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Prospective analysis of the energy efficiency in a farm studio under Saharan weather conditions

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ABSTRACT

The main objective of this contribution is to identify the dominant source and the principle reason for high energy consumption. The most reliable method is to provide a consistent assessment of energy consumptions of a farm studio under Saharan weather conditions. Our approach was based on a new model for the prediction of energy requirements; the production of domestic hot water, free (except for solar gains) and internal loads related to lighting, occupants and equipments are fully considered. Economic-financial aspects are assessed according to the electric bill adopted by the Algerian state; annual and monthly energy needs will be evaluated by kilowatt-hours (kWh) and then converted in Algerian Dinars (DZD) or Euros (€).

As a result, the net electric energy bill required to maintain comfort in all areas at a temperature of T_{comf} amounts to 144171.59 DZD/year. The building envelope is the main source of energy loss. According to the technico-economic study, the external integration of an insulating material (thickness of 6 cm) in facades and roofs can provide a decrease of 56.05% of the energy loads. Priority will be given to active concepts to reduce energy demand:

- A grid-connected PV system feed directly the electrical network and the surplus of energy injected into the national grid network
- It is appropriate to consider solar thermal collectors

Introduction

In accordance with a number of experts, large-scale energy conservation would lead to the realization of energy efficient buildings. These high performance buildings reduce greenhouse gas and air pollutant emissions [1]. According to the International Energy Agency (IEA), Algeria's primary energy consumption has nearly doubled in 2012; this increase in consumption is mainly due to the use of heating devices in winter and air-conditioning units in summer [2]. However, prediction of energy consumption is a great challenge which will be related to the several factors including weather conditions, building structure, geographic location, occupant behaviour, seasonal changes, etc. . .

Furthermore, some relevant papers led to an in-depth diagnosis on energy needs to maintain thermal comfort. In [3], the authors were interested in the study of thermal comfort and energy consumption in a cold environment. They opted for an assessment model a new index called CEP "Corrective Energy & Power". In another work, Hongting et al. [4] have analyzed the main factors that may affect the characteristics of building energy consumption. The results led to conclude that the building envelop, lighting and air conditioning system are the main factors. In the literature, a few methods have been proposed to estimate the heating and cooling energy demands. Rafael et al. [5] were based on ISO 13790:2008 standard using linear regression models and Artificial Neural Networks (ANN). Results of other study [6] suggest that the neural network approach was suitable for the given data set and comparable with the literature results. The energy consumption would be also a useful indicator at the rural scale to understand the economic situations in the city [7]. In other research, Ali-Toudert et al. [8] describe the principal results obtained from a method applied

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Nomenclature

T_{comf}	Comfort temperature (°C)
T_{out}	The monthly average of outdoor temperature (°C)
Dj	Number of degree-days' in the heating and/or cooling season
U_i	The overall heat transfer coefficient (W/m^2 K)
S_i	Surface of the building element (m^2)
b_i	The heat transfer reduction coefficient
k	Thermal conductivity of the thermal bridge (W/m K)
l_{pb_i/m_j}	Low floor i – wall j
l_{pi_i/m_j}	Intermediate floor i – wall j
l_{ph_i/m_j}	Top floor i – wall j
l_{men_i/m_j}	Shear wall i – wall j
l_{rf_i/m_j}	Shear wall i – wall j
hsp	The average ceiling height
N	Number of habitable space
niv	Number of levels
qv_{eq}	The equivalent volumetric flow rate of the air, transiting in the volume space (m^3/h)
0.34	The volumic thermal capacity of the air (Wh/m^3 K)
qv_{wind_aer}	The aeration air flow rate when windows are used as a hygiene ventilation system (m^3/h)
D_{hyg}	The hygiene flow rate
Sp	Is the surface of the piece (m^2)
qv_{add_comb}	Is the additional extract air flow rate relative to the operation of the combustion equipment in the heated rooms (m^3/h)
P_{heat}	Is the power supplied by the heating system (w)
U_T	Is the heat transmission coefficient (W/m^2 K)
U_V	Is the heat transfer coefficient for heat loss by air exchange (W/m^2 K)
ΔT	Is the difference between the base and the room temperature (°C)
qv_{VMC}	Is the flow rate extracted by mechanical ventilation systems VMC (m^3/h)
C_d	Is a multiplicative factor of hygiene flow rates intended to take into account the dimensioning constraints of the ventilation system and the dispersion of the component characteristics
C_{fr}	The network leakage coefficient
qv_{perm}	Is the leakage flow rate of the envelope (m^3/h)
A_T	Is the total internal surface area separating the heated space from the external environment, the floor and the unheated space (m^2)
$qv_{condext}$	Is the air flow rate extracted through the ductwork with a natural draw (m^3/h)
ΔP_{tot}	The total pressure loss (Pa)
$\Delta P_{driving}$	Driving force (Pa)
ΔP_{cond}	Conduit pressure drop (Pa)
ΔP_{elb}	Singular pressure drop of the elbows (Pa)
ΔP_{sup_valve}	Singular pressure drop of the supply valve (Pa)
$\Delta P_{driving}$	The driving force due to the difference in density between warm and cold air (Pa)
Te	External temperatures (K)
Ti	Internal temperatures (K)
h	Is the height of the vent pipe from the supply valve axis to the top of the duct (m)
g	Is the acceleration due to gravity, equal to 9.81 m/s^2
A	Section (m^2)
P	Perimeter (m)
v	Speed (m/s)
L	Length of the duct (m)
N_{elb}	Is the number of elbows into consideration
Q_{DHW}	Is the amount of energy required to produce DHW for one day (Wh)
p	Is the water density which is a function of its temperature T_{CW}, can be equal to1 (kg/L)
V_{DHW}	Is the volume of water (m^3)
Nb_{occp}	Is the number of persons occupying the building
A_{Buil}	Is the living area of the building (m^2)
T_{DHW}	Is the temperature of the hot water at the filling point (°C)
T_{CW}	Is the average monthly temperature of the cold water entering the storage tank or the DHW production coil (instant production)
Q_{Occup}	Internal heat gains (Wh)
Cp	The amount of heat given off by occupant (W/occupant)
$D_{pres/day}$	The period of presence during the day (h/day)
Nb_{heated_days}	Number of heated days (days/year)
P_{elec_appl}	The power of electrical appliances (W)
Nb_{hours}	The number of hours when the device is in an operational state during the day
Nb_{days}	The number of days when the device is in an operational state during the year
Q_{solar}	Represents the direct solar gain, the sum is carried out on all orientations (Wh), there are no solar gains
j	Number of orientations equivalent to the total number of façades
I_j	The incident solar irradiation on the façade j (W/m^2)
Id_j	Daily solar irradiation incident on the façade j (Wh/m^2)
As_j	The equivalent receiving area of the solar gain (m^2)
A	Surface area of the transparent wall (m^2)
Fs	Correction factor for shading
S	The solar factor
U	The surface heat transmission coefficient per degree of difference between the inside and outside (W/m^{2}K)
R_{si}	The surface resistance on the inside (m^2 K/W)
R_i	Is the thermal resistance of the construction layers (m^{2}K/W)
R_{se}	The surface resistance on the outside (m^{2}K/W)

to the estimation of the required energy demand of a multi-zone building for two regions of different climatic regimes, Algiers and Ghardaïa. The found values confirm that the pilot's house can go to a reduction of 55% for cooling and 89% for heating if this low-energy building is located in Algiers. If this building is subjected to the Ghardaïa climate, the energetic consumption corresponds to a saving of 29% for cooling and 94% for heating. The study presented by Filippín et al. [9] is interesting, the ultimate goal is to integrate the past, present and future periods in the energy consumption analysis.

In a recent work, a cost-optimal methodology was developed by Cristina et al. [10]; the used methodological approaches were exploited as a decision-making tool for supporting the private investor in choosing the most viable energy scenario. The involved predictions are able to connect technical and economic aspects and may be considered for future applications. However, an in-depth reflection may raise some questions on the level of energy efficiency. According to Vítor et al. [11], it is best to upgrade the energy efficiency up to the medium level and then offset the demand with alternative equipments of offsetting the energy needs. One of the conduct steps entailed the identification of costs and a life cycle economic analysis [11]. On the other hand, from an environmental