SCENARIOS OF THERMAL ENERGY PRODUCTION FROM FLUE GASES

Ana Rita Seita[p], Cristina Fernandes, Henrique A. Matos, C. P. Nunes

Instituto Superior Técnico – DEQB, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

Bruno Silveirinha

IFM, Apartado 078 Tomar, 2304-909 Valbom, Portugal

Abstract

The utility production at an industrial site is of vital importance because all the process depends on it. Large benefits to manufacturers can be obtained through the optimization of the utility production and operation.

This work aims to study different scenarios for steam production in a hardboard industry, improving the economic performance. The sustainable thermal energy is generated in a biomass moving grate furnace, using the residues produced at the site (hardboard trimming, dust and bark).

In the alternatives studied, steam may be directly or indirectly produced, respectively, from the flue gases or through an intermediate thermofluid heated by the combustion gases. The different scenarios were compared in terms of the required furnace power, the biomass consumption, the total heat transfer area and the total number of equipments, as well as the outlet temperature of the stack, and, consequently, the total global heat recovery efficiency.

Keywords: Heat recovery efficiency, biomass, utilities, flue gases

1. Introduction

The energy supply and production have become one of the most popular subjects discussed all over the world due to the climate changes and the Kyoto protocol. This United Nations protocol has the objective to reduce the greenhouse gases emissions. Therefore, the countries that signed the Kyoto protocol have to create strategies to mitigate the greenhouse gases emissions, through the use of renewable energies and by improving the efficiency of the industrial processes.

The energy production with fossil fuels has contributed strongly to the global warming caused by the elevated greenhouse gases emissions. Due to this effect, the use of biomass, a renewable and carbon-neutral resource, to produce energy has increased in the last years [1,2].

IFM, the hardboard plant interested in this work is located in Tomar and produces panels using eucalyptus as raw material. The fibres are obtained by thermo-mechanical process where the wood chips are heated with steam before defibration. The panels formed in a wet line are pressed inside a multi-stage press and sent to moisture absorption stabilisation chambers.

During the panel's pressing, a black liquor is produced which is sent to an evaporation plant for treatment. In the multiple-effect evaporation plant, the black liquor circulates in counter current with vapour: fresh black liquor is fed to the last effect while live steam is fed to the first one.

Hence, this site is widely dependent on steam, for various processes units such as panel's pressing, wood chips defibration, stabilisation chambers and evaporation.

Currently, biomass and fuel oil are used to produce steam, particularly during winter when biomass moisture is too high, and so fuel oil must be used to guarantee the required steam flow for the process. Consequently, the final hardboard cost is widely dependent on the efficiency and the fuels used for thermal energy production.

The scenario of a world rise of the fuel oil cost accommodates an urgent study of new alternatives to optimize the thermal energy system of this plant.

Therefore, in this study it was firstly identified and quantified the consumption of steam in each process unit mentioned before. In this paper, several scenarios to produce the required thermal energy for the hardboard plant were developed using different equipment such as oil heat exchangers and steam generators. All these alternative designs include a new furnace that allows using only biomass a fuel. Finally, the seven scenarios were simulated and compared in terms of total heat transfer area, total number of equipments and global heat recovery efficiency.

2. Current Steam Network

Proposing new alternatives to improve or substitute an installed utility system requires, to begin with, an overall study of the complete system, enhancing the total description of the units and identifying the steam consumption in each one.

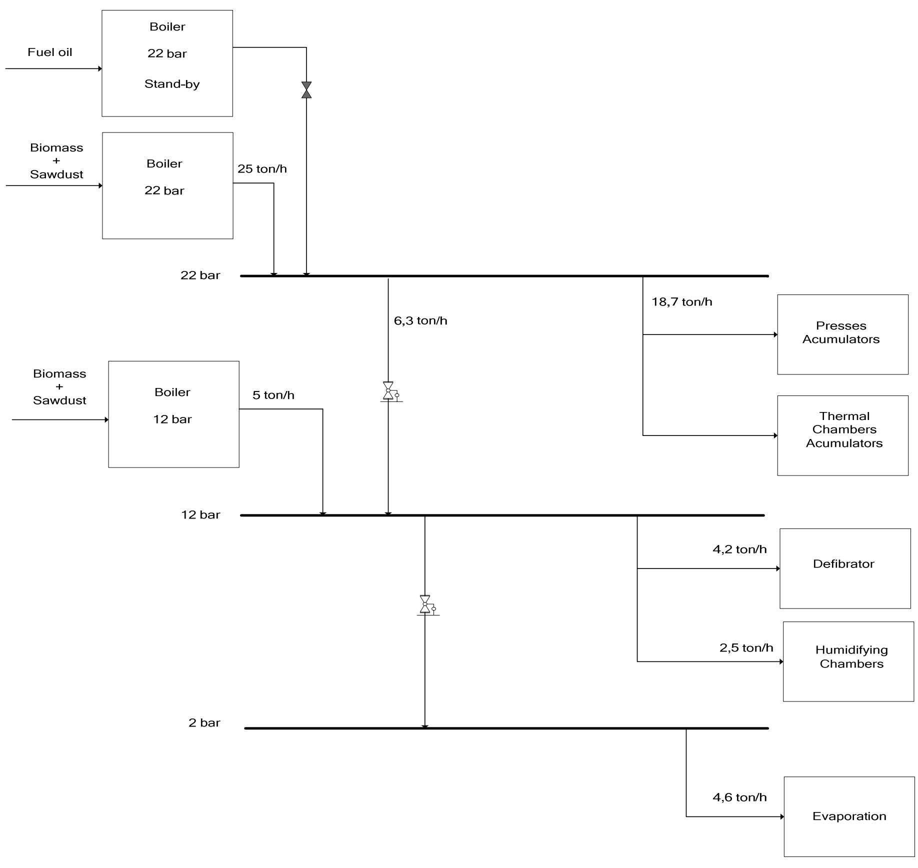

Figure 1 - Current Steam Network

In this site, the steam is generated in two boilers using biomass in a grate furnace. This furnace burns sawdust, hardboard trimmings, bark and wastes produced in the process.

When the moisture of the biomass is high, especially in winter, the site uses fuel oil in another boiler that, otherwise, remains in stand by mode.

The main boiler generates steam at 22 bar, which is used in the panel's presses and thermal chambers, while the other boiler produces steam at 12 bar for the wood chips defibration, humidifying chambers and for the evaporation unit (at 2 bar). The two steam systems are connected, to guarantee a constant supply of steam. This system produces a total of 30 ton/h of steam as shown in figure 1.

The values inserted in the figure 1 were obtained during the normal operation of the plant, and therefore used as average input values in mass and energy balances.

Since the real steam duties of the each unit are defined, it is possible to study the viability of new alternatives in comparison with the current installed system.

3. Scenarios for a New Utility System

In all alternatives proposed, only one furnace is necessary to generate the combustion flue gases to produce the total steam required by the process. The furnace includes a moving grate moving which is able to burn biomass with high moisture and the sawdust generated in the process.

The new concept of this system is that the flue gases from the combustion chamber will generate steam indirectly in a thermo-oil/water heat exchanger. Therefore using different designs, almost all alternatives studied exploit this strategy to produce steam.

3.1 Scenario 1

This scenario uses the flue gases to heat the thermofluid that circulates in a closed loop with a 40 º C temperature increase. Thus, the hot oil is used in the 22 bar saturated steam generator and in the 12 bar steam generator to satisfy the process requirements at those levels.

The flue gases exiting the oil heater, after preheating the feedwater, are released into the atmosphere at 324 ºC, as shown in figure 2.

3.2 Scenario 2

In this scenario, the generation of the steam at different pressures is made separately. While the steam at 22 bar is generated directly with the flue gases, the steam at 12 bar is generated indirectly with a hot oil, This heated fluid is obtained in the oil heater with the flue gases coming from the steam generator at 22 bar.

Finally the flue gases from the oil heater, at a lower temperature about 303 ºC, generate the steam at 2 bar for the evaporation unit, as shown in the figure 3.

Before the exhaust gases are released into the atmosphere at about 118ºC, they are used to preheat the feedwater for the steam generators.

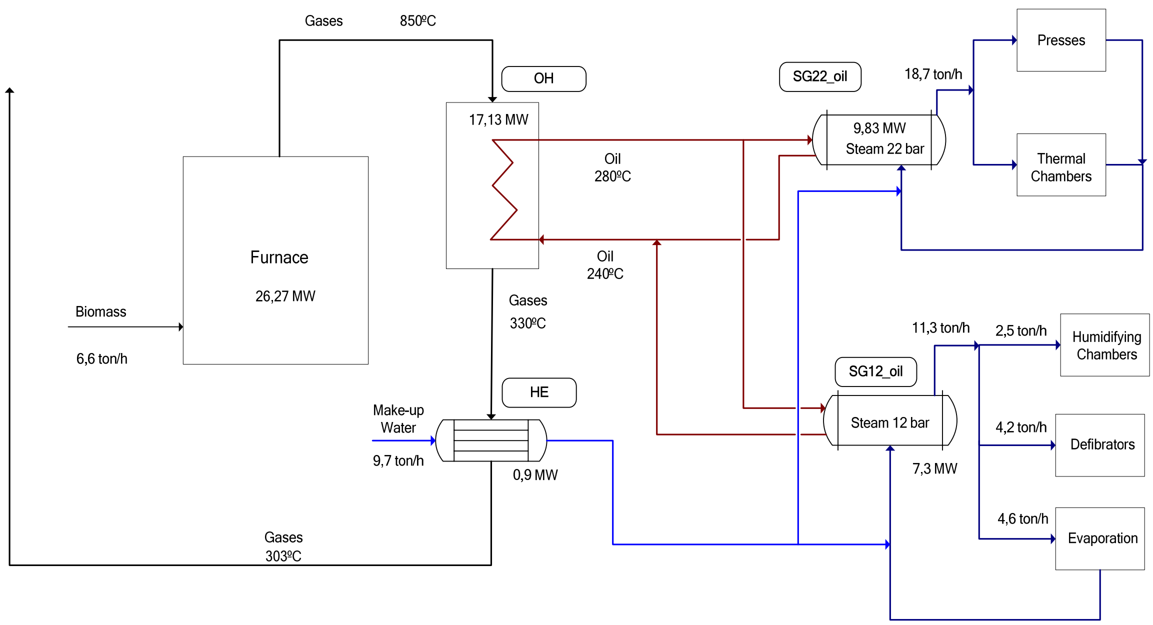

Figure 2 – Scenario 1

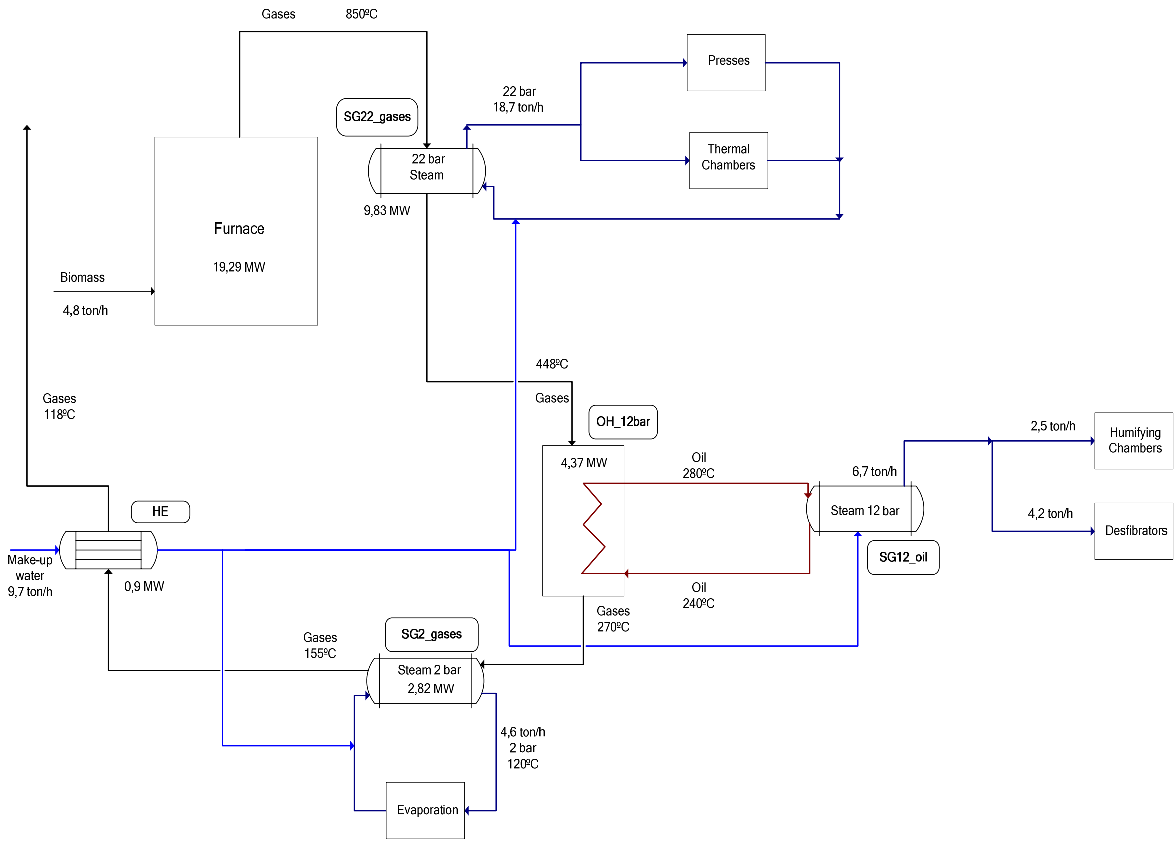

Figure 3 – Scenario 2

3.3 Scenario 3

The third scenario is similar to the second one but in this case the oil heater is used to generate the steam at 22 bar. The steam at 12 and 2 bar are produced by the flue gases from the oil heater as shown in figure 4.

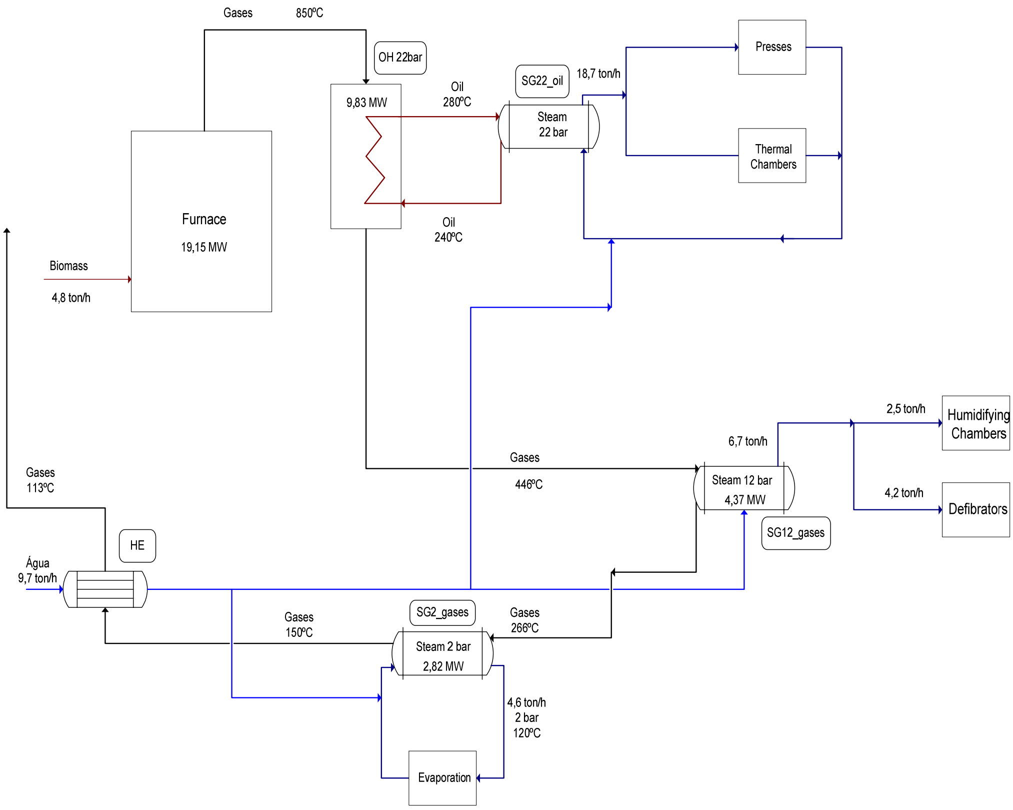

Figure 4 – Scenario 3

The flue gases from the lower pressure steam generator will preheat the feedwater required for the steam generators. The exiting temperature for this scenario is 113º C.

3.4 Scenario 4

This scenario has two oil heaters for steam generation at 22 bar and 12 bar.

The required 2 bar steam is obtained through the flue gases exiting from the oil heater that generates the 12 bar steam. Finally, the flue gases are used for preheating the feedwater before being released into atmosphere at a temperature of 118 ºC (figure 5).

3.5 Scenario 5

In this scenario, the two oil heaters are used to produce all the steam required for the process. Therefore, the 22 bar steam and the 12 bar steam are generated, respectively, in the first and second oil heater.

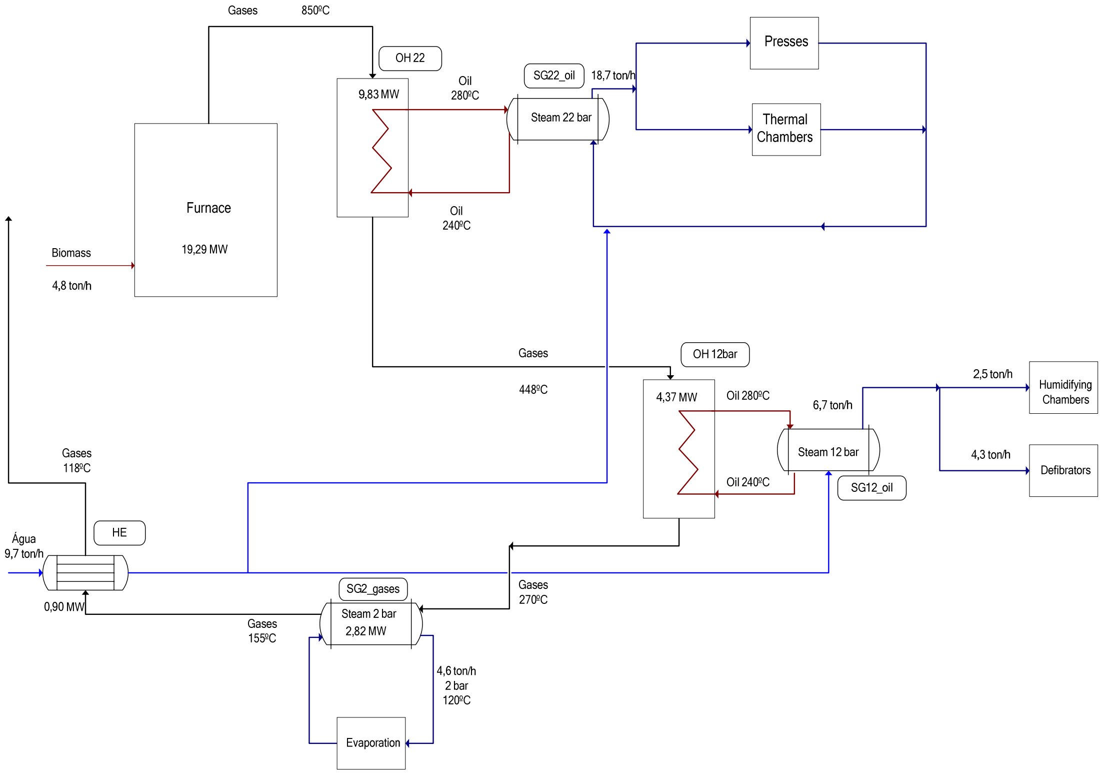

Figure 5 – Scenario 4

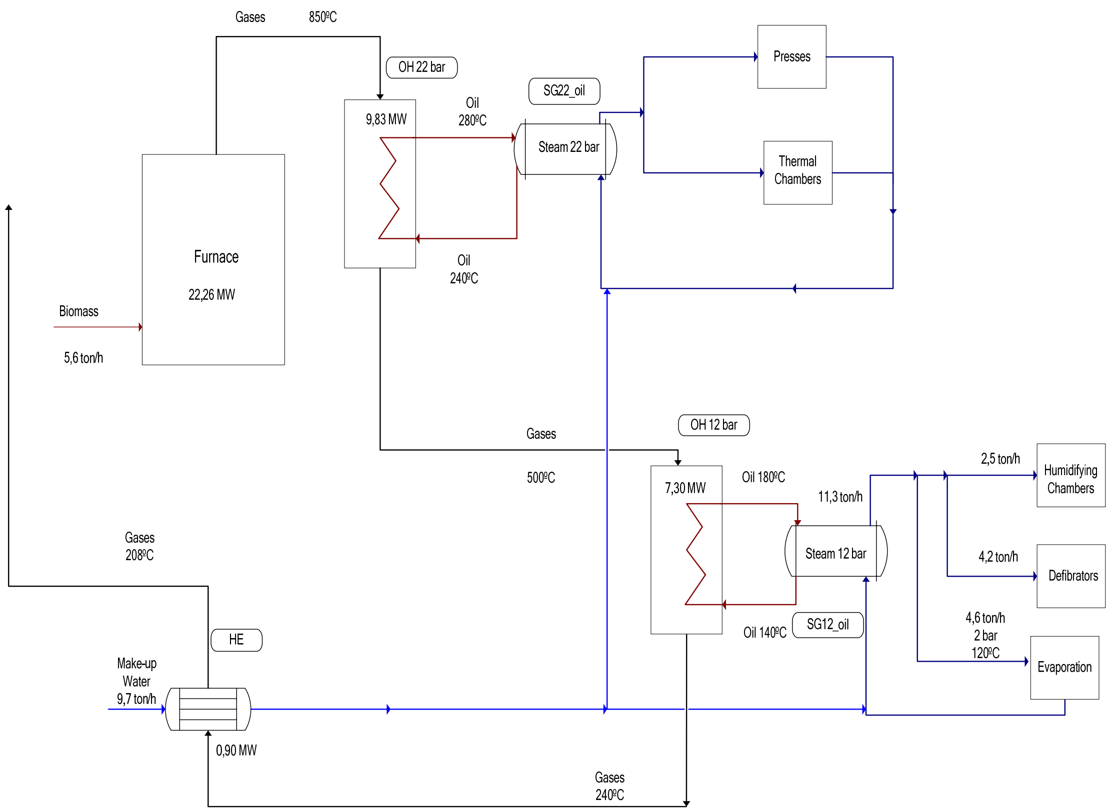

Figure 6 – Scenario 5

The required 2 bar steam for the evaporation unit is obtained by expanding some of the produced 12 bar steam using a reducing valve. Hence, the second oil heater has to give the thermal energy to produce the total flow of steam at 12 and 2 bar.

3.6 Scenario 6

The scenario 6 has three oil heaters to generate steam at 22 bar, 12 bar and 2 bar as shown in the figure 7.

Once again, the flue gases from the last oil heater will preheat the feedwater for the steam generators and exiting at 155 ºC.

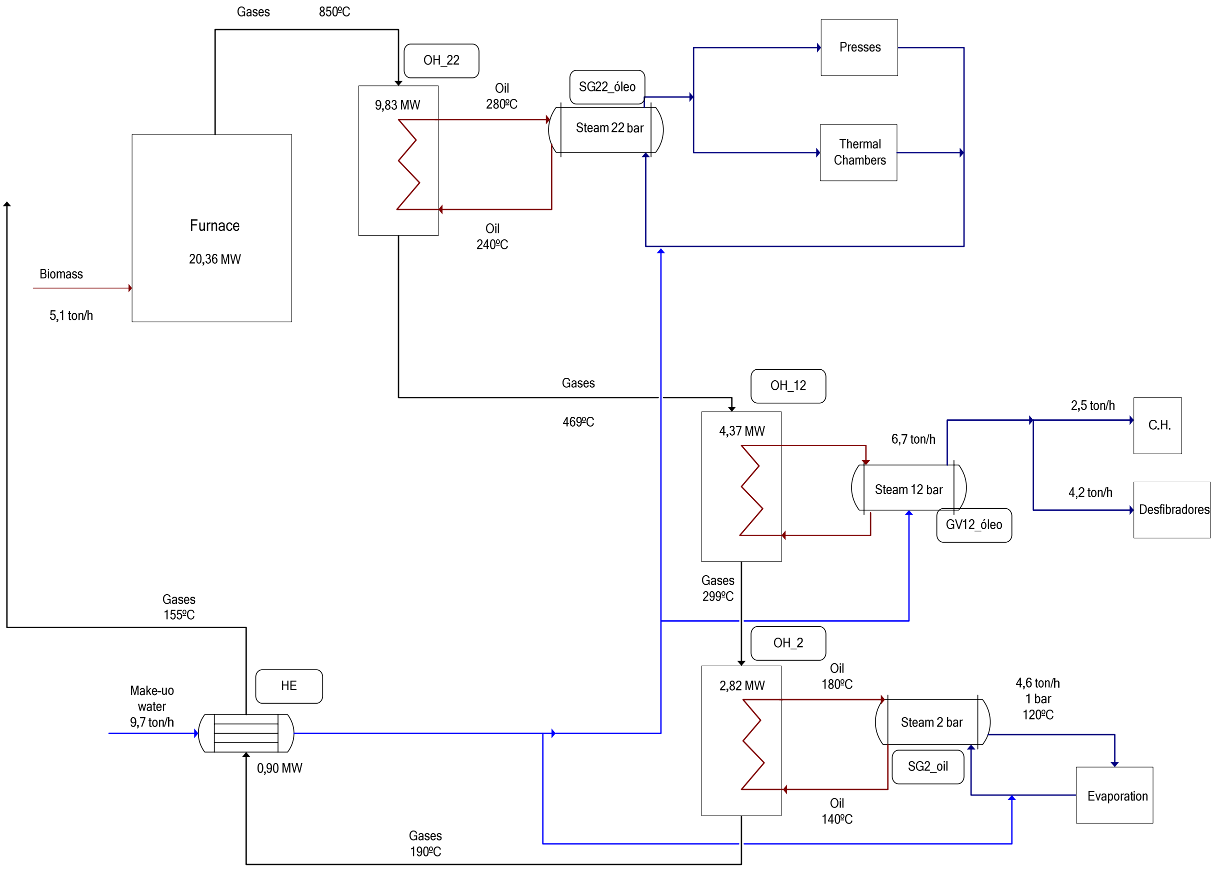

Figure 7- Scenario 6

3.7 Scenario 7

In this scenario, the configuration is slightly different from the others scenarios because there is no 12 bar steam generator. In this case, the 12 bar steam is obtained by mixing the 22 bar steam with 2 bar the steam as shown in figure 8.

Hence, there are two oil heaters for the steam generation at 22 and 2 bar and, the exit flue gas preheats the feedwater for the steam generators, before being released into the atmosphere, at 161.4 ºC

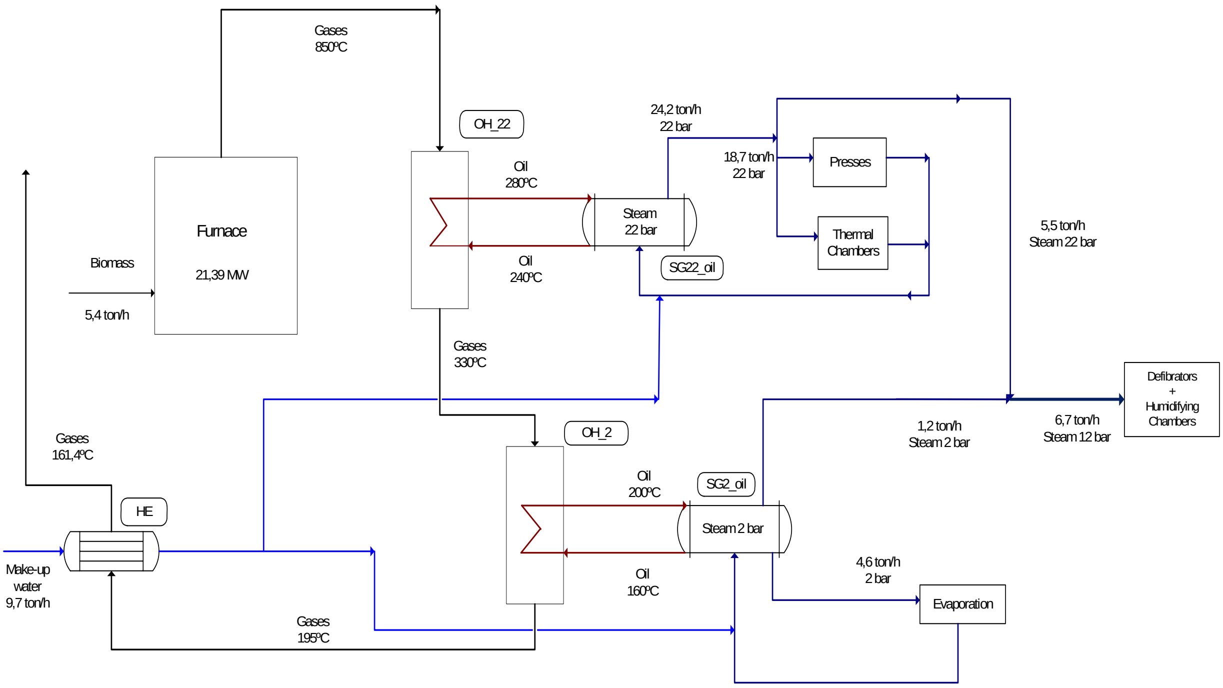

Figure 8 - Scenario 7

4. Simulation Results

The furnace power required in each scenario was calculated by considering the weighted average of low heating value (LHV) of the biomass used. The LHV obtained for this case study is 14374 kJ/kg based on the average composition of the combustible used mainly dust, trimming hardboard, bark and others.

The water make-up takes into account the losses in the steam network (blowdown boiler, purges) and the steam used in the defibrators and humidifying chambers, because in these two units the steam is used without return. Moreover, the losses assumed in steam network were 10% of the total steam produced.

The scenarios variables, such as flowrates, temperatures and heat-exchanger's area, were calculated through the minimisation of the exhaust gas temperature, assuming a minimum of ΔT equal to 90ºC in the flue gas heat exchanger just after the furnace. In the others heat-exchangers a minimum ΔT of 30ºC was assumed.

Table 1 shows, for each scenario the furnace power, the furnace grate area, the exiting gases temperature, the total heat exchanger area, the biomass flowrate, the global efficiency and the number of main heat transfer equipments.

The global efficiency was calculated according to the equation (1), which gives the ratio between the net heat used in the process (Q_{used}) over with the total heat produced at the furnace ($P_{furnace}$).

$$\eta\,(\%) = Q_{used} / P_{furnace} \times 100 \quad (1)$$

Table 1- Simulation Results obtained for the scenarios

	$P_{furnace}$ (MW)	Grate area (m^2)	T exiting gases (ºC)	Heat transfer area (m^2)	Biomass ton/h	Efficiency	# Equip.
Scenario 1	26,3	19,8	302,6	1221	6,6	69%	3
Scenario 2	19,3	14,6	118,1	1690	4,8	93%	4
Scenario 3	19,2	14,5	113,1	1628	4,8	94%	4
Scenario 4	19,3	14,6	118,1	2134	4,8	93%	5
Scenario 5	22,3	16,8	207,9	1729	5,6	81%	4
Scenario 6	20,4	15,4	155,0	1824	5,1	88%	6
Scenario 7	21,4	16,1	161,4	1948	5,4	87%	4
Current Situation	27,2	-	200,0	-	6,8	75%	-

The scenario 1 is the worst scenario, because it has the higher power furnace due to the high exhaust temperature of the gases. This is an unfeasible situation given the regulatory norms that limit the flue gas exiting temperature. Besides, it is also a waste of energy which causes the lowest energy efficiency and the higher operational costs namely in the biomass consumption.

The fifth scenario has an exiting gases temperature higher than the current situation, therefore it is an infeasible solution. Like in the scenario 1, the 2 bar steam is generated through an expansion of 12 bar steam causing a reduced usage of the flue gases enthalpy at a lower temperature.

The scenarios 2, 3 and 4 are very similar and only differ in the number of oil heaters and their position in the configuration. Therefore, the power furnace, the efficiency and consumption of biomass are also very analogous.

Scenarios 6 and 7 have lower energy efficiencies and higher exiting gases temperature compared with scenarios 2, 3 and 4.

5. Conclusions

The energy efficiency of each scenario depends on the exiting gases temperature. If the exiting temperature is lower, the efficiency will be higher and consequently the consumption of biomass is reduced. For that reason, the scenario with the highest energy efficiency will be also the one with reduced operational costs.

Although, this study was yet performed without a detailed cost evaluation, it is possible to choose scenario 3, as the best scenario. This alternative was selected based on the higher efficiency, the lower biomass consumption, the lower heat transfer area and the lower exiting gases temperature. These variables values also guarantee the lower power furnace and the lower number of heat transfer equipments.

In comparison with the current situation, scenario 3 will reduce the power furnace in about 30%, the exhaust temperature will decrease 87ºC and the consumption of biomass will be reduced around 2 ton/h and the energy efficiency will increase 19%.

References

[1] United Nations Framework Convention on Climate Change. Kyoto Protocol, <http://unfccc.int/kyoto_protocol/items/2830.php> [accessed January 09]

[2] Frankl, P. and Gielen D.;"*Energy Technology Perspectives 2008*", IEA, 2008

[3] Smith, R.; "*Chemical Process Design and Integration*", Wiley, 2005

Contact

Instituto Superior Técnico

Departamento de Engenharia Química e Biológica

Av. Rovisco Pais, 1049-001 Lisboa, Portugal

Phone: +351 841 9166 / 351 841 9170 / 351 841 7639

Fax: +351 841 7638

E-mail: anaritaseita@gmail.com, mc.fernandes@ist.utl.pt, henrimatos@ist.utl.pt

URL: http://groups.ist.utl.pt/cpq/