Application of Biomass for the Production of Energy in the Portuguese Textile Industry

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Abstract—The use of biomass as energy source becomes considered again as a possibility, after a period in which practically felt in disuse, especially in industrial environments. Nowadays is becoming again an alternative, mainly due to the increasing prices of fossil fuels, especially oil and natural gas, as well as by the growing environmental and sustainability concerns, since the biomass fuel is considered neutral in terms of CO$_2$ emissions. The use of biomass as solid fuel presents logistic difficulties, which do not allow their straightforward dissemination in all industrial units that intend to change its fuel. However, counterbalanced by excellent results from the economical point of view, achieved due to the stability of biomass prices in Portugal, the application of biomass is envisaged in this paper as a sustainable alternative to fossil fuels for the Portuguese textile industry. Hence, a real case study is provided to discuss advances and developments in the field of biomass applications.

Keywords—biomass; textile industry; application; energy source.

I. INTRODUCTION

The world’s demand for energy grows rapidly, and therefore, the time has come to look for alternative sources of energy, such as renewable energy, to replace the rapidly depleting supply of fossil fuel [1]. Energy resources will play an important role in the world's future. Energy is considered a prime agent in the generation of wealth and a significant factor in economic development [2]. There are many alternative new and renewable energy sources which can be used instead of fossil and conventional fuels. Biomass is a renewable energy source from the point of view of energy security and climate change mitigation [3]. Energy security is a factor of great importance, vital to the economic growth of any developing country. According to a recent study from the European Commission, the price of oil and natural gas in 2050 will double current price [4]. Renewable energy resources that use domestic resources have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases [5]. Renewable energy technologies produce marketable energy by converting natural phenomena into useful forms of energy [6]–[7].

The global energy needs will also double the current ones by mid-century, mainly due to fast industrial growth in developing countries [8]. Another study, from the International Energy Agency, points to a similar trend, with an increase of about 50 % of energy needs by 2030, of which 70 % correspond to the needs of China, India and other developing countries [9].

The Portuguese textile industry faces serious competitive difficulties, mainly due to high production costs, caused by extremely high energy costs that are currently practiced in Europe, particularly in Portugal. Being a highly diversified industry, with many different production processes, a specific sector has been identified, the textile dyeing sector, for being a large energy consumer, needing large amounts of steam in its manufacturing process [10].

The textile industry is a fragmented and heterogeneous sector dominated mainly by small and medium enterprises, focusing on clothing, home textiles and industrial use. This industry represents in the European Union (EU) [11]:

- 3.4% of the manufacturing sector;
- 3.8% of the economic value added;
- 6.9% of industrial employment.

In energy terms, the textile sector accounts for 6.3 % of the total energy consumed in the manufacturing industries of Portugal, which in turn accounted for 27.5 % of final energy consumption in Portugal [12].

Productive sectors of textiles with greater weight in energy consumption are the finishing and dyeing, when compared with others (such as spinning, weaving and tailoring). The dyeing and finishing sectors have a strong thermal component, which allows to take action to reduce waste in the current system and where major investments are acceptable, or are able to minimize the limitations of the Second Law of Thermodynamics, or allow the recovery and utilization of the heat rejected to the environment at present [13].

The textile industry activities are distributed throughout Europe, but are more concentrated in some EU countries. Italy is the main producer in Europe, far ahead of Germany, UK, France and Spain. These five countries account for over 80 % of companies in the textile industry in the EU, which in 2000 reached a turnover of 198 billion employing about 2.2 million people [14].

In Portugal, the location of textile companies occurs mainly in the north of the country, and in terms of skilled labor employed in the sector also the North is predominant. The textile and clothing chain is composed of a large number of sub-sectors that encompass the entire cycle raw materials (synthetic fibers and raw semi meshes) and the final products of consumption (home textiles, clothing and industrial use).
The Portuguese textile dyeing industry still relies mostly on natural gas as fuel, using also naphtha and propane gas due to logistical reasons or in the absence of natural gas distribution.

The cost of steam production using steam boilers (typically 90°C temperature and 10 bar pressure) represents about 60% of total industrial energy costs in textile dyeing industry. Therefore, since biomass is an important source of primary energy, renewable and with clear advantages when compared with fossil fuels, in particular with regard to issues related to global warming, the possibility of using this form of energy, as an alternative, is very promising [15].

Steam production engineering alone, however, will not be able to transform the energy markets. New, highly distributed business processes will need to be established to accommodate these market evolutions, mainly due to biomass logistic control networks. The traditional static customer process will increasingly be superseded by a very dynamic, decentralized and market-oriented process where a growing number of providers and consumers interact [16].

This paper addresses the major economic issues related to the use of biomass energy as a sustainable alternative for the textile industry, taking into account real-world data from ten major textile dyeing industrial units located in the north of Portugal.

II. ENERGY SOURCES USED BY THE TEXTILE INDUSTRY

Textile industry is an industry with tradition, and despite the serious crisis affecting, it is still one of the most important Portuguese industrial sector, always assuming a prominent role in terms of employment and a prominent position in the Portuguese economy. It is a mature sector, fragmented and subject to periodic mismatches between supply and demand, whose performance is strongly affected by fluctuations in global economic activity [17].

The liberalization of the global textile trade, with the consolidation of the position of Asian countries in the European market, has aggravated the difficulties that the industry has experienced in recent years, affecting not only Portugal but all over the European sector of the textile industry. The future and recovery of this sector pass through increasingly larger bet on factors such as R&D, design, innovation, pursuit of excellence, quality, distribution, logistics, internationalization of their products, especially those containing high levels of differentiation, and also by rationalization of energy consumption by both the savings and the adoption of new energy sources and the modernization of production processes.

The textile sector should thus strengthen and invest in intangible factors of competitiveness in order to project companies in the market and companies orient themselves to the elements that contribute most to add value to their products, thus becoming more competitive.

In terms of energy, the textile sector represents about 6.25% of the total energy consumed in manufacturing industries in Portugal, which in turn represents 20.4% of final energy consumption in Portugal. Of the total energy consumption in this industry, heating processes represent up to 60% of that total.

Audits of this sector showed that it is characterized by preparation or production of fibres, thread production, fabric production, finishing of textiles and final product fabrication. Of all these processes, finishing processes in particular consumes mostly thermal energy. Thermal energy is used in steam production processes, thermal oil heating, drying and coating heating. It is also consumed in washing phases, which vary depending on the product and material, and in fibre harvesting processes or in following ones for textiles or after coloring and stamping [18].

The textile industry is traditionally an industry with intensive energy expenditures. In general, the energy is used in the textile industry in the form of [19]:

- Electricity consumed in operating industrial machinery and equipment production, lighting, and other office equipment;
- Liquid or gaseous fuels, such as naphtha, propane or natural gas for thermal power equipment, such as steam boilers and thermal oil, or production equipment.

Productive sectors of textiles with greater weight in energy consumption are the finishing and dyeing, when compared with other sectors. The thermal component is much higher than the electric component in these sectors, so that the implementation of energy conservation measures becomes imperative. In fact, in Portugal, one begins to notice a decrease in total energy consumption (coal, oil, electricity, natural gas) since 2000. Note that this reduction is certainly linked to decreased production, but also the energy rationalization measures adopted by the industry in an attempt to reduce costs [20].

The costs of electricity, and especially oil, have increased significantly in recent years, so the energy conservation has become a key issue. Before the energy issue has become relevant in the textile industry, energy losses through discharges of hot water, leaks and improper maintenance, lack of insulation of pipes and machinery, non-recovery of gases and hot air, and improper settings of high energy events were rather common. These losses were generally neglected at the expense of the pressures arising from the production and delivery of the products produced. However, the rising energy costs have become unsustainable these occurrences, both in terms of profitability and in terms of the corresponding environmental concern [21].

A further form of energy used by the textile industry site is natural gas, necessary to feed the boilers that produce steam for sectors with higher thermal requirements, as is the case with dyeing sector.

For this study some of the leading companies in this sector, all located in the neighbor regions of Vale do Ave and Vale do Câvado (northern Portugal) were chosen, with particular feature to the municipalities of Guimarães, Fafe, Famalicão and Barcelos, traditionally areas of larger and stronger implementation of the Portuguese textile industry, with more than 150 years of sector activity [22].

The use of three types of fuel in steam boilers, namely natural gas, propane gas and naphtha, was very typical. These two last ones are mainly used in smaller units without direct access to the natural gas distribution grid.
In none of the visited companies was discovered any use of biomass energy, neither met any bibliographic reference to this type of fuel in this industry sector.

The most common steam boilers found in the visited industrial plants have power between 6 to 12 MWh, and steam production capacities between 6 to 12 ton/h at 90°C temperature and 10 to 12 bar pressure (Fig. 1).

The change of traditional fuels to biomass implies several changes in equipment for the production of steam, being often difficult to achieve by logistical and/or space problems, since these companies, many with decades of activity, occupy old facilities that have been developed according to the needs of production, relegating "utilities" to a secondary plan.

III. ECONOMIC STUDY COMPARING BIOMASS AND FOSSIL FUELS

The most used fuel in steam boilers is natural gas, being propane gas and naphtha used only as last option when there is no logistical possibility of natural gas supply (Fig. 2).

The annual consumption data of natural gas in the ten major textile dyeing units in the regions of Vale do Ave and Vale do Cávado (northern Portugal), during 2012, were collected and monthly average values are presented in Table I.

Table II provides the average annual consumption of natural gas for year 2012, assuming that only 60% of the total energy refers to steam production.

### Table I. Monthly Natural Gas Consumption in 2012 in Ten Major Dyeing Companies in Vale do Ave

<table>
<thead>
<tr>
<th>Month</th>
<th>kWh/month</th>
<th>m³/month</th>
<th>€/month</th>
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</thead>
<tbody>
<tr>
<td>January</td>
<td>1,959,057.00</td>
<td>164,404.89</td>
<td>71,948.82 €</td>
</tr>
<tr>
<td>February</td>
<td>1,173,506.00</td>
<td>98,481.12</td>
<td>43,098.48 €</td>
</tr>
<tr>
<td>March</td>
<td>1,739,134.00</td>
<td>145,948.86</td>
<td>63,871.87 €</td>
</tr>
<tr>
<td>April</td>
<td>2,178,023.00</td>
<td>182,780.61</td>
<td>79,990.62 €</td>
</tr>
<tr>
<td>May</td>
<td>1,967,789.00</td>
<td>165,137.68</td>
<td>72,269.51 €</td>
</tr>
<tr>
<td>June</td>
<td>1,925,380.00</td>
<td>161,578.70</td>
<td>70,711.99 €</td>
</tr>
<tr>
<td>July</td>
<td>2,113,237.00</td>
<td>177,343.74</td>
<td>77,611.27 €</td>
</tr>
<tr>
<td>August</td>
<td>1,109,359.00</td>
<td>93,097.88</td>
<td>40,742.60 €</td>
</tr>
<tr>
<td>September</td>
<td>2,240,434.00</td>
<td>188,018.17</td>
<td>82,282.74 €</td>
</tr>
<tr>
<td>October</td>
<td>1,867,351.00</td>
<td>156,708.88</td>
<td>68,580.80 €</td>
</tr>
<tr>
<td>November</td>
<td>2,613,019.00</td>
<td>219,285.66</td>
<td>95,966.39 €</td>
</tr>
<tr>
<td>December</td>
<td>1,904,838.00</td>
<td>159,854.81</td>
<td>69,957.56 €</td>
</tr>
<tr>
<td>Total</td>
<td>22,791,127.00</td>
<td>1,912,641.00</td>
<td>837,032.64 €</td>
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</tbody>
</table>

### Table II. Annual Average Values of Natural Gas Consumption in 2012

<table>
<thead>
<tr>
<th></th>
<th>Monthly Average</th>
<th>Annual Average (11 months)</th>
</tr>
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<tbody>
<tr>
<td>m³ consumption on steam</td>
<td>173,876.45</td>
<td>1,912,641.00</td>
</tr>
<tr>
<td>production (60% of total energy consumption)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kWh consumption on steam</td>
<td>2,071,920.64</td>
<td>22,791,127.00</td>
</tr>
<tr>
<td>production (60% of total energy consumption)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam production costs</td>
<td>76,093.83</td>
<td>837,032.64</td>
</tr>
<tr>
<td>kWh Cost (€/kWh)</td>
<td>0.037 €/kWh</td>
<td></td>
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</table>
Woodchips of pine wood (Fig. 3) and wood pellets (Fig. 4) were used as biomass forms for the comparative study. Woodchips are characterized as being a product consisting of particles with an average size of 40x40x20 mm, an average moisture content of 40% and a PCI of 3.50 kWh [23], in opposition to natural gas that has a PCI which is between 9.16 and 11.92 kWh [24].

Wood pellets are characterized as being cylindrical forms of 6 mm to 8 mm in diameter, not longer than 38 mm, having an average moisture content of 10% and a PCI of 4.80 kWh [25]. Therefore, for an equivalent consumption of woodchips, about 739,971.66 kg/month of woodchips totalizing 8,139,688.21 kg/year (Table III) are needed. For an equivalent consumption of wood pellets, 431,650.13 kg/month are needed totalizing 4,748,151.46 kg/year (Table IV).

An annual reference value of 11 months was used, since it is current practice to stop this type of industrial plant one month per year for maintenance and staff holidays, usually during August.

The average quotation of pine woodchips obtained from local suppliers was 0.075 €/kg or 75 €/t, while for wood pellets the average quotation was 0.145 €/kg or 145 €/t. All these prices include transportation costs from supplier to final destination.

Real savings in energy costs are obtained for steam production, corresponding to 27% for woodchips and 18% for wood pellets, as shown in Table V.

IV. SWOT ANALYSIS OF THE USE OF BIOMASS ENERGY

SWOT analysis is a method that identifies strengths, weaknesses, opportunities and threats of the proposed target, in this case the use of biomass as a viable energy alternative for the textile industry, allowing, through a comprehensive analysis, the choice of an optimal deployment strategy [26]-[27]. The SWOT analysis is provided in Table VI.

One of the most important strengths of biomass is the promotion of the development of rural areas, reducing the rural exodus and reinforcing local industry. Another very important aspect is the possibility of creating jobs predominantly in less favored regions of the country [28].

As a potential weakness the possible use of land that may be needed for food production is frequently referred [29]. There is still also a lack of knowledge about energy crops. This may delay the effective implementation of these crops as well as may put in question the farmers' decision of using the fields for the production of bioenergy [30].
TABLE VI. SWOT ANALYSIS

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tr>
<td>• Economic development.</td>
<td>• The need for initial investment.</td>
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<tr>
<td>• Increase of competitiveness by production costs reduction.</td>
<td>• Adaptation of spaces for new equipment.</td>
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<tr>
<td>• Parallel development of other industries, encouraging the creation of indirect jobs.</td>
<td>• Logistics and supply biomass supply.</td>
</tr>
<tr>
<td>• Contribution to the reduction of importation of energy products (coal, natural gas, etc.).</td>
<td>• Seasonal fluctuations in prices and technical characteristics of the biomass.</td>
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</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
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<tr>
<td>• Circular development of the regional economy.</td>
<td>• Control of the energy market by “dominant energies”.</td>
</tr>
<tr>
<td>• Implementation of a policy of resources preservation.</td>
<td>• Lack of a consistent national policy of promoting sustainable use of renewable energy in industry.</td>
</tr>
<tr>
<td>• Increase the use of national resources instead of imported resources.</td>
<td>• Distrust of the industrial managers when faced with new technologies and alternative energy sources.</td>
</tr>
<tr>
<td>• Parallel development of the forest industry.</td>
<td>• Lack of demonstrative examples to help validate this option.</td>
</tr>
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V. CONCLUSIONS

Textile industry is very important for Portuguese exports and the economy in general. It has been recorded that energy takes about 60% of total energy costs. In this paper, an overview of the energetic matrix of the Portuguese textile dyeing industry was presented, as well as its prospect of development and growth, being a key sector for the Portuguese economy. High production costs are mainly caused by the ever rising energy costs. In this context, biomass emerges as a viable, permanent and sustainable alternative for the textile industry, mainly due to favorable economic factors when compared with other energy sources, such as natural gas, naphtha and propane gas. Biomass allows very significant savings in energy costs, up to 27%, associated with the steam production necessary for the industrial process. This advantage may allow boosting competitiveness of this particular industry. Indeed, the use of biomass energy as a main source for steam production promotes the consumption of a product of national origin, contributing to the reduction of Portuguese imports, besides being a neutral fuel in what concerns CO₂ emissions. Nevertheless, and despite the advantages presented, the replacement of traditional fossil fuels is not an easy task, requiring significant investments for upgrading existing equipment, or even its total replacement, associated with a change in the whole process of logistical supply and storage of biomass in its different forms. It is expected that many research challenges will have to be tackled effectively, so the distributed applications as well as the technologies developed during the last years will once more have to be tested in real world scenarios.

ACKNOWLEDGMENT

The authors would like to thank the companies that provided the data for this study. This work was supported by FEDER funds (European Union) through COMPETE and by Portuguese funds through FCT, under Projects FCOMP-01-0124-FEDER-020282 (Ref. PTDC/EEA-EEI/118519/2010) and PEst-OE/EEI/LA0021/2013. Also, the research leading to these results has received funding from the EU Seventh Framework Programme FP7/2007-2013 under grant agreement no. 309048.

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