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Energy optimization of Greenhouse

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***Abstract*— This paper presents a new method for optimising the energy consumption inside small greenhouses, which generally have very limited surfaces such as balconies, roofs and garden. we have developed an improved intermediate modelling to determine the energy balance with greater precision. Compared to the classic approach that emphasises the need for heating and cooling and neglects the deep influence of the lighting parameters, our research has shown that for optimum energy efficiency we have to take into account all the three components. Our contribution is to improve the existing model and to show that heat gain from the luminaires as well as the energy used by this equipment have a significant effect on the design of the energy balance as well as on the choice of the adequate shape and coverage of the greenhouse.**

***Keywords*—** IOT; LED luminaire; Raspberry Pi; Smart Greenhouse; Web application.

I. Introduction

Crops in Tunisia are composed of market gardeners in the open field and under shelter on an average area of 140 000 ha. Greenhouse cultivation represents only 6.2% of this area, i.e., 8650 ha of which 1250 ha are covered by heated greenhouses: The species most cultivated under these conditions are mainly tomatoes (56% of the surface area), peppers (26% of the surface area on average) and melons and watermelons (less than 6%). In addition, the governorate of Monastir alone occupies an area of about 39% of the vegetable area planted under unheated greenhouses (572 ha), followed by the governorates of Sidi Bouzid (14.3%), Mahdia (13.2%) and late Sfax (12.7%) of the total area. However, the major problem of these greenhouses is mainly related to energy management in order to make the project profitable and minimize the costs.

Reducing energy consumption inside a greenhouse requires accurate and rigorous sizing of the thermal model of the greenhouse and ensuring that the heat transfer process is well described. Currently, Energy balance of GH models are divided into three main categories: static, intermediate and dynamic. The static models [1] define the heating and cooling equipment's capacity and estimate heat exchange based on weather data and neglect the sun light factor. However, the intermediate models [2-6] include the element of sunlight, finally the complex model [7] in spite of their precision, they require a very complicated modifications and does not include the impact of plant evapotranspiration.

II. Methodology

Our advanced model, named "BGHM" as described in the Figure 1, was first of all designed under the platform of Matlab-Simulink in fact to simulate the indoor weather parameters as shown in Figure 2.

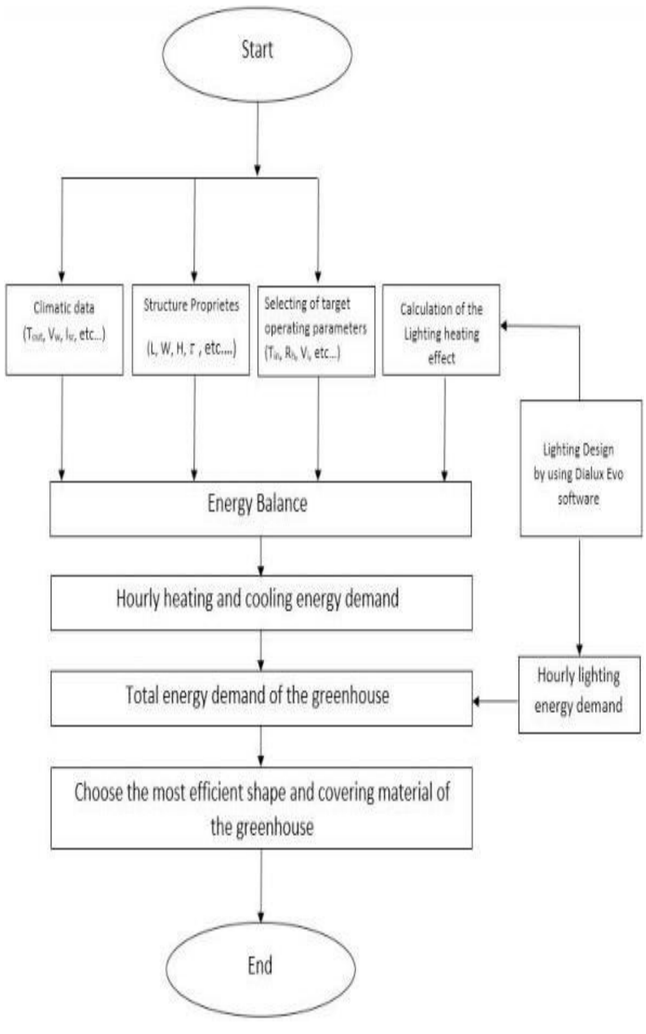

Figure.1. Program design Model

The estimation of the daylight amount was established through the platform of Dialux evo as shown in Figure 3 in order to predict the required energy of lighting fixtures as well as the heat gain.

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"BGHM" is based on the growing of tomatoes inside small greenhouses according to the weather conditions of the Tunisia, it takes into consideration the main heat exchange components Qcd-cv, Qinflitration and Qsolar_rad [2-6] and all the neglected factors of the conventional model such as: Qlong_wave, Qfloor, Qperimeter, Qlightting and Qevapotranspiration.

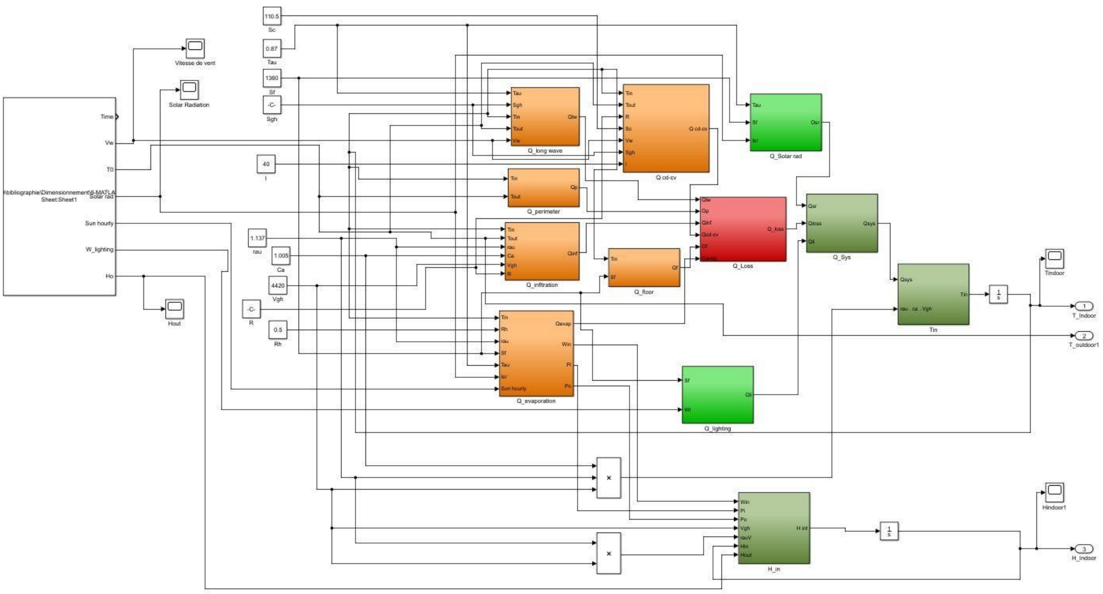

Figure.2. Simulink Model

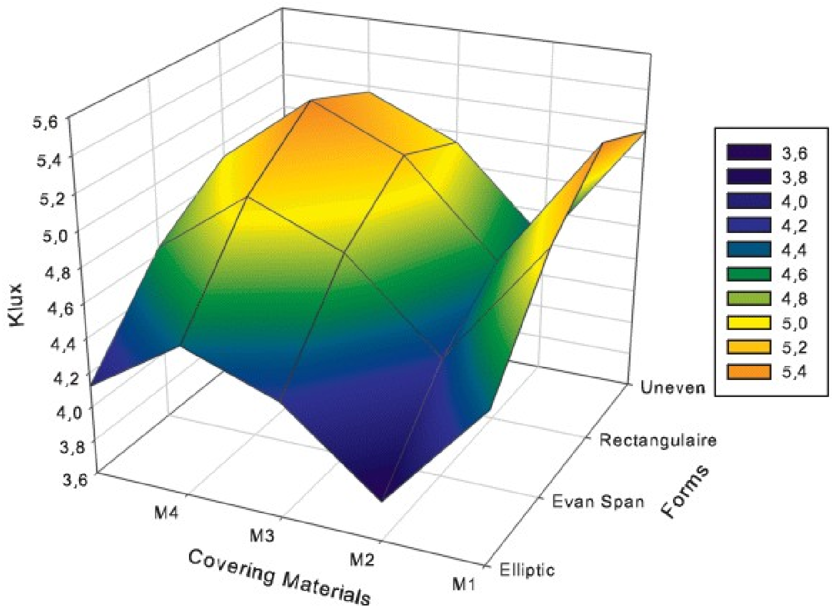

Figure.3. Average Annual aylight

In the conventional studies the researchers focus only on Qcd-cv, and Qinf for estimating the heat loss and the Qsolar rad for estimating the heat gain

-"**Qcd-cv**" : the heat transfer due to conduction and convection. Thermal conduction is specific to solids (wood, metals, etc.), it is a direct transfer within a material medium, which is done by close-to-close heat propagation. The movement of thermal agitation (heat flow) always goes from hot areas to cold areas. Bad conductors (gas, glass wool or polystyrene) are called insulators.

Thermal Convection: is specific to fluids (liquid, gas, air), as well as to deformable elements (such as rocks at high pressure in the earth's mantle), it is linked to the movement of the fluid, therefore to a transport of matter. The fluid state

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includes the gaseous state and the liquid state which have the faculty to be deformable. It adapts to the shape of the container offered, and can flow.

-"**Qinf**" : Infiltration heat loss relates to the amount of heat lost inside a greenhouse. It may escape via cracks, open doors or other gaps in the structure. Because a greenhouse is a regulated environment, an excessive loss of infiltration heat presents a significant problem and challenges for a farmer.

- "**Qsolar rad**": Solar gain (also called passive solar gain) means the amount of thermal energy of a space, object or structure that rises when it receives incident solar radiation. The quantity of solar gain which a space receives depends on the total incident solar irradiation and the ability of all intervening materials to transfer or absorb radiation.

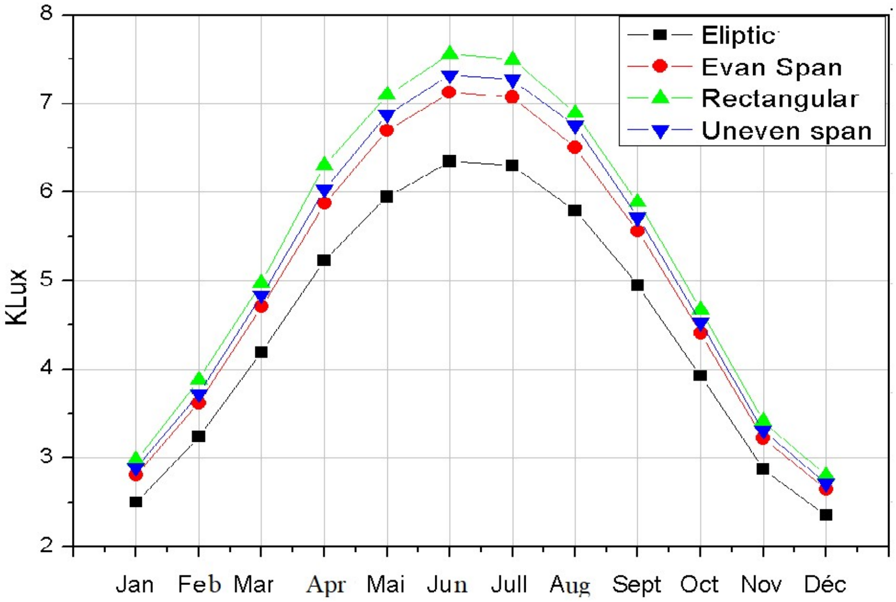

Figure.4. Heat Loss

Our model will take into account new heat exchange in order to improve the accuracy of the energy model

-"**Qlong_wave**" : Heat loss from long wave radiation in general, thermal radiation emitted from inside the greenhouse can be partially absorbed by the cover, reflected in the greenhouse or transmitted outside the greenhouse. Depending on the degree of transparency of the greenhouse cover, the exchange of long-wave radiation across the transparent surface will have a significant effect on heat loss and a significant amount of heat will be transmitted outwards.

"**Qf**" : Heat loss in soil and heat due to perimeter and the heat losses caused by greenhouse soil "**Qp**": are mainly due to soil conduction and perimeter heat transfer. This quantity has an effect on the estimation of the energy balance equation, which should not be overlooked to increase the accuracy of the results of the energy balance equation.

- "**Qevap**": Heat loss by evaporation: Evaporation remains a crucial element that should not be overlooked in establishing the energy balance equation because it represents a significant amount of heat loss, this amount is produced by the leaves of the plant and the surface of the soil.

- "**Qli**": Heat gain due to Lighting fixtures it reflects the effect supports the sufficient amount of specific heat usually emitted by the lighting system. Previous studies and research have overlooked the energy weight of lighting in choosing the shape and cover of the greenhouse and its impact on the energy balance equation, while our model will take into account in its analysis the expected effects of lighting on the model.

These neglected heat exchange parameters have a significant impact on the elaboration of the energy balance as shown in Figure 4 and Figure 5.

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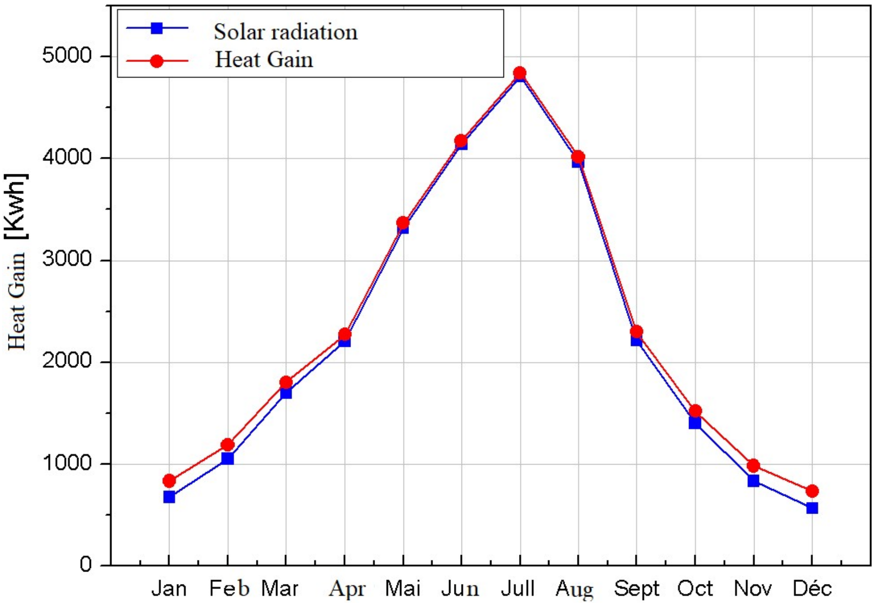

Figure.5. Heat Gain

The calculation of the heat balance was established for all type and covering materials of the greenhouse as mentioned on the Table 1.

Energy demand of all Materials and Forms (Heating, cooling and lighting) [kwh m-²]				
Shape / **Materials**	Evan Span	Uneven Span	Elliptic	Rectangular
M1: Glass 3mm	0,3044	0,302	0,3168	0,3056
M2: Acrylic	0,341	0,3392	0,3524	0,3474
M3: Polyethylene	0,2526	0,2502	0,2648	0,255
M4: Polycarbonate	0,2992	0,2968	0,3116	0,3002
M5: Double Glass	0,2658	0,2638	0,2776	0,2696

By referring to the results of the total energy demand of all materials and shapes, we can deduct that these new heat transfer amounts have a big influence on the choice of the most efficient cover and shape.

As per the table above we can see that the Uneven Span is the most efficient shape equipped by the Polyethylene M3 is the most efficient cover material, whereas the rectangular greenhouse equipped within the material M2 is the worst choice in terms of energy consumption.

In the next section, we are going to superimpose the results of the different models, the conventional model which does not take into account the parameters we have injected in our Model, the BGHM model which takes into account all the transfer parameters but without the indirect impact of the lighting, i.e., without Qli and finally our BGHM model which takes into account all the parameters including the direct impact of the lighting. The Figure 6. Shows the comparisons between the different models.

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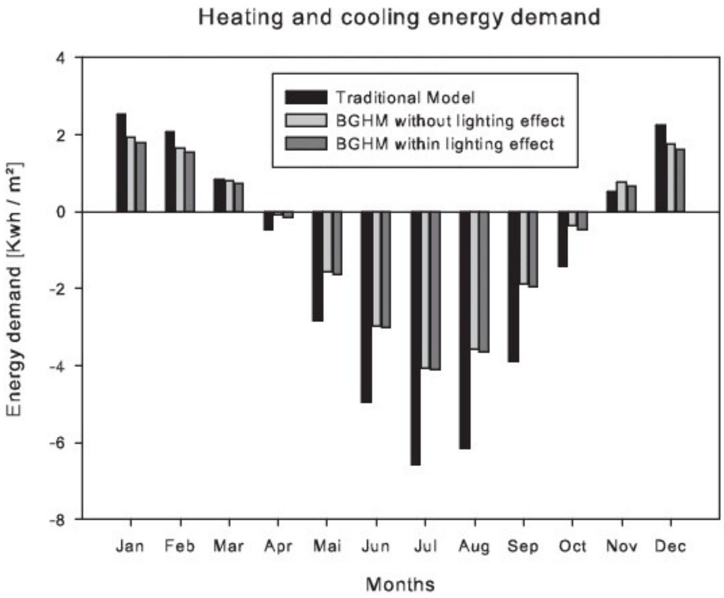

Figure.6. Total Energy demand

By referring to the Figure 6 we can deduct that the BGHM model with lighting effect consumes less than 49% than the traditional model. It is also more efficient than BGHM without lighting effect and this due to the heat gain from lighting fixtures as the luminaires produce heat energy that have a very important contribution during cold season which decrease the heat need during these periods.

III. Conclusions & Discussion

Based on our funding, we have successfully proven that the energy balance of a GH can't estimate optimally the amount of energy used if only we take into consideration all the key parameters. Based on our empirical analysis, we can summarize the following conclusions:

Optimized energy consumption needs, have been achieved by adopting an uneven greenhouse's forms equipped within a polyethylene covering material, whereas the rectangular greenhouse equipped within M2 is the most energetic choice.

The heat gain from lighting fixture have an important influence on electrical energy, especially during the cold period.

The developed model reveals that a significant gain of 49% in cooling and heating energy consumption was achieved compared to the "conventional model".

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