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Cogeneration supply by bio-energy for a sustainable hotel building management system

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ABSTRACT

In this work we presented the development of an energy model based on a mixed system of renewable energy, with primary energy sources as solar and biomass. It is a hybrid and autonomous system with solar PV panels and gasification cogeneration technology. Also it is an environment friendly process aiming the reduction of energy demand, costs and emissions. This energy model is a new sustainable standard about energy consumption efficiency (electrical and thermal demands) of a small hotel building and a relevant contribution to certify the building, in compliance with the laws of the country on the thermal performance of buildings.

1. Introduction

Energy has become an essential element for our livelihood and for the advancement of humankind. Indeed, the rise of worldwide energy consumption throughout the last decade has accelerated in regions of population growth. Taking into account that fossil fuels supply a huge percentage of the primary energy worldwide and is a significant source of GHG emissions, energy consumption is acerbating global warming and climate change.

This research note is a case study which focuses on the development of a new hybrid energy model for a small hotel. Special emphasis will be given to analyzing the building's energy consumption and to providing meaning to the concept of a "Sustainable Hotel Building Management System." We are also interested in establishing a new sustainable energy model which mitigates the effects of global warming and can be expanded to residential and other urban service areas. Our particular interest is in the building sector, which in EU alone accounts for more than 40% of the total primary energy consumption, a value higher that in Portugal.

The hybrid energy model (Fig. 1) consists of the following four principle parts: a cogeneration process, which employs a sustainable propulsion system; a thermal process; a PV solar process; and an electrical process, which implements an environment friendly system aimed at reducing energy demands, costs and emissions.

The cogeneration process uses pellets or wood chips as a primary energy source [1] (see Fig. 2), and biomass gasification thermochemical technology to synthesize gas for an IC motor electric generator [2].

During this work we have present that the WEC addresses climate changes in relation to three primary energy goals: accessibility, availability and acceptability. Better access to energy is essential for economic and social evolution of developing countries. Renewable energies, beside their environmental advantages, facilitate the creation of new businesses and jobs [3].

Energy consumption over the 20-year period 1980–2000 is projected to double over the next 20-year period; however, compliance with the EU energy saving initiative is expected to reduce energy consumption approximately 20%. Buildings are the major source of CO_2 emissions [4,5]. Thus, to combat GHG and global warming it is essential to develop efficient technologies and reduce consumption.

The wide spread of combined heat and power (CHP) presents a substantial potential for increased energy efficiency and reduced environmental impact [6]. It is considered to be a priority area for many EU member states. The efficient use of traditional fuels, for simultaneous production of heat and power offers energy savings and reduced CO_2 emissions, when compared with separate production of heat and power. Newly developed fuels used for CHP are cleaner, and there is growing trend in the use of bio-fuels. Nearly 40% of the

Abbreviations: CHP, Combined Heat and Power; EU, European Union; GHG, Greenhouse Gases; IC, Internal Combustion; IRR, Internal Return Rate; NPV, Net Present Value; PPMV, Parts Per Million by Volume; PV, Photovoltaic Panels; RCCTE, (Features Regulation for Buildings Thermal Behaviour); RSECE, (Energetic Systems Regulation for Buildings Comfort); SCE, (Energetic Certification for Buildings Indoor Air Quality Regulation); SHW, Sanitary Hot Water; TOE, Tone Oil Equivalent; UPS, Uninterruptible Power Supply; WEC, World Energy Council.

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Nomenclature

kJ	kilojoule
kg	kilogram
kWh	kilowatt hour
kWhe	kilowatt hour electrical
kWht	kilowatt hour thermal
kWhtb	kilowatt hour thermal biomass

electricity produced from cogeneration is for public supply purposes, often in connection with district heating networks, the remaining 60% is generated for industrial processes [7].

2. Experimental work

Although the building is only ten years old, a few isolated problems were found. The energy requirements for heating, cooling and SHW should be provided by an efficient energy model, and primary energy uses should satisfy the thermal comfort buildings requirements.

The hotel is located within the walls of the historic Marvão Castle [8] with the geographic location of our case study is latitude 39° 23′ 38.41″ N; longitude 7° 22′ 34.43″ W; elevation 805 m and hence extensive renovation is limited by architectonic restrictions. The hotel consists of: 15 rooms, 18 bathrooms, a restaurant dining room seating 40 people, a fully equipped kitchen, a laundry with 1 dryer and 3 washing machines, a wet bar, a reception desk equipped with a computer and a fax, two combustion engines, a boiler for hot water, an elevator, an emergency engine used to supply electricity and a no homogeneous addition. The average monthly solar radiation is 193.8 W/m^2.

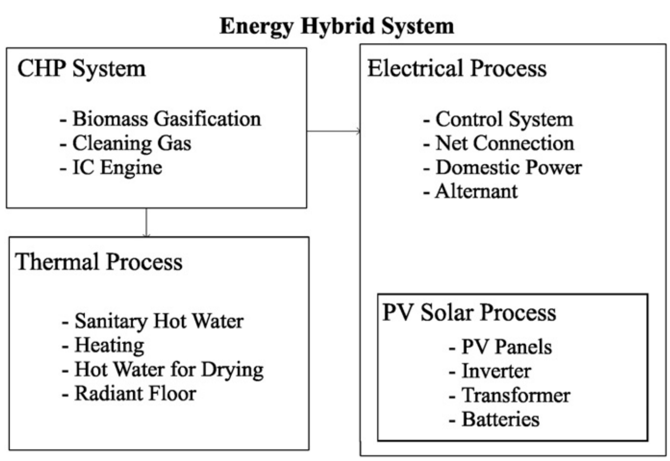

Fig. 1. Proposed model hybrid energy.

The hotel's yearly primary energy consumptions and expenses respectively are represented by the next figures (Figs. 3 and 4). The next graphic contains the three currently used energy sources (electricity, gas, fuel) and its evolution to the period between the years 2002 to 2008 in TOE unity. To obtain the national energy consumption certificate label we need to perform a structural analysis of the building.

Although the region has abundant forest biomass and good solar exposure, the fuel and gas costs over the last few years were too high and led to economic difficulties. The electricity load diagram collected of the installation has 318.4 kWe consumption up the 20 kWe and peaks of 26.4 kWe that correspond to 15 hours period during 4.5 weeks.

Overall power consumption depends on the number of hotel guests and the number of restaurant clients. The increased number of hotel guests and restaurant clients over the last eight years has had a considerable effect on overall energy consumption; nevertheless, the introduction of highly efficient electrical appliances such as refrigerators, washing machines, television sets, as well as low voltage light bulbs, has decreased the hotel's electrical energy consumption over the last three years. Laundering by the hotel staff, however, is done in the afternoon; thus significantly increasing electrical energy consumption at high peak rates (see Fig. 5). To reduce electricity costs it should be done during off-peak periods at reduced electrical rates. The hotel's high consumption electrical appliances are: dryer, elevator, deep fryer, washers and dish washer machine.

The building has exterior double walls, interior insulating material and insulated roofing; however, excessive condensation in some corners indicated that indoor humidity levels are too high. The windows are double glazed and have a wooden frame. Pictures taken by a thermal camera indicate insulation problems and heat loss through some doors, ceilings and windows (see Fig. 6).

The daily SHW and heating requirements are represented by figures (Figs. 7 and 8). Morning SHW consumption and the evening heating needs, which both depend on the number of occupied rooms, must be guaranteed.

The hybrid energy model not only meets these needs, but will also comply with the energy efficiency standards decreed by new national legislation, and thereby the hotel should readily obtain its energy certification label. Local bio-energy/biomass trade system makes a good contribution for sustainable and decentralized energy production. In addition it is expected that the hotel can reap new profits by selling excess electricity and hot water to the neighbors. The desire to distribute occasional excesses in electricity production to a neighbourhood grid mandates the notion micro grids. The idea of passive energy consumers is being replaced by that of active energy producers. Low costs of energy

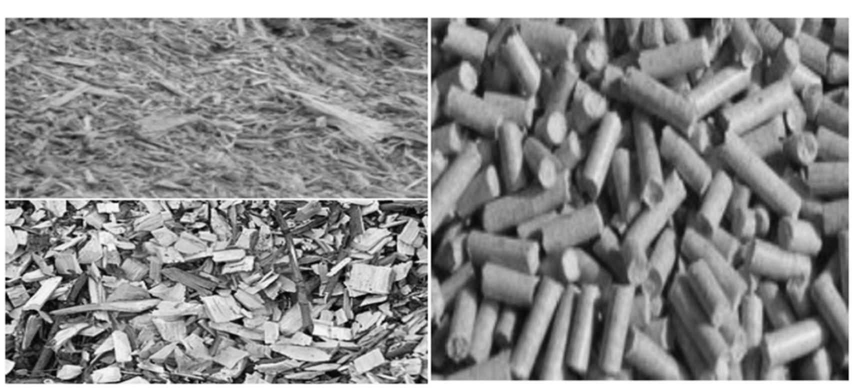

Fig. 2. Bio-energy: wood chips types and pellets.

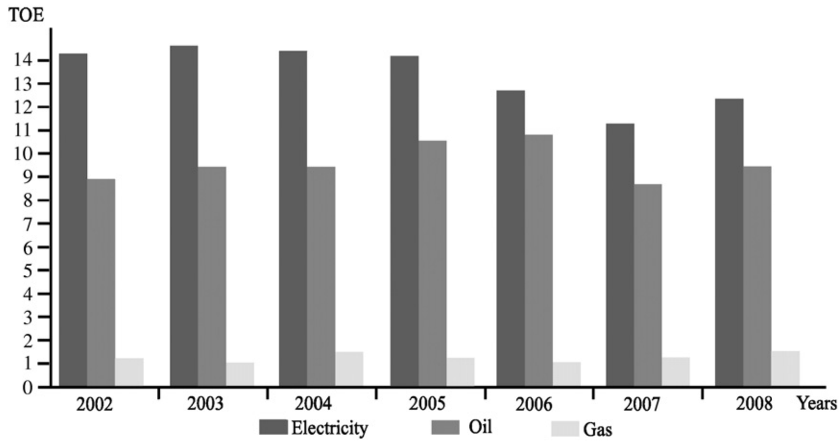

Fig. 3. Energy consumptions in TOE.

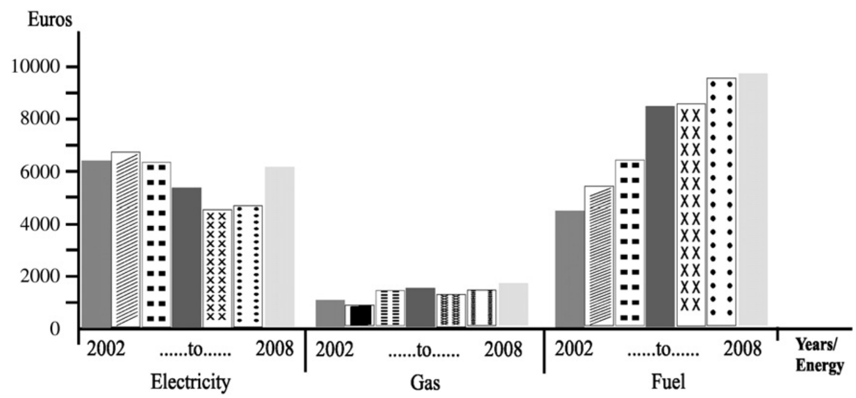

Fig. 4. Energy costs in period from 2002 to 2008.

transportation and distribution, as well as protection of generalized wipe out, make micro grids very competitive. Like conventional energy grids, losses in micro grids increase when congestion is high, at critical periods can be up to 20%. High efficient systems of small cogeneration [9,10] are available; they usually use thermal power to meet electrical demands.

3. Results and discussion

The time of use and peak period electricity consumption were extremely relevant for determining efficient utilization of electrical equipment. The wide spread use of CHP presents a substantial potential for increased energy efficiency and reduced environmental

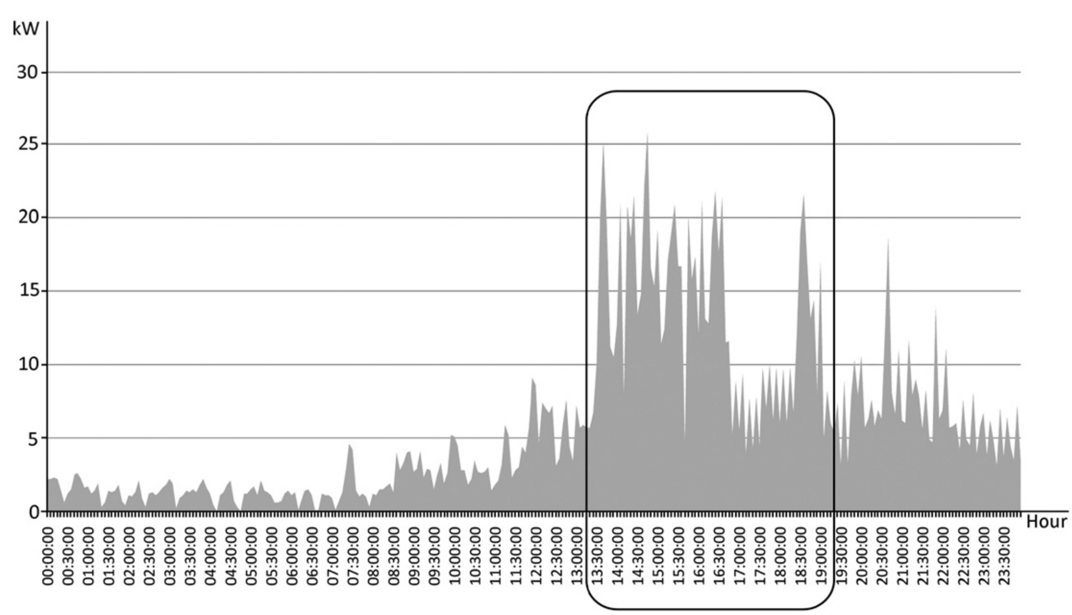

Fig. 5. Electricity diary load diagram sample.

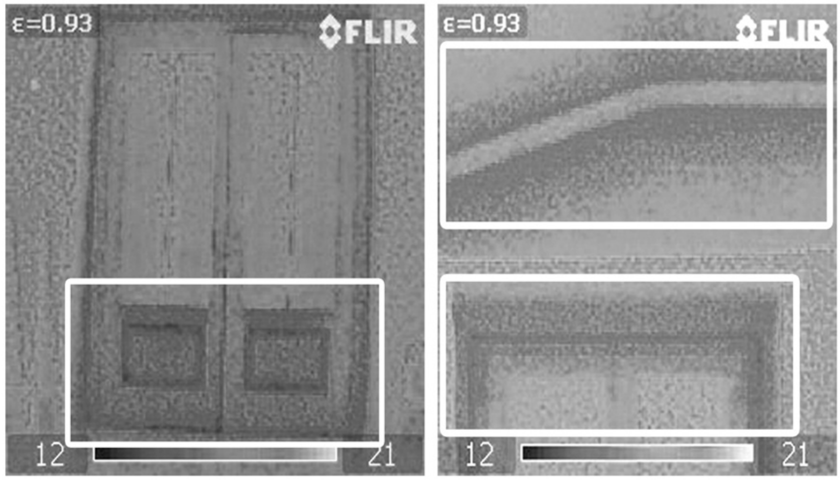

Fig. 6. Door, ceiling and window thermal leaks (black color).

impacts. Since this is a priority for many EU member states, a small efficient cogeneration system with an associated electrical generator (see Fig. 9) is the recommended energy model. Part of the CHP system is a fixed bed down-draft gasifier (see Fig. 10), which is integrated with an engine/generator to produce 20 kW/h of electrical power and 87.8 kWt/h of thermal power (see [11] and [12]). This system also uses a variety of local forest biomass such as pellets or wood chips (see Table 1).

The technology of biomass conversion by gasification has the potential to produce a clean homogeneous fuel, called synthesis gas, from contaminated and inhomogeneous solid biomass fuel. A number of chemical reactions take place as soon as the biomass gas is ignited. The clean gas is derived from the intermediate raw gas after sufficient cleaning and conditioning. The gas volumes to be conditioned after gasification (producer gas) are much smaller than those after combustion (flue gas). Producer gas can be used in multiple ways. Biomass gasification can be efficiently applied at very small scale (fixed bed) and others scales. Moreover, it is possible to remove CO_2 before subsequent usage.

Some advantages of gasification are that the fuel gas produced is more versatile in power generation and chemical synthesis. There is a potential for higher efficiency conversion using integrated gasifier combined cycles when compared to conventional Rankine steam cycle power systems, and there is a lower volume of gas which requires treatment to reduce NO_x and SO_x emissions when compared to that of combustion flue gas. The fuel nitrogen evolved principally as NH_3 and sulfur as H_2S is more readily removed than NO_x and SO_2 , which is normally produced by standard combustion systems. Finally the applications for power generation are in smaller scales than direct combustion systems although gas cleaning is still a primary concern and expense.

Gas cleaning required for use of fuel in engines, turbines and fuel cells is one constraint of gasification processes. For engines, tar and particulate matter removal are a primary concern, as tar removal is difficult to achieve. Reactor designs influence tar production, some newer two stage gasifiers reduce tar but cleaning is still an issue. The need for cool gas to maintain engine volumetric efficiency leads to tar condensation and waste water production for wet scrubbing systems. For gas turbines, alkali concentration in gas must be kept low (typically less than 1 ppmv), there is a need for hot gas cleaning to maintain high efficiency. Alkali is typically removed by condensing on particles and hot filtering at temperatures of about 1,300 °F [13].

The impact on the existing electrical grid by this device is through a standby application with base and peak loading for nearby end users. Gensets, i.e., engine-generator sets, are frequently used as a backup power supply in residential, commercial and industrial areas. When used in combination with a 1–5 minutes UPS, the system is able to supply seamless power during a utility outage. The output power of gensets is very reliable, flexible and of good quality. Thus the impact of output power injection to the grid has no hazardous effects on the reliability and safety of the system; moreover, this distributed production reduces the amount of energy to be transported through transmissions lines, whose capacity is limited [14].

Some calculations, using the energy consumption database between the years 2002 to 2008, were made to determine the thermal and electrical energy needs. To obtain overall CHP efficiency,

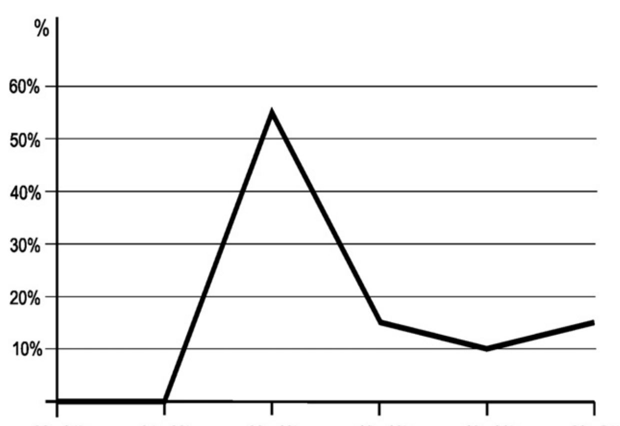

Fig. 7. Daily thermal consumption SHW throughout the year.

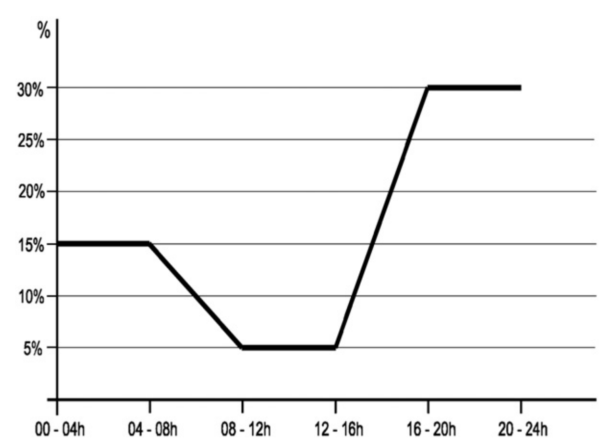

Fig. 8. Daily heating during the heating season.

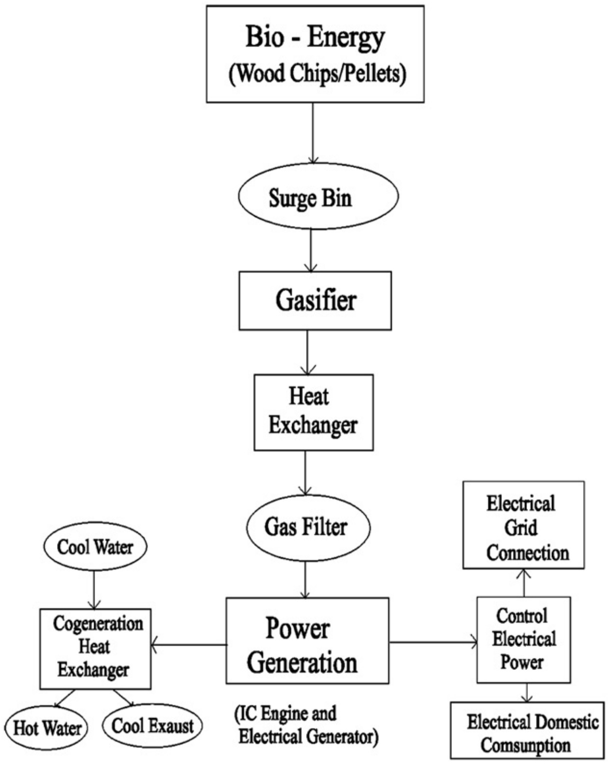

Fig. 9. Bio-energy cogeneration by gasification main features.

we took into account the higher electrical consumption during the summer months of July and August.

Electricity Part (Include Air Conditioned consumption):

- Total Electricity Energy Annual: 52,293 kWhe
- Total Electricity Energy Monthly Average: 4357.5 kWhe
- Total Electricity Energy Daily Average: 143 kWhe

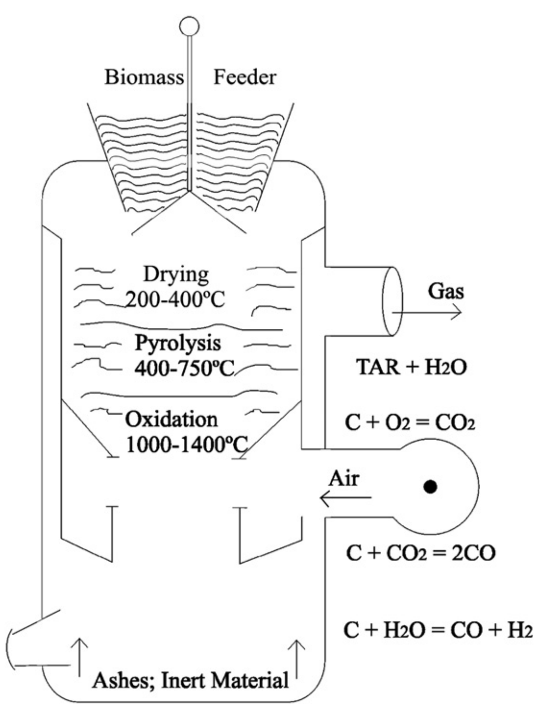

Fig. 10. Gasification reactor for sustainable.

Table 1
Power features by bio-energy, wood chips and pellets.

Calorific power biomass — wood chips 13,800 kJ/kg	Calorific power biomass — pellets 18,900 kJ/kg
Maximum biomass kWh/day 480 kWh	Maximum biomass kWh/day 480 kWh
Wood chips/kWh 1.5 kg	Pellets/kWh 1.102 kg
Max. wood chips/day 720 kg	Max. pellets/day 529.3 kg

Thermal Part (Heating and SHW):

- Total Thermal Energy Annual: 114,347 kWht from 13,145 liters fuel
- Total Thermal Energy Monthly Average: 9566.9 kWht
- Total Thermal Energy Daily Average: 313.27 kWht

We calculate the CHP overall efficiency having as reference the minimum values proposed.

$$Establishing: \eta\ electrical = [Electrical\ Energy\ (\mathrm{kWhe}) / Biomass\ Energy (\mathrm{kWhtb})] = 0.25 = 25\%$$

This means to generate 1 kWhe generated we need 1.5 kg biomass/wood chips or 1.2 kg of biomass/pellets, which is equivalent to 4 kWh of biomass and 1.96 kWht.

$$\eta\ thermal = \eta\ total - \eta\ electrical = 0.74 - 0.25 = 0.49 = 49\%$$

$$143.2\ \mathrm{kWh}\ electrical/day\ correspond\ to\ 314.52\ \mathrm{kWht/day}$$

$$Maximum\ Thermal\ Daily\ Energy = 940.8\ \mathrm{kWht}$$

To fulfill European Directive 2002/91/EC [15] on Energy Performance of Buildings, the Portuguese parliament passed laws 78/2006 (SCE), 79/2006 (RSECE) and 80/2006 (RCCTE) which assert that all service and residence buildings, constructed after 2009 must have an energy certification label. The directive requires that the energy needed to supply SHW as well as other important energy consumptions be determined before the introduction of solar energy systems or other renewable energy sources. By the National Statistic Institute [16] this covers about 3,3 million buildings and 5,5 million single family residences.

This hybrid energy model provides a technically reliable and economical viable solution for efficient energy consumption and low emissions levels, in the electricity production and it should readily satisfy the requirements for a top energy certification label.

Finally, a photovoltaic process for the energy model can be added to the main CHP system to supply additional electrical energy at peaks periods. Excess energy can be sold at 0.6175 €/kWhe. PV panels produce 7.22% of electricity used each year, and during the months of July and August the PV panels can produce more than 8.23%.

4. Conclusions

To comply with current legal regulations required to obtain an energy certification label and preserve the local architectonic structure, we propose one integrated solution based on a hybrid energetic system with several renewable energetic sources, as primary energy source, the biomass, to increase efficiency. Other features developed in this model are an environment friendly and autonomous energy system for a sustainable building, which will improve both thermal and electrical building management performance. This case study provides an economically and technically viable energy model, whose implantation will be granted a top energy certification label.

The innovation part of this system consists of a single economically and technically viable hybrid renewable energy model, which is eco-friendly and provides an autonomous environment in terms of electricity use, heating and cooling. The economic viability of the CHP system and the PV solar process are also demonstrated by the economic payback parameters NPV and IRR, and the energy hybrid model proposed can be characterized as a very favorable investment.

References

[1] Biomass Program, USA (2006). See also <http://www1.eere.energy.gov/biomass>.
[2] R. Walt, Modular Biopower Systems for the 21st Century, Community Power Corporation, USA (2007). See also: http://www.gocp.com.
[3] World Energy Council, Energy & Climate Change. See also, < http://www.worldenergy.org/wec-geis/publications/reports/ecc/ecc.asp>.
[4] ADENE – Portuguese Energy Agency, (2009). See also < hpp://ww.adene.pt>.
[5] P. Wilkinson, K. Smith, S. Beevers, C. Tonne, T. Oreszczyn, Energy, energy efficiency, and built environment, Lancet 370 (2007) 1175–1187.
[6] R. Critchley, J. Gilbertson, M. Grimsley, G. Green, Living in cold homes after heating improvement: evidence warm-front, England's h. e. efficiency scheme, Appl. Energy 84 (2007) 147–158.
[7] Directive 2004/8/EC. On the promotion of cogeneration based on a useful heat demand in the internal energy market, European Parliament and Council. See also <http://www.managenergy.net/products/R81.htm>.
[8] Hotel/Albergaria El-Rei Dom Manuel, Marvão-Portugal (2009). See also < http://www.turismarvao.pt>.
[9] A. Hawkes, M. Leach, Cost-effective operating strategy for residential micro-combined heat and power, Energy 32 (2007) 711–723.
[10] M. Badami, A. Casetti, P. Campanile, F. Anzioso, Performance of an innovative 120kWe natural gas cogeneration system, Energy 32 (2007) 823–833.
[11] R. Walt, The Biomax: a new biopower option for home power, distributed generation and CHP, Community Power Corporation, USA, 2008. See also <http://www.gocp.com>.
[12] J. Galvão, S. Leitão, S. Silva, T. Gaio, Biofuel for the energy efficiency on a building with small CCHP, 2nd International Conference on Clean Electrical Power – ICCEP/IEEE, Italy, 2009.
[13] B. Jenkins, Technologies for treating dairy manure gasification developing projects and partners to comp. treat dairy manure in the San Joaquin Valley, University of California, USA, 2006.
[14] ENIRDGnet: WP1, Work plan concepts and opportunities of DG: The driving European forces and trends. See also <http//www.dgnet.org>.
[15] Directive 2002/91/EC, On the energy performance of buildings. Available from, <http://ec.europa.eu/energy/demand/legislation/buildings_en.htm>.
[16] Instituto Nacional Estatística, (2009). Available from, <https://webinq.ine.pt>.