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Contribution to the Success of the Energy Audit in the Industrial Environment: A Case Study about Audit of Interior Lighting for an Industrial Site in Morocco

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Abstract**—**The energy audit is the essential initial step to ensure a good definition of energy control actions. The in-depth study of the various energy-consuming equipments makes it possible to determine the actions and investments with best cost for the company. The analysis focuses on the energy consumption of production equipment and utilities (lighting, heating, air conditioning, ventilation, transport). Successful implementation of this approach requires, however, to take into account a number of prerequisites. This paper proposes a number of useful recommendations concerning the energy audit in order to achieve better results, and a case study concerning the lighting audit of a Moroccan company by showing the gains that can be made through this audit.

Keywords**—**Energy audit, energy diagnosis, consumption, electricity, energy efficiency, lighting audit.

I. Introduction

ENERGY comes in different forms; heat, electrical, radiant, mechanical, chemical, and nuclear energy. Coal and other fossil fuels, which have taken plus than three million years to form, are likely to deplete soon. In near the last 2000 years, we have consumed nearly 70% of all resources. For sustainable development, we need to adopt energy efficiency measures [2]. Today, 80% of primary energy comes from non-renewable and fossil sources. These reserves are continuously decreasing with future consumption and will not exist for future generations [1].

The energy consumption increases due to the increase in the population and the production and use of millions of electrical appliances, industries, construction, the rapid economic and technological growth in the world [12].

The source of energy is either renewable or non-renewable, where non-renewable energy sources such as coal, crude oil and gas account the big percentage of world's energy source compared with renewable sources such as solar, wind and water. The non-renewable energy is currently in phase out of stock from time to time due to use for energy, and the future is towards renewable energy sources: they are available and environmental friendly with no gas emissions. Energy in the form of electric current is one of the major contributions of energy usage in our practical daily life. A proper use of our electricity consumption is essential to save energy, in the current reality, nearly 81% of the world's energy is fossil fuels; if we reduce the consumption of this source, we are also reducing greenhouse gas emissions [6]. Therefore, an energy consumption audit such as electricity audit is essential to study, evaluate our energy consumption, and implement appropriate energy saving mechanisms [3].

Proper management of energy management is essential to curb our energy consumption. The verification of energy and/or electricity is the first step in monitoring and controlling our energy consumption and then using energy saving techniques. In recent years, the campus energy audit has been conducted at several colleges and universities. In the study of [4], data were collected and energy consumption per day, and month was estimated. Energy wastage areas have been identified and behavioral changes and cost-effective measures have been suggested to improve energy efficiency and use [5].

II. The Energy Audit, an Essential Step in the Business

A. 20% Energy Savings

A recent study by the French Agency for the Environment and Energy Management on the prospects for the evolution of energy demand shows possible energy efficiency gains of about 20% on average in the industry by 2030 [10]. The only organizational measures would represent between 10 and 25% of the gains in question depending on the sectors concerned. Faced with the inevitable rise in energy costs for the years to come, energy control represents a "competitiveness deposit" that it is now essential to exploit [7].

B. The Case of Morocco

In Morocco, energy efficiency, together with the development of renewable energies, is a major priority in the national energy strategy. The ambition of this strategy is to save 12% in 2020 and 15% in 2030 of energy consumption. In this context, action plans and normative texts have been put in place in all key sectors, including transport, industry, construction and agriculture.

- **Law 47-09:** In the context of the country's almost total energy dependence on a significant fluctuation in energy prices, Morocco is obliged to implement an ambitious energy efficiency policy. In this sense, our country has laid down Law 47-09 published on 17 November 2011,

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and this law is made up of eight chapters divided into 28 articles in order to clarify the relations between the administration and the operators, improve energy performance, encourage industrial companies to rationalize their energy consumption by obliging them to carry out the energy audit.

III. The Energy Audit, the Core of the Energy Strategy

The energy study is the means of identifying the deposit of energy savings and to draw up a master plan for its rational exploitation which makes it possible to adapt continuously the energy strategy of the company. This approach involves three phases: the audit in question, the feasibility studies and the resulting master plan [8].

The energy audit consists of three stages, generally carried out by specialized experts, in close consultation with the technical managers of the company [9].

Step 1. Preliminary Analysis or Pre-Diagnosis Energy

This essential step aims to have a global view of the company's situation, which makes it possible to highlight low-cost, no-regret low-cost actions and direct it towards more targeted audits concerning the most profitable shares.

Step 2. Detailed Analysis of Energy Saving

On the basis of the results of stage 1, the manufacturer decides to direct the audit on all or part of the pools of savings identified by the service provider. The latter develops the preferential axes of work selected by establishing the energy requirements (in quantity and quality, according to the production cycles and over time) of the various industrial processes, and the energy resources

Step 3. Actions and Solutions

In agreement with the company and according to the results of the previous phase, the expert determines the actions to be taken on the processes and utilities (heating, lighting, etc.). The costs related to the improvement solutions are evaluated (studies, investment, good practices, etc.) as well as the impact on the site's operating balance sheet. This makes it possible to establish the gross return times. Actions can include optimization of energy purchases.

IV. The Keys to the Success of an Energy Audit

The success of an energy audit depends on:

1. The commitment of the company
2. The choice of specialist
3. The precision of the specifications

A. Make Energy Control a Priority of the Company and Organize

- **Mobilizing management and technical teams at a time:** When the search for greater competitiveness becomes crucial to ensure the sustainability of the company, the energy management component (EM) must be taken into account as a matter of priority at the level of the General Directorate and not only in energy-intensive enterprises.

For the energy audit process to reach its full potential, it is necessary to have a strong involvement of the chain of command. The integration of energy management approaches into the overall strategy must be sustained over time, avoiding too "short-term" approaches.

- **Create positions of Operational Energy Managers:** The company must have an internal organization with the necessary technical expertise, authority and resources. Depending on the size of the company, this structure will be more or less expanded around the Energy Manager. For SMEs / SMIs or companies for which energy has little to do with the balance sheet, there are shared and outsourced solutions such as the shared energy manager. It is essential that the conduct of the audit is carried out jointly by the operator and the external expert with "equality of powers" and without diverging objectives, the purpose of the operation is not only to define a catalog of recipes to be implemented quickly but rather to propose an exchange approach aimed at launching some real dynamics over time.

B. Choose the Specialist

- **Bring a fresh, convincing and discreet eye:** Diagnostics are generally not carried out by industrialists alone but in partnership with specialists (engineering, design office, technical center, etc.). These providers must provide evidence of their qualifications, knowledge of the state of the art (best available techniques, existing energy saving pools, etc.) and their ability to choose realistic and economically acceptable solutions. They come naturally to bring their experience and their analytical faculties, as well as a new external eye to draw as much as possible the possibilities of action and by undertaking to respect the confidentiality of the data that they collect.
- **Guarantee the neutrality of the intervener:** Between an independent engineering firm, an energy supplier, an operating service company, a control office, a supplier of equipment, a technical center, a Chamber of Commerce and Industry, it is clear that the principles analysis and the selection of priorities for action may be different. As a result, the offer of diagnostics may seem to be difficult to read for contracting authorities.

C. Establish a Precise and Structured Specification for

- **Define precisely the nature of the proposed energy audit:** Is the energy audit a simple assessment? Should it lead to a quantified action plan? Should there be support in the implementation of the proposed actions? What is its precise perimeter (utilities, processes, climatic engineering, etc.)? In all cases, it seems essential to carry out a pre-diagnosis phase before defining what needs to be analyzed in detail. Pre-diagnosis is too often perceived as a very simple audit whereas it requires a great experience for the diagnostician leads to grasp in a short time, on a wide perimeter and often without campaigns of measurements, the energy stakes of the company. It should be noted that the provider of an accompanying

phase (of the implementation of one or more recommended recommendations) may be different from the one who performed the audit.

- **Detail the "check list" of the information needed to carry out the energy audit:** The energy audit must be based on a corpus of information that can be usefully prepared in advance. These are first and foremost general documents concerning the site: figures of activities, organization and organization chart, factory plans and flow diagrams, production lines. The next step is more specific information on energy management, such as:

- the organization of the "counting plan" (energies used, installation of meters, mode of reporting, automation projects);
- the scoreboard (energy bills, energy consumption distributions by use, various ratios, measurement campaigns);
- energy supply contracts (types, penalties, tariff simulations, suppliers and prices, local taxes, foreseeable changes in activity).

- **Clearly specify the different stages of the study in time and space:** It is important to distinguish the interventions, their chronology and to detail them in the specifications provided to the provider. In the first place, the selected auditor will provide his/her designated interlocutor with the "checklist" of the operations necessary for carrying out the study.

This will be followed by a detailed description of the meetings scheduled on site: meeting with the site management (work plan and signature of a confidentiality agreement), presentation of the site and review of all the documents prepared, meetings with the various managers concerned, Production and methods, financial control, purchasing, etc.). An important time must be reserved for the dialogue between the expert and the corresponding energy to take into account in the analysis the internal issues (or even the "pressures") concerning the management of the energy, the realistic and the choice of priorities given a specific context.

- **Propose useful results, ranked in order of priority:** The recommendations should cover, first and foremost, good behavioral practices (awareness and training of personnel, knowledge of installations and monitoring of operations) as well as the operating processes of the installations (maintenance, process control, replacement or installation of low-investment materials, for example). They should then focus on actions requiring investments at significant cost.

The actions to be implemented must be consistent with any commitment made by the site or the company (environmental management, quality, sustainable development, etc.).

Ideally, energy saving recommendations can be prioritized. First of all, the immediate actions allow an energy saving without requiring investment. Then, the priority actions are to be carried out in the short term because they have a high level of profitability.

V. Case Study: Lighting Audit

This audit retains the lighting of the work premises of a Moroccan company, the objective is to ensure a good level of illumination which allows a good productivity with an effect of reduction of errors, accidents, visual fatigue. And in addition to the average level of illumination required, a decrease in energy consumption [11].

The illumination within the premises of this company must respect the minimum levels required for each type of local presentations in the table of the standard. The illumination levels measured in the plant give the following results:

TABLE I
Comparison between Existing Illumination and Minimum Illuminance

Zone	Subzone	illumination	Minimum illumination
zone 1	Inside the S / S	90-100	300
	In the room	170	300
	Staircase	31-31	150
	In the top	31-27-69	300
	entry	15	160
Establishment	Route between factory entrance and group	40-55	160
	Car park restaurant	10-13-18-8	20
	Training room	280-195-110	300
	Machine shop bottom	85-100-118	300
	Entrance workshop	60-30	160
	home	245-140-172	300
	Electrical Workshop	60-68-95-145-198	300

The illumination existing within the premises of the company does not respect the minimal regulatory values ensuring performance and visual comfort. This is due to:

- The number of lightings out of service
- The dusty atmosphere
- Locations that are sometimes unsuitable.

A. Interior Lighting Design: Application to Administrative Building Zone 1

The administrative building consists of a single floor. It contains offices, meeting rooms, training rooms, a hall. The different views of this building are shown in Fig. 1.

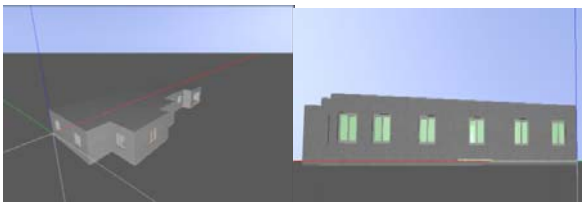

Fig. 1 Different views of the administrative building

B. Lighting Design

Here, we will take the example of the lighting of office 1 located in the administrative building. It is intended for administrative tasks and according to standard NF EN 12464-1, it requires an average illumination of 500 lux.

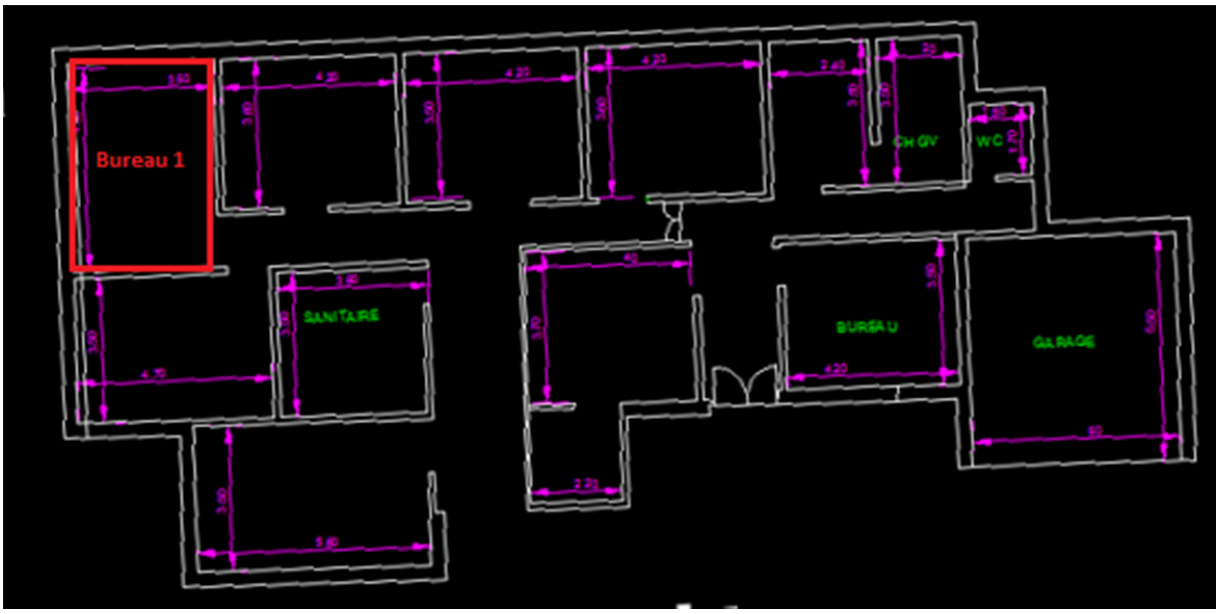

Fig. 2 Architectural building plan

- **Calculation of the total flow to be produced:** The total luminous flux to be supplied by the light sources shall be calculated as:

$$\emptyset = \frac{E*a*b*fd}{fu}$$

with: E: initial average illumination, a: length and b: width, fd: Depreciation factor, fu: Usage factor

- **Calculation of the number of luminaires:** The distribution of luminaires is given by:

$$N = \frac{\emptyset}{n*\text{Flow of a lamp}}$$

with n: the number of light sources.

- **Choice of luminaire type:** A compromise must be found between the number of luminaires, their power, their cost and their energy efficiency. It should also take into account the color index to be insured, the maintenance strategy, the lifetime of the lamps

Table II summarizes the main characteristics of the different lamps.

TABLE II
SUMMARY TABLE OF INDIVIDUAL LAMPS

Lamp Type	Power (w)	Luminous flux (lm)	Light Efficiency (lm/W)	Color index	Average lifetime (h)
incandescent	7 to 300	21 to 48950	3 to 19	100	1000
Halogen incandescent	5 to 500	60 to 9900	12 to 28	100	1500 to 5000
Fluorescent tube	4 to 140	120 to 8350	30 to 112	50 to 112	12000 to 66000
LED Light	1 to 12	8 to 810	8 to 80	80 to 90	25000 to 50000

For the choice, we opted for the LEDs light which have the following advantages:

- High energy efficiency
- Improved consistency
- Robustness and adaptation to the climate of Managem.
- Maintenance and easy maintenance.
- Reasonable price

Thus, the LEDs lights that we have chosen for the administrative building are shown in Table III.

C. Simulation Using the DIALux Evo Software

DIALux Evo. The complete free software offered by DIAL to professionally plan lighting is open to luminaires from all manufacturers.

Table IV shows the results of the theoretical calculation and those obtained by the simulation for the BUREAU 1 in Fig. 2. We obtained the same results with the two methods, theoretical and paralogical, now we will opt for the verification of illuminance of the premises by the software. Fig. 3 shows the results of simulation of the illumination of the Bureau 1.

TABLE III
LEDS LIGHT CHOSEN TO ILLUMINATE THE ADMINISTRATIVE BUILDING

	LEDs light	Location	Power (w)	Number
Administrative building	WT120C L600 1xLED16S/840	offices	16	42
	WT120C L600 1xLED16S/840	Lobby	16	16
	WT120C L600 1xLED16S/840	corridor	16	7
	NEC4T40	bathroom	5	3

TABLE IV
THEORETICAL CALCULATION AND THOSE OBTAINED BY THE SIMULATION

local	E (lux)	Luminous flux	Power (w)	Nth	N Dialux
Bureau1	500	2000	16	6,52	6

Nth: Number of luminaires required theoretically.**N Dialux:** Number of luminaires found by the DIALux Evo software.

Fig. 3 Results of simulation of the illumination of the Bureau 1

D. Financial Study

The overall study that we have carried out allows us to say that the choices that we have adopted meet the different requirements.

- Good light distribution achieved with an optimal number of luminaires offering:
- Less glare
- Correct uniformity
- Good lighting
- Low operating cost:
- Lamps with long service life and good efficiency.
- Luminaires with a good degree of sealing
- Luminaires with high mechanical strength

Table V shows the gains generated through this lighting audit for this company

TABLE V
GAINS GENERATED THROUGH THIS LIGHTING AUDIT

Total energy savings (kWh)	Total earnings (MAD)	Total cost LED purchase (MAD)	Return on investment (months)
658904	477046	1831400	38

VI. CONCLUSION

In this paper, we have proposed a number of useful recommendations that are essential to the success of an energy audit strategy in the industrial environment. We also dealt with a case study concerning the lighting audit of a Moroccan company Using the DIALux Evo software, we have shown the financial gains that can be more beneficial from this audit and the benefits of using the new lighting system at the base of led lighting.

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