SHAPE AND COVER MATERIAL IMPACT ON GREENHOUSE PERFORMANCE

Norma A. Rodriguez-Muñoz[1,3], Juan Carlos Barragán-Medrano[2], Jorge Escobedo-Bretado[3], Mario Nájera-Trejo[3], Ignacio R. Martin-Dominguez[3]

1. Consejo Nacional de Ciencia y Tecnología, Cátedras CONACYT, norma.rodriguez@cimav.edu.mx; 2. Instituto Tecnológico de Durango, Departamento Ingeniería Mecánica; 3. Centro de Investigación en Materiales Avanzados, Unidad Durango

Abstract

An analysis of the influence on the thermal performance of greenhouses due to the shape and selection of materials is conducted through dynamic simulations. In Latin America and overall in developing countries the design of a greenhouse shape and construction materials is often due to availability of resellers and amount of initial investment to be made. The selection is usually a plastic film covered structure, which is transparent to short wavelength radiation and opaque to long wavelength radiation. In this work, TRNSYS 17 was used to model the system and to perform a parametric analysis in order to determine the best shape and construction material from both a technical and economic point of view. The location of the studied greenhouse is on a region within the BS climate, according to the Köppen climate classification. The evaluation is performed in equal area greenhouses with different chapel shapes and different cover materials. The results show the calculated greenhouse energetic demand for heating and cooling through a typical year.

Introduction.

Nowadays agriculture and open air agriculture the cultivation is performed in controlled environments such as greenhouses [1]. In Latin America, there are some regions with suitable environmental conditions for greenhouse cultivation which has motivated its sustained growth. The unawareness of new technologies and lack of financial means to condition and automation of greenhouses have led low and medium technology producers to use unfit techniques to condition their environment, causing damages to the greenhouse structure and products. The location of the studied greenhouse is placed on a region within the BS climate, according to the Köppen climate classification, where a 31°C summer maximum temperature is achieved and a winter minimum temperature of 1.5°C. This climatic variability of the analyzed greenhouse can be observed in Fig. 1, where the average, minimum and maximum monthly temperatures are shown. Within this climate the greenhouse producers apply different techniques in order to maintain an adequate temperature range where the use of fossil fuels is a predominant practice.

System conditions and methodology.

The studied greenhouse is located in a BS climate known as steppe. A climatic analysis was made considering the following parameters: solar radiation, houly mean temperature, humidity and wind speed. The climatic information is supplied as a TMY (Typical Meteorological Year) file, obtained from the Meteonorm software. Fig. 1 shows an adapted graph by Nisen et al. [2], where the climatic suitability can be qualitatively estimated. The original graph by Nisen displays the average monthly temperatures and the region solar radiation, whereas in the adapted diagram the minimum, average and maximum monthly temperatures can be observed. Although this simplified approach can be used, depending on the temperature variation of each area, misleading conclusions can be obtained.

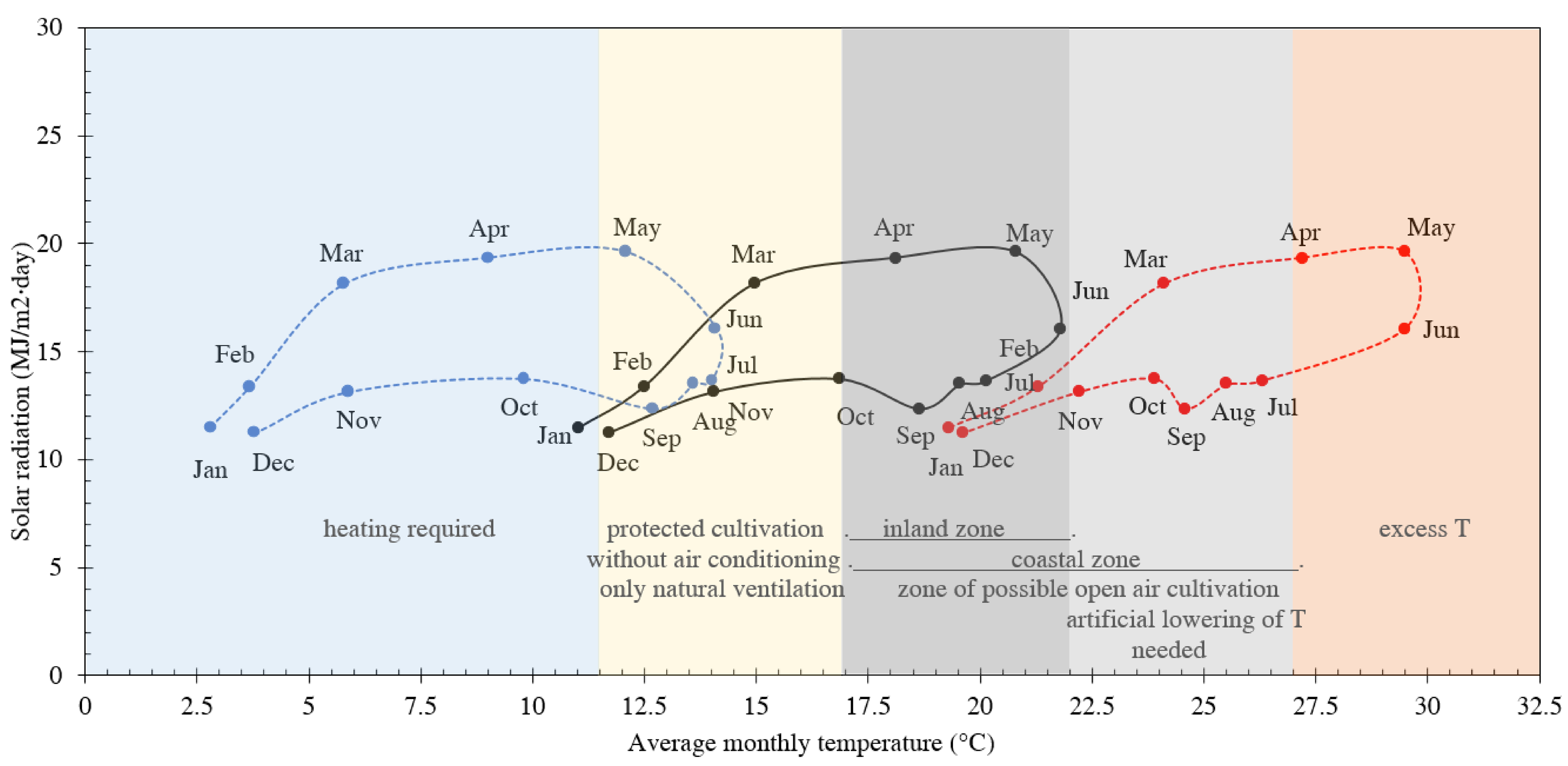

Fig. 1. Solar radiation and air temperature (CICESE-SMN-CONAGUA). Adapted graph from Nisen et al. [2].

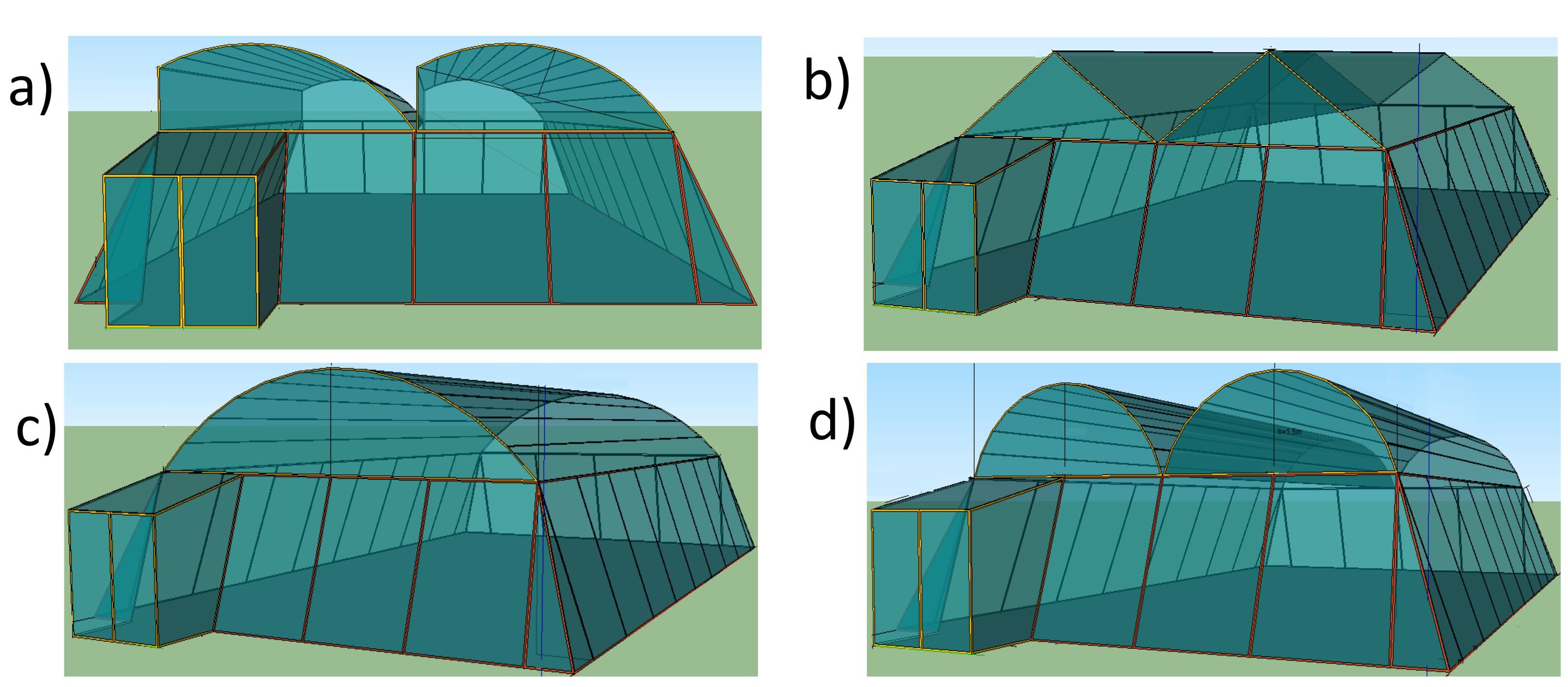

Fig. 2. Greenhouse shapes.

A detailed hourly analysis of the effect on the thermal performance of greenhouses due shape and choice of cover materials through the dynamic simulations software TRNSYS 17.02.0004 is proposed. Taking into consideration the hourly variation of the climatic variables and its effect on the yearly energy consumption given the case when the greenhouse needs air conditioning (heating and cooling). At Figure 2, the analyzed greenhouse shapes can be observed, meanwhile in Table 1, the dimensions and air volume of each greenhouse shape are shown. The selected cover materials were glass, low density polyethylene, polyvinyl chloride and polycarbonate (GLASS, LDPE, PVC and PC).

Shape	Dimensions (m)	Volume (m^3)	Area (m^2)
a) Saw tooth	3.5 x 18 x 10	528	183
b) Standard peak or chapel	4.0 x 18 x 10	488	
c) Single tunnel	4.2 x 18 x 10	541	
d) Double tunnel	4.0 x 18 x 10	532	

Results.

Taking into account the climatic conditions of Durango city, in Mexico region, and the thermal and optical properties of the greenhouse's cover and structure, the energy demand results were obtained:

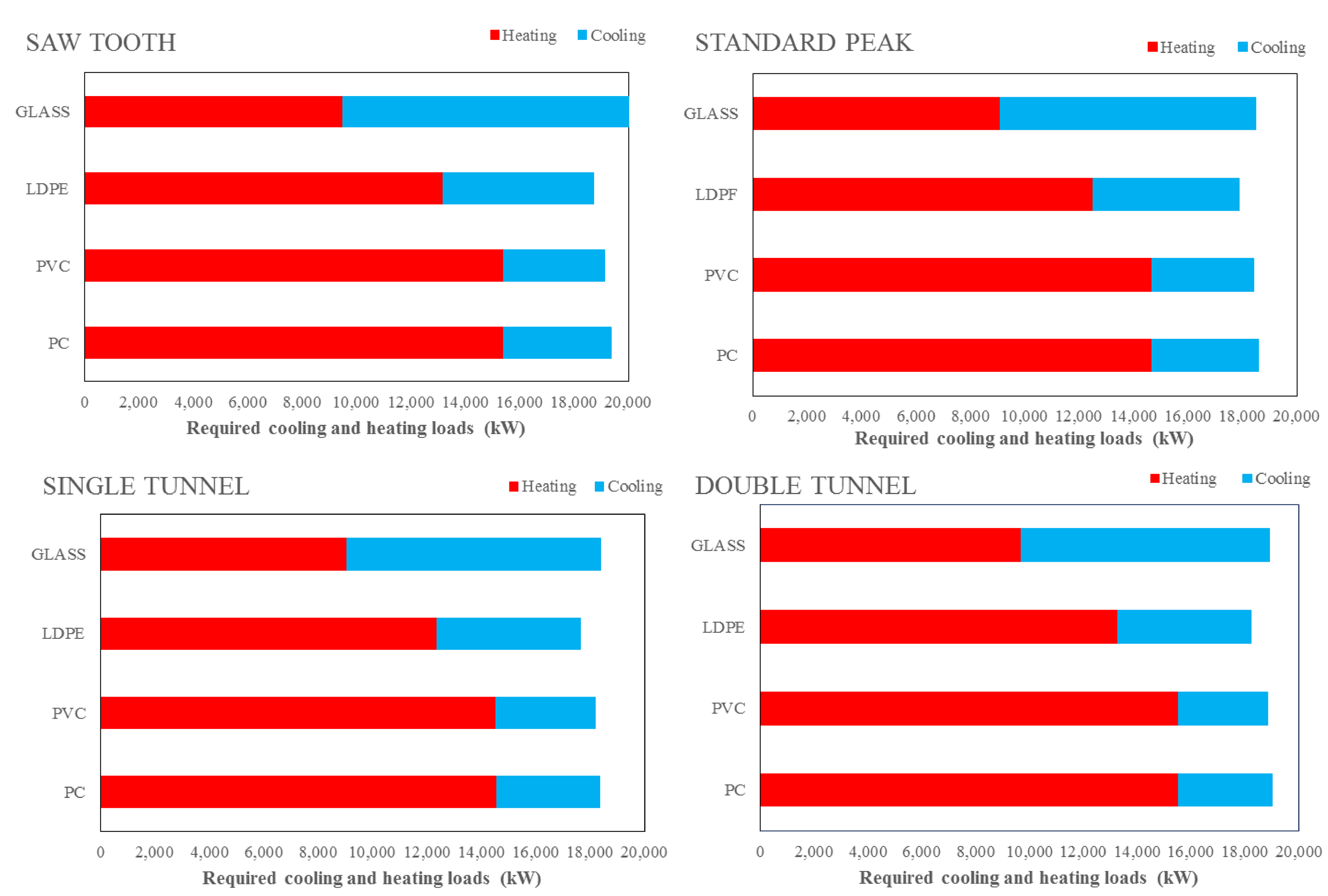

Fig 3. Greenhouse energy demand.

Conclusions.

An analysis of the influence on the thermal performance of greenhouses due shape and choice of materials is conducted through dynamic simulations. From the evaluated greenhouse shapes the cover material that needs less energy for heating is glass, nevertheless, when the overall annual energy consumption is analyzed the cover material needing less energy is the low density polyethylene (LDPE). It was found that the optimum greenhouse shape is the single tunnel greenhouse, which would need 4% less energy in a yearly basis. The LDPE covered greenhouse consumes 14.9 % less energy for heating than the PC and PVC covered greenhouses and 43% less energy for cooling than the glass covered greenhouse.

Aknowledgements.

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