INTEGRATION OF RENEWABLE ENERGY SOURCES FOR INDUSTRIAL CONSUMERS

Roxana PĂTRAŞCU[1], Andreea BĂDICU[2], Eduard MINCIUC[3], Ioana DIACONESCU[4], Horia NECULA[5]

The paper presents an alternative of integrating renewable energy sources for industrial consumers. The object of the case study is a wood processing company. In order to increase the energy and economic performance of the technological process, an energy audit has been performed. One of the proposed solutions following the audit is to valorize waste biomass from technological process for covering a part of heating demand for the analyzed contour. Technical and economic analyses of the solution led to the conclusion that using wood waste as an energy resource is economically efficient.

Keywords: renewable energy sources, biomass, wood waste, energy efficiency, energy audit

1. Introduction - General aspects regarding integration of renewable energy sources for industrial consumers

Reducing environmental impact in industrial sector with an emphasis on the reduction of the greenhouse effect gas emissions (GHG) is one of the existing priorities of the current time. This concern rises not only around the major energy producers but also in the consumption area, including the prosumers.

Regarding this, it is found an increase in the integration level of these systems, as their operation becomes more and more interdependent.

Although starting from 2017, the support scheme for renewable sources („green certificates”) has been eliminated, it is expected that they represent an alternative for covering the thermal and/or electrical energy demand. Regarding the prosumers, it is expected that the use range of biomass, biogas, photovoltaic panels,

[1] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: op3003@yahoo.com
[2] PhD Student, Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: andreea.badicu@gmail.com
[3] Associate Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: eduard.minciuc@energ.pub.ro
[4] Associate Prof., Depart. Of Materials Science and Engineering, “Dunarea de Jos” University, Galați, e-mail: ioana.diaconescu@ugal.ro
[5] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: horia.necula@energ.pub.ro

and heat pumps will increase. Also, worth mentioning is the trend by which a consumer wishes to interact with as few utilities providers as possible regarding the coverage of their own needs. [1]

2. General aspects of the evaluation of industrial contour's energy efficiency based on energy audit

Energy efficiency, as a ratio between the value of the performing outcome obtained, consisting in services, goods or resulted energy, and the energy used for these purposes shall be carried out based on an energy audit in the analyzed contour. [2]

Therefore, the energy audit is the systematic procedure of acquiring data about existing energy consumption of an activity and/or industrial equipment, of identifying and quantifying profitable opportunities for energy savings and reporting the results.

The mentioned procedure highlights:

- energy exchanges (under various forms) between the inside and outside of the contour;
- energy exchanges which take place within the referential contour, between the analyzed system's components, and the way the outside resources are used;
- consumption centers, where energy inefficiency manifests, the value and nature of energy losses;
- decisions taken after the analysis are intended to improve the energy efficiency of the whole system: reorganization, rationalization, enhancements, upgrades, refurbishment. [3]

The main steps for the drawing up of an energy audit of an industrial contour have the following structure:

- Establishing the contour;
- Technical characteristics of the main devices and industrial equipment within the contour;
- Flow diagram of the technological process;
- Main presentation of the technological process (technical, functional, economic and environmental impact parameters);
- Setting the referential unit for the audit (hour, cycle, year, tone, charge) – in the case that mass and energy balance is used as work tool;
- Measuring equipment used, technical characteristics and accuracy class;
- Schemes and the measuring points;
- Measurement sheets;
- Measures and balance equations;

- Measures calculation from balance equations (analytical expressions, calculation formula);
- Drawing up and synthesis of balance tables and Sankey diagrams;
- Balance analysis (comparing the useful components and losses with those carried out from the processes and similar installations, project, reception, assimilation, known worldwide and in technical literature);
- Plan of measures which is intended to increase the energy efficiency;
- Economical evaluation of measures to increase proposed energy efficiency;
- Ecological evaluation measures to increase proposed energy efficiency. [4]

3. The case study – Presentation

The object of this case study is a company of wood processing which manufactures windows, doors and furniture from the laminated wood, using modern and environmentally friendly technologies and computer-aided equipment.

The stages of the analyzed technological line, for the manufacturing of composite panels of wood used to obtain the finished product are:

- storage of wood in stacks or in bulk, in covered spaces, to ensure the natural drying and wood preservation;
- trimming and assembling by pasting wood of small length, which may not be cut off directly into the plates;
- trimming the wood selection having minimum two sides perpendicular, which will allow the positioning and the advance on the across cut of the plates;
- finishing thin wood selection and bonding it into blocks of four, six or more pieces; this technique can also be applied to the thicker wood type;
- cutting on the normal direction of the plates fiber, their numbering and storage in boxes in the order of their cutting; a particular case is cutting to an angle of approximately 40-45^0, which affects the texture and which increases the contact area of the connection made by pasting the edges;
- storage of the boxes into adequate spaces in order to avoid plates’ deformation;
- the formation of the wood plates by cutting and sanding on the edge, with or without chipping, depending on the design; the polygonal shape of the plates differs, from triangle and square to 8-9 sides polygon;
- assembling by gluing on the edge of the plate, for the purpose of carrying out the decorative blade, through the use of bonding adhesive;
- chemical or mechanical releasing of the decorative blade or of each plate, in order to release the panel to avoid distortion and establish flatness;
- making the decorative blades from the design and technical point of view;
- storing the decorative blades by stacking on the plan stands in the conditioning space;

- gluing under pressure of the decorative and tension balance blades on the composite support using adhesives with warm or cold gluing;
- stacking and conditioning of the resulting panels in adequate spaces;
- calibration by sanding of the panels on broadband machinery, using abrasive belts with appropriate grit for the density of the wood used for the plates with cross texture;
- forming the panel and edge protection by applying the veneer blades, solid wood or trimmings.

The technological line incorporates a modern equipment, ROVER C 6 40 type, which is a wood processing equipment with numeric command CNC, with five interpolation axes, providing complex, precise and qualitative processing operations, making it possible to obtain any geometry of the product. “Y” axis is independent, which allows the operator to exchange the tool without affecting the work cycle. Also, high axial speed and acceleration guarantee the high productivity of the process. [5] [6]

The energy audit has led to the identification of the various types of problems which solving can lead to increasing energy efficiency through the integration of advanced recovery of wood waste (biomass) in the same time with effects on growth in economic efficiency of the company. [7] [8]

The recovery of wood waste (biomass) would also have a positive impact on the environment by reducing the quantity of wood waste and by reducing the inputs of primary non-renewable energy sources (conventional fuel saved). [9]

One of the major technological problems for any wood processing company is the production of wood waste in variable quantities according to the number of marks and work orders. The storage of the wood waste is expensive and pollutant and at the same time, it poses a self-ignition hazard issue.

This aspect leads to proposing a strategy for reducing the wood waste quantity at the same time with a strategy for using the waste in real time for technological purposes and for increasing the energy performances.

Generally and practically, a multi-task approach could solve the identified problem, through technological and energy optimization. [10]

a) From technological point of view: the implementation of the best cutting technology for wood plates leads to reducing the quantity of wood waste.
b) From energy point of view, the process of optimization implies:

- using the wood waste as a secondary energy source to produce heat required in the wood drying process;
- if the resulted heat flow is greater than that required for the wood drying process, the excess heat could be used to produce hot water for consumption. Practically, in this situation, the wood waste could also be used for energy

production in order to cover the thermal energy needs of the company (heating, ventilation);

- integrating a hot water biomass boiler into the existing technology. The boiler uses the wood waste of the technological process to cover the thermal energy demand of the company;
- using the waste wood as fuel for a cogeneration plant, to produce both thermal and electric energy. [7]

4. Energy and economic evaluation of the analyzed industrial contour – furniture factory

The evaluation of the company has been carried out based on the energy audit. In this regard, the contour limits for the audit have been considered as follows:

a) the technological line for wood processing
b) the whole industrial company

The energy audit led to the following preliminary observations:

The company’s annual expenses with utilities are shown in Table 1.

Table 1

Annual expenses with utilities

	Annual consumption [MWh/year]	Annual expenses [euro]
Electricity	2555	215.704
Natural gas	439	14.333

The heat demand (for space heating) is 130 kW.

The annual wood consumption: a total of 240 m^3, of which 70% semi-finished wood and 30 % sawed timber.

The annual wood losses after processing: 55% of the total processed amount.

Heating value of wood: the medium value is in the range of (18000-18800) kJ/kg.

Following the elaboration of the energy audit, the program of measures to increase the energy efficiency includes:

- Implementation of parametric modeling software which would allow creating 3D models of the finite wood products. This will lead to optimization of the woodworking technology and diversification of wood products supply, with the final goal of reducing technological wood losses. This measure refers to technology improvements.

- Integration within the existing technology of a dryer for the raw material (wooden panels), allowing the recovery of wood waste resulting from the technological process. This measure refers to energy improvements.
- Integration into the existing technology of a hot water biomass boiler (using technological wood waste as fuel) to cover the heat demand for heating and domestic hot water preparation within the industrial contour.

After the implementation of the first two measures mentioned above – the integration of a parametric modeling software and the use of a dryer for raw materials – the wood mass losses of the technological line became approx. 35%, of which 15% for semi-finished wood and 50% for sawed timber, cumulating a volume of 61,2 m^3 of wood waste annually.

Under these circumstances, it has been found appropriate to implement into the existing technology of a hot water biomass boiler to provide the necessary heat to cover part of the industrial contour's demand for heating and domestic water preparation. [8] [9]

4.1. Estimation of annual heat production from biomass (industrial wood waste)

$$Q_{b\ annual} = V * \rho * PCI * \eta_b = 155\ [MWh/year]\ , \tag{1}$$

Where:
V = annual volume of wood waste [m^3/year]
ρ = average wood density [kg/ m^3]
PCI = average heating value of wood [MWh/kg]
η_b = biomass boiler efficiency [%]

The annual heat demand (for space heating and domestic water preparation) of the analyzed contour is estimated to be 418 MWh/year, therefore the heat production of the biomass boiler can cover approx. 37% of the total demand.

The annual fuel savings will be:

$$Q_{ec\ annual} = \frac{Q_{b\ annual}}{\eta_c} = \frac{155}{0.95} = 164\ [MWh/year] \tag{2}$$

Where:
η_c = natural gas boiler efficiency [%]

The natural gas boiler efficiency has been assumed as being 95 %, although the annual value of this efficiency is lower. But there should be mentioned that the lower annual natural gas boiler efficiency is the more annual fuel savings can be achieved, and thus the more efficient is the proposed project of using biomass replacing fossil fuel.

4.2. Economic analysis of the solution

In order to assess the economic efficiency of the solution, the analysis has been performed based on actualized values, using the Net Present Value (NPV), Internal Rate of Return (IRR) and Simple Payback Period (PBP). [11]

$$NPV = \sum_{i=1}^{n} \frac{IN_i - C_i}{(1+a)^i} \quad \text{[euro]} \tag{3}$$

$$PBP = \frac{I}{IN - C} \quad \text{[years]} \tag{4}$$

Where:
I = total investment [euro]
IN_i = annual revenues [euro]
C_i = annual expenses [euro]
a = actualization rate = 0,1
n = period of evaluation = 10 years

The total investment of the analyzed solution is:

$$I = 8000 \ [euro] \tag{5}$$

The annual gross savings will be:

$$E_{annual} = Q_{ec\ annual} * p = 164 * 32.66 = 5357 \ [euro/year] \tag{6}$$

Where:
p = selling price of natural gas [MWh/an]

Considering the annual maintenance expenses for the biomass boiler approx. 2% of the investment price, the annual net savings will be:

$$E_{net\ annual} = E_{annual} - C_m = 5357 - 160 = 5197 \ [euro/year] \tag{7}$$

Where:

$$C_m = 0.02 * I = 160 \ [euro/year] \tag{8}$$

The results of the economic efficiency analysis reveal that the solution is economically efficient, as NPV>0 and IRR>10%. The investment will be recovered in a short period of time (PBP=1,54 years). The results are shown in Table 2.

Table 2

Economic efficiency criteria results

NPV [€]	21 575
IRR [%]	64%
PBP [years]	1,54

5. Conclusions

A. Energy effects

The energy effects are quantified by the economy of fuel achieved as a result of wood waste recovery. The main energy criterion used to assess the energy efficiency of the proposed solution is the fuel equivalent of the energy savings, defined as the difference between fuel consumption before and after recovery (absolute value and relative value). The positive result of this energy savings is reflected upon both the restricted contour of the plant and the broad contour of the economic operator.

B. Economic effects

Economically, the immediate effects are primarily determined by the energy savings. The energy demand of the contour decreases, thus reducing the consumption of conventional fuel. This will diminish the production expenses and will lead to lower cost prices of the technological products – wood product delivered. The indirect economic effect above mentioned, namely reducing the call on primary energy, is determined by lowering the energy losses and the actual energy consumption during the fuel extraction and transport stages.

C. Environmental effects

Wood waste recovery leads to important environmental effects, such as: reducing the amount of waste produced by the company, reducing the share of non-renewable primary energy sources (fuel savings). Hence, the project will help to increase the energy and implicitly, the economic and financial performances of the company and will improve the services quality of the company, both on domestic and foreign markets. [12] [13]

The results of implementing energy efficiency projects for the presented case study may lead to an expansion in experience and good practice in this industrial field in terms of:

- realizing a Guide for efficient use of wood processing technologies, which will subsequently enable the implementation of a coherent and efficient energy management, with maximum effects;

- validating the complex energy, environmental and economic performance analysis methodologies of wood processing, which will allow for the obtained results to be transposed into flexible energy models, with broad applicability in the wood processing industry (in similar technological flows).

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