergy injected to the cycle are also joined (in J_E) and distributed from the bifurcation (B_E) to the units that consume exergy.

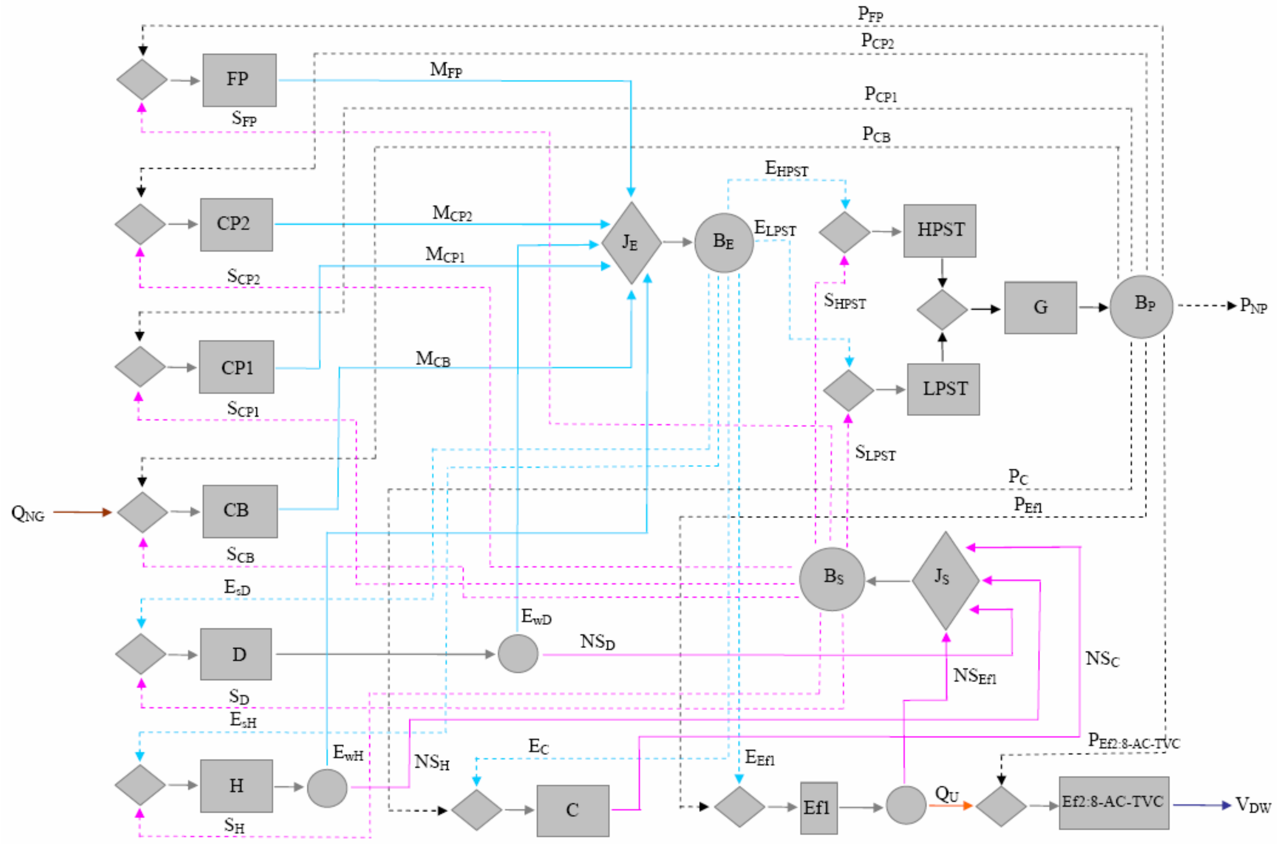

Figure 3: Productive Structure of the Dual-Purpose Power and Desalination Plant using the E&S Model

The equations of the E&S Model are shown in Table 3. Although the productive structure details all the equipment of the plant, the model has only 12 equations that are enough for the attainment of the unit costs of the two final products. The productive structure of Figure 3 could, in a detailed way, be represented by 32 equations, although the use of only 9 equations (joining FP, CP2, CP1 and CB in a single equation) would not modify the final results of the costs.

Table 3: Equations and Productive Units of the E&S Model

UNITS		EQUATION
PRODUCTIVE	PHYSICAL	
CP1	CP1	$c_{CP1}\cdot M_{CP1} - c_{NP}\cdot P_{CP1} - c_S\cdot S_{CP1} = Z_{CP1}$
H	H	$c_H\cdot(E_{wH}+NS_H) - c_E\cdot E_{sH} - c_S\cdot S_H = Z_H$
CP2	CP2	$c_{CP2}\cdot M_{CP2} - c_{NP}\cdot P_{CP2} - c_S\cdot S_{CP2} = Z_{CP2}$
D	D	$c_D\cdot(E_{wD}+NS_D) - c_E\cdot E_{sD} - c_S\cdot S_D = Z_D$
FP	FP	$c_{FP}\cdot M_{FP} - c_{NP}\cdot P_{FP} - c_S\cdot S_{FP} = Z_{FP}$
CB	CB	$c_{CB}\cdot M_{CB} - c_{NP}\cdot P_{CB} - c_S\cdot S_{CB} = Z_{CB} + C_{NG}$
C	C	$c_C\cdot NS_C - c_{NP}\cdot P_C - c_E\cdot E_C = Z_C$
Ef1	Ef1	$c_{Ef1}\cdot(Q_U+NS_{Ef1}) - c_E\cdot E_{Ef1} - c_{NP}\cdot P_{Ef1} = Z_{Ef1}$
Ef2:8-AC-TVC	Ef2:8-AC + TVC	$c_{DW}\cdot V_{DW} - c_{NP}\cdot P_{Ef\,2:8-AC-TVC} - c_{Ef1}\cdot Q_U = Z_{Ef\,2:8-AC-TVC}$
J_EB_E	-----	$c_E\cdot(E_{HPST}+E_{LPST}+E_{Ef1}+E_C+E_{sH}+E_{sD}) - c_{FP}\cdot M_{FP} - c_{CP2}\cdot M_{CP2} - c_{CP1}\cdot M_{CP1} - c_{CB}\cdot M_{CB} - c_D\cdot E_{wD} - c_H\cdot E_{wH} = 0$
J_SB_S	-----	$c_S\cdot(S_{HPST}+S_{LPST}+S_{FP}+S_{CP2}+S_{CP1}+S_{CB}+S_H+S_D) - c_C\cdot NS_C - c_H\cdot NS_H - c_D\cdot NS_D - c_{Ef1}\cdot NS_{Ef1} = 0$
ECSTG	HPST + LPST + G	$c_{NP}\cdot(P_{NP}+P_{FP}+P_{CP2}+P_{CP1}+P_{CB}+P_C+P_{Ef1}+P_{Ef\,2:8-AC-TVC}) - c_S\cdot(S_{HPST}+S_{LPST}) - c_E\cdot(E_{HPST}+E_{LPST}) = Z_{ECSTG}$

In the productive structure (Figure 3), the products of the equipment, whose only function is to inject exergy in the cycle (FP, CP2, CP1 and CB), are valued by the mass flow (M). This procedure can be adopted to calculate the cost of these flows by mass unit without any implication in the cost of the final products. This type of flow valuation can be applied to the flows that do not leave bifurcations (for example: the product of the condenser).

3.3. H&S Model

This model (proposed by this work) appears by questioning the way that the second law of the thermodynamics is interpreted and applied by the E&S Model. When defining the exergy as an equipment fuel or product, the concept of neguentropy or entropy generated is already included. This way the E&S Model charge some equipment twice due to the entropy that they generated (Equation 4). Therefore the H&S Model consists of the substitution of the flows that are valued by the variation of the exergy (*E*) in the E&S Model (in the productive structure and in the equations) by its respective variation of enthalpy (*H*). The argument can be shown by calculating the efficiencies of three productive units that consume the heat injected in the cycle and generate entropy or neguentropy: HPST, C and Ef1.

The high pressure steam turbine (HPST) produces 1175.24 kW of mechanical work (P_M). The generated entropy (S_{HPST}) is 460.17 kW and its enthalpy consumption (H_{HPST}) is 1175.24 kW. The consumed exergy (E_{HPST}) is 1635.41 kW. Its efficiency can be calculated based on the definition of fuel and product by the H&S Model and also by the E&S Model represented by Equations 3 and 4, respectively.

$$\eta_{HPST}^{H\&S} = \frac{100 \cdot P_M}{H_{HPST} + S_{HPST}} = \frac{100 \cdot P_M}{m_1 \cdot (h_1 - h_2) + m_1 \cdot T_0 \cdot (s_2 - s_1)} \tag{3}$$

$$\eta_{HPST}^{E\&S} = \frac{100 \cdot P_M}{E_{HPST} + S_{HPST}} = \frac{100 \cdot P_M}{m_1 \cdot [(h_1 - h_2) - T_0 \cdot (s_1 - s_2)] + m_1 \cdot T_0 \cdot (s_2 - s_1)} = \frac{100 \cdot P_M}{H_{HPST} + S_{HPST} + S_{HPST}} \tag{4}$$

Equation 3 calculates the turbine isentropic efficiency (71.86 %), which it is the second law efficiency, but the efficiency calculated by Equation 4 (56.08 %) exaggerates the irreversibility in the turbine, this way the E&S Model can overcharge the cost of the electricity. The condenser efficiency considering the H&S Model (Equation 5) is 96.75 % because 3.25 % are losses due to the cooling, but the efficiency calculated by the E&S Model (Equation 6) is 2976.92 %. In the E&S Model the product of the condenser is greater than its fuel.

$$\eta_C^{H\&S} = \frac{100 \cdot NS_C}{H_C} = \frac{100 \cdot m_6 \cdot T_0 \cdot (s_6 - s_8)}{m_6 \cdot (h_6 - h_8)} \tag{5}$$

$$\eta_C^{E\&S} = \frac{100 \cdot NS_C}{E_C} = \frac{100 \cdot m_6 \cdot T_0 \cdot (s_6 - s_8)}{m_6 \cdot [(h_6 - h_8) - T_0 \cdot (s_6 - s_8)]} \tag{6}$$

$$H_{Ef1} = NS_{Ef1} + Q_U = NS_{Ef1} + E_{Ef1} \Leftrightarrow Q_U = E_{Ef1} = H_{Ef1} - NS_{Ef1} = m_4 \cdot (h_4 - h_{11}) - m_4 \cdot T_0 \cdot (s_4 - s_{11}) \tag{7}$$

The H&S Model can easily justify the function of the Ef1 unit (Equation 7) considering that it receives 7945.72 kW of fuel (H_{Ef1}), which 6072.13 kW is returned as neguentropy (NS_{Ef1}) and 1873.59 kW is absorbed as useful heat (Q_U) to the process. Considering the E&S Model, the justification of the Ef1 function in the plant it not coherent since the Ef1 products (NS_{Ef1} = 6072.13 kW and Q_U = 1873.59 kW) is greater than its fuel (E_{Ef1} = 1873.59 kW).

4. Unit Cost

The objective of the cost allocation in a dual-purpose plant using thermoeconomy is to determine the unit cost (*c*) of the final products, which is generally expressed in \$/MWh for electricity (c_{NP}) and in \$/m^3 for desalted water (c_{DW}), since net electric power (P_{NP}) is expressed in MW and the flow of desalted water (V_{DW}) in m^3/h. The external flows that represent the costs of the equipment and services (*Z*) and also the one that represent the fuel cost (C_{NG}) must be in \$/h.

The set of cost equations in the thermoeconomic modeling also calculates the unit costs (*c*) of the others internal flow. Therefore if the flows that leave the bifurcations will be expressed in kW, their unit cost will be in \$/kWh and if they are in MW, their unit cost will be in \$/MWh. The flows that do not leave bifurcations can assume compatible values with the desired unit cost. For example, the flows of mass (M) in t/h allow the attainment of costs of units of mass (\$/t).

The unit cost assumed for natural gas is 7.20 \$/MWh. The specific capital cost in the desalination unit is assumed to be 12 \$/gpd (1760 \$/m^3) and its operation and maintenance cost is 0.1 \$/m^3. For the remaining equipment that composes the cogeneration unit, the specific capital cost is 950 \$/kW, its fixed operation and maintenance cost is 32 \$/kWy and its variable operation and maintenance cost is 0.0035 \$/kWh. To calculate the hourly cost of real productive units (*Z*), the economic parameters considered are: plant factor (0.9), plant lifetime (25 year) and interest rate (0.08) (El-Nashar, 2001). The cogeneration and desalination unit hourly costs are distributed among the respective real productive units, as it is shown in Table 4.

Table 4: Distribution of the Total Equipment Cost for the Real Productive Units

COGENERATION								DESALINATION	
CB	FP	D	CP2	H	CP1	C	ECSTG	Ef1	Ef2:8AC-TVC
55 %	1 %	1.5 %	0.5 %	1 %	0.2 %	5.4 %	35.4 %	12.5 %	87.5 %

The allocation of the fuel cost and the equipments cost allows the calculation of the monetary unit cost of the two products (in \$/MWh for electricity and in \$/m^3 for desalted water), but the same equation set of the models can be applied to obtain the energetic unit cost of water (in MJ/m^3) and the energetic unit cost of electricity (in MJ/MWh). In this case the equipment hourly cost (*Z*) must be considered null and the hourly fuel costs must be substituted by the fuel consumption (in MJ/h). Figure 4 shows the energetic unit costs of the two products calculated by the three Models.

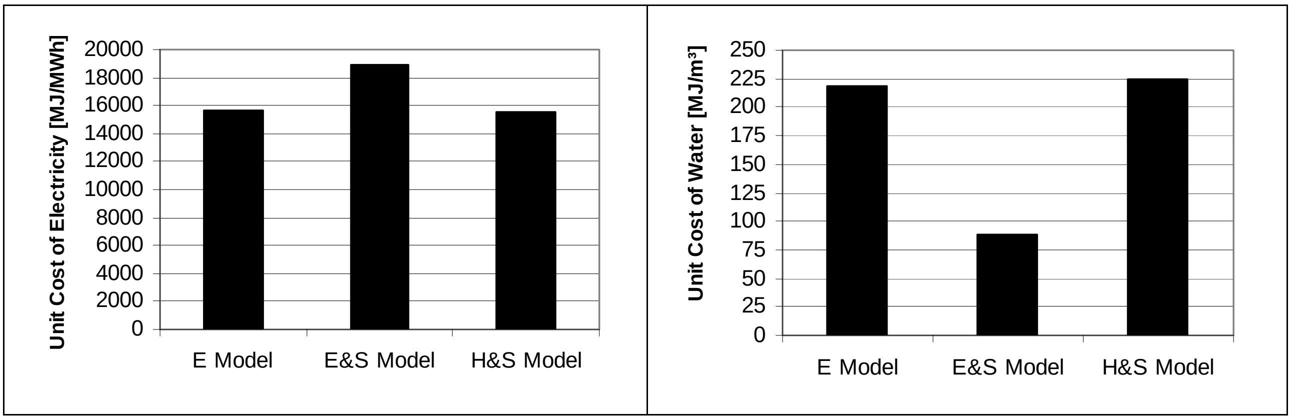

Figure 4: Energetic Unit Cost of Electricity and Desalted Water According to the Three Models

The results shown in Figure 4 demonstrate that the E&S Model overcharges the cost of electricity in detriment of the cost of desalted water. The energetic unit cost of electricity using the E&S Model (18886 MJ/MWh) is greater than the energetic unit cost of the electricity in the same plant when it operates in pure condensing mode (16116 MJ/MWh). This result is not coherent and unacceptable because it contradicts a established energetic advantages of cogeneration. In other words, the energetic cost of the electricity in cogeneration (by E&S Model) is greater than the cost of electricity in a similar thermal power plant. The established advantages of cogeneration say the contrary.

The other two models (E Model and H&S Model) give close results, but the H&S Model allows the plant to be modeled with more details. This way, based on the H&S Model, the energetic unitary cost of the electricity is 15552 MJ/MWh and of water is 225 MJ/m^3. The monetary unit costs of water and electricity in Figure 5 confirm that the E&S Model overcharge the cost of electricity when compared with the E Model and with the H&S Model.

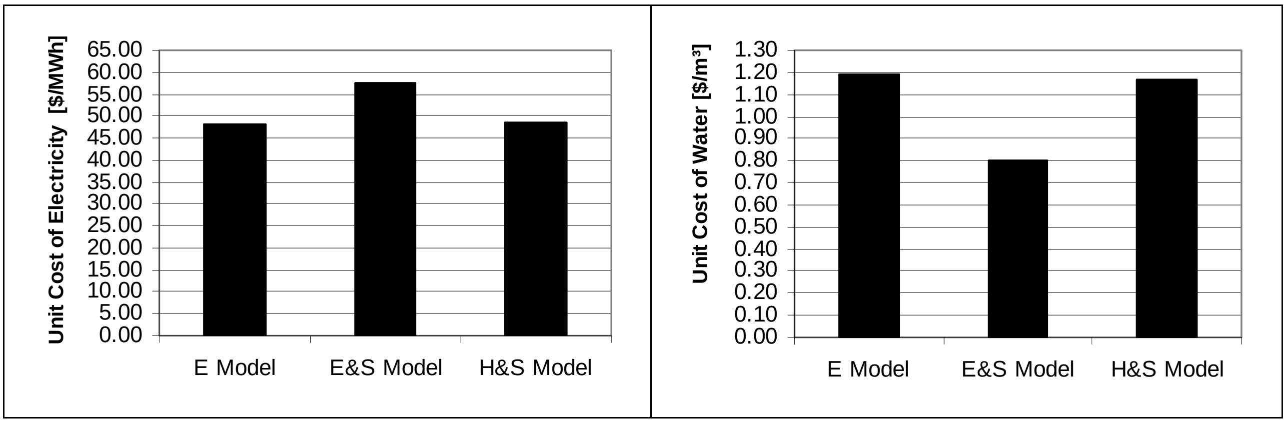

Figure 5: Monetary Unit Cost of Electricity and Desalted Water According to the Three Models

The E Model gives a monetary unit cost of 48.14 \$/MWh for electricity and 1.19\$/m^3 for water. These costs using the H&S Model are 48.66 \$/MWh and 1.17 \$/m^3, respectively. Using the E&S Model the energetic and monetary unitary cost of electricity is overcharged in approximately 20 % in relation to the other two models (E Model and H&S Model).

5. Conclusion

The neguentropy internalization in thermoeconomy is a technique that (if it is applied correctly) allows the attainment of good results for cost allocation in a dual-purpose power and desalination plant, modeling it with all the necessary details.

By using exergy to value part of the internal flows of the productive structure in thermoeconomic modeling with neguentropy internalization (E&S Model) the results overcharges the cost of electricity in detriment of the cost of cost of desalted water. In this work, it was shown that the result of cost allocation using this method (represented by E&S Model) is unacceptable because it contradict some established advantages of cogeneration technologies.

The best way to value the flows of the productive structure in the thermoeconomic modeling is by combining enthalpy with neguentropy or entropy (H&S Model). This way, the concept of physical exergy is indirectly applied because exergy is also the combination of enthalpy and entropy in relation to the reference temperature.

A good alternative of thermoeconomic modeling is the application of exergoeconomy, when the internal flows of the productive structure are valued by their exergy (E Model). This technique does not permit total isolation of the plant (like the H&S Model does), but the results can be satisfactory if the productive structure units are defined by using correct criteria.

6. Acknowledgements

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8. Responsibility Notice