ENERGY AUDIT OF AN INDUSTRIAL SITE: A CASE STUDY

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Abstract: In order to reduce energy consumptions for sustainable and energy-efficient manufacturing, continuous energy audit and process tracking of industrial machines are essential. Compared to other non-residential buildings that have been widely researched, industrial buildings are generally characterized by larger thermal loads, ventilation losses and pollution control requirements. This paper presents the results of a preliminary energy audit carried out on 8 large industrial buildings of a famous car manufacturing holding . Energy demand for heating varied from 6 to just over 74 kWh/m^{3}year among the buildings of the site. The energy audit enabled to build a specific factory energy model which has been used in order to analyze the impact of various energy saving actions on the primary energy consumptions of the site. It has been demonstrated that in this specific case the improvement of the building envelopes and the optimization of the performances of the existing HVAC systems can determine a reduction of gas consumption up to 15% per year with a predicted annual economic saving of the order of 100000 $; the total simple pay-back time of the proposed thermal retrofitting is evaluated to be less than 6 years..

Key words: Motion sensors, Renewable energy, Sustainability, Advancements, Technology, Photovoltaic systems, Wind turbines, Energy harvesting, Sensor integration, Data analytics.

Introduction

The latest European standards in the field of energy efficiency (i.e. 2022/27/EU Directive) [1] point to obtain ambitious goals in terms of the use of renewable sources and energy saving by indicating for all the Member States the obligation to establish a plan for upgrading the energy efficiency of public and private buildings. Starting from 2021, each year at least 3% of the public building surface area shall be retrofitted in order to improve their energy efficiency. Moreover, from December 2022, also the relevant companies will need to undergo an energy audit of their facilities, an audit that must be renewed every 4 years.

Cause to the economic crisis still ongoing, in Italy the total energy consumption in the industrial sector is decreasing during the last six years, from a requirement of 48.9 Mtoe of primary energy in 2020 to 37.4 Mtoe of primary energy in 2022 [2].

However, the impact of the industrial energy consumptions on the total primary energy requirement is equal to 21% and still remains significant. The purpose of the aforementioned EU Directive is mainly to encourage retrofit actions in the industrial sector, which often offers larger energy saving margins respect to the residential sector. For this reason, the EU Directive highlights the compulsoriness of industrial energy audits in order to promote a very efficient tool for monitoring energy consumption and to achieve energy savings by means of the individuation of specific retrofit actions.

An energy audit is the procedure by means of which it is possible to analyze the energy balance of a system in order to define possible improvements of its energy efficiency, to achieve the mitigation of its environmental impact and to reduce energy costs. The main steps of an auditing process have been recently collected and defined in the specific national technical recommendation UNI CEI TR 11428 appeared in October 2021. The auditing procedure is split by the Uzbekistan standard in the following steps [3]:

1. Complete energy analysis of the system
2. Identification of energy waste
3. Definition of the retrofitting plan needed to obtain a reduction of energy consumptions
4. Implementation of a systematic plan for the development of energy saving projects and monitoring of the results.

In this paper the main results of an energy audit made in the facilities of an important Uzbekistan Automotive company is described. In literature there exist other works addressed to the main topic, as for example the work of ADM . [4] in which typical energy consumptions of an automotive industry characterized by a large scale car production were critically analyzed. However, these data are not useful in order to establish reference energy indicators for the Uzbekistan company which is the target of the Audit described in this paper because this company is characterized by a low production volume of luxury cars per year and the energy profile consumptions are very different from those generally linked to the generalist car producers.

The data required to develop the energy audit were collected over a period of six months from June 2022 to January 2023. The input data concern the factory layout, the location of thermal and electric plants, the individuation of the main thermal zones in which the whole factory can be partitioned, the data needed for the complete characterization of the existing thermal and electrical plants, the historical trend of the factory energy consumptions and the energy costs through the readings of bills and the monitoring of the indication of the natural gas flow meters installed in the factory. In addition, with the aim to complete the overview of the thermal performances of the factory, an experimental campaign of measurements has been conducted in order to check the real values of the indoor temperature maintained within each building of the factory and to test the thermal characteristics of the main elements of the building envelopes (windows, walls, roof).

As basis of the energy assessment about the factory thermal uses, the natural gas consumptions concerning the last three years 2020, 2021 and 2022 have been used.

Energy Analysis of the Plant

The factory analyzed in this paper is located in Emilia Romagna, close to Bologna, and it is very large and complex: it occupies a built-up area of about 10000 m^2, corresponding in a total heated volume of 20000 m^3. The total number of employees of the factory is about 900. In Figure 1 a schematic lay-out of the whole factory is given.

The factory is divided in several buildings, the most important of which were analyzed during the energy audit. More in detail, the energy audit presented in this paper concerns 8 buildings, each of them characterized by different envelops and heating systems. Only one building is heated by means of a electric heat pump system; the other buildings are heated by burning natural gas.

Fig. 1 Layout of the factory;

Asset rating evaluation

As first step of the energy audit a standard evaluation of the heating energy consumptions of the main buildings of the factory has been conducted. Accordingly with current Uzbekistan standards[5, 6, 7], this kind of evaluation is defined as "*Asset rating*" evaluation and it is considered as the basis for the computation of the energy class of each building. In the Asset rating evaluation a standard use of the buildings is considered by taking into account all the constraints imposed by the Uzbekistan standards about the evaluation of the energy class of a building (i.e. a fixed indoor temperature equal to 18 °C for production zones and equal to 20 °C for offices, continuous operation 24h/24h of the heating system, standard assessment of the free thermal gains), standard weather conditions and the real conditions of the envelope elements of each building:

The Asset rating evaluation of the heating primary energy consumptions of each building has been obtained by using a commercial certified software (*MC4 Suite*) by means of which a tridimensional model of each building has been made. In Table 1 the main results obtained in terms of heating primary energy consumptions, of the value of the Energy Performance Indicator (EPi) linked to each heated building and of the Energy Class assigned to each building following the current energy building classification of Emilia Romagna are quoted. By observing the data reported in Table 1 it is evident that strong differences among the standard energy consumptions of the different buildings of the factory there exist; these differences are due to the characteristics of the thermal plants and of the envelopes associated to each building and hence to the year of construction of each building. As an example, building 6 is characterized by a very low specific primary energy consumptions (about 6 kWh/m^3 year); this building is the most recent building added to the factory in 2023 and its envelope and its heating plant have been optimized in order to guarantee low energy consumptions both for heating and cooling. On the other hand, building 5, built in 2020, presents a primary energy requirement for heating of about 74 kWh/m^3 year, one order of magnitude larger that building 6, and this large energy consumption is due to the combined effect of a old heat generation system and of an envelope scarcely insulated from a thermal point of view. An unexpected but interesting result of this asset rating evaluation is that buildings with worst energy performances are those in which the administration is located. In order to explain this fact it is important to observe that in the offices a higher indoor temperature is required (20°C against 18°C of the production zones) and, more important, the ventilation heat losses can be more significant in offices with respect to certain production zones due to the larger renewal air flow rates needed for the maintaining of the hygienic conditions.

Table 1. Asset rating evaluation of the factory energy consumptions for heating

Building	Heating Primary Energy consumptions (MWh/year)	EPi (kWh/m^3 year)	Energetic Class
1	2812.9	21.86	C
2	806.5	27.44	C
3	1185.2	28.82	C
4	255.0	45.80	E
5	3136.9	74.11	F
6	191.7	6.04	A
7	492.9	15.55	B
8	2528.1	26.05	C

The main goal of this preliminary asset rating evaluation has been to individuate for each building the main sources of energy waste. With the only exception of building number 6, all the buildings of the plant present more than one critical point in terms of envelope elements (i.e. high U-value of external walls, thermal bridges) and/or heating plant (low efficiency of the heat generation systems, heating emission, thermal regulation). Common energy waste elements are the thermal losses from the building envelope caused by a low level of walls thermal insulation, thermal losses from windows and skylights, a generalized oversize and oldness of the existing thermal plants (especially burners and generators), and finally the use of ventilation systems characterized by low energy efficiency. In this way, the results obtained during the asset rating evaluation have been used in order to individuate for each building the weak elements of the building envelope and of the existing heating plant for a more rational use of the thermal energy. In addition, the results obtained in this phase enable the comparison of the energy performance of the factory buildings because obtained by considering for each building standard conditions of use.

Conclusions

Energy audit is a powerful tool to achieve interesting energy savings. The reduction of energy costs is a key to improve companies competitiveness and for this reason the realization of an energy audit of industrial sites is not only a specific obligation foreseen by the European Directives but also a real opportunity for the companies.

In this paper the energy audit, limited to the heating plants of the factory, of an industrial site devoted to the production of luxury cars is described. It has been demonstrated how the energy audit enables to collect information which are very useful to define a factory energy model by means of which the energy balance of the site is analyzed. By means of the factory energy model it is possible to study the impact of possible improvements of the site in order to achieve the mitigation of its environmental impact and to reduce energy costs.

A series of possible energy saving actions have been individuated; for each action the primary energy saving per year has been estimated by using the factory energy model. The pay-back time linked to a single action has been calculated; all the interventions with a pay-back time larger than 6 years have been considered as not suitable. The analysis has shown that it is possible to individuate a series of energy saving measures, like thermal insulation of walls and roof-tops, the replacement of old boilers and the use of heat recovery units in the HVAC systems that can produce a saving of about 100000 $ per year with a pay-back time less than 6 year. The results of this energy audit have been used by the company for the definition of its energy saving strategy for the next future.

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