

Evaluation of Temperatures in Mexico to Analyze the Saving and Efficiency Energy

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Recibido 17-06-2015, aceptado 21-11-2015.

Abstract

Natural gas and coal have caused serious damage to human health and the environment over the last 100 years, its emissions. In the last 10 years, it has increased the use of non-renewable energy, but even so, they are still used fossil fuels such as oil and nuclear energy, which generate significant concentrations of air pollution, being mainly the pollutants derived from the carbon. This has caused problems for the environment and health in populations of large cities. This has led to generate extreme climates, where the climate in indoors of buildings, is responsible for the increased energy consumption in areas of extreme weather such as the city of Mexicali and many other urban areas of our country. Because of this, there are a lot studies of temperature levels, where is carried out in different regions, with thermal simulators that are based on scientific principles and operated from computing platforms to evaluate the thermal performance of buildings indoors. With mathematical simulations of heat transfer levels of outdoors to indoors of buildings, it can be known the process of climate in

indoors, and thus able to recommend and evaluate some energy saving measures. This can minimize the consumption of electrical energy and support to not affect the environmental and with this the climatic factors and the human health. This work aims to collect data on time in some regions of our country, from specialized data systems for thermal simulation as residential housing, office buildings, or any construction in Mexico. The study was conducted in the period of 2010-2012.

Index terms: analysis of temperatures, saving energy, energy efficiency.

Resumen (Evaluación de temperaturas en México para analizar el ahorro y eficiencia de energía)

El gas natural y el carbón han generado graves daños a la salud humana y el medio ambiente en los últimos 100 años, por sus emisiones. En los últimos 10 años, se ha incrementado el uso de energías no renovables, pero aun así, se siguen utilizando combustibles fósiles como el petróleo, energía nuclear, que generan concentraciones considerables de contaminación del aire, siendo principalmente los polutantes derivados del carbón. Esto ha originado problemas al medio ambiente y salud en las poblaciones de las grandes urbes. Esto ha generado climas extremos, donde el clima artificial de interiores de edificaciones, es responsable por el mayor consumo de energía en las zonas de clima extremoso como la ciudad de Mexicali, y muchas otras áreas urbanas de nuestro país. Debido a esto, se tiene una gran diversidad de estudios de los niveles de temperaturas en diversas regiones del país, con simuladores térmicos que se basan en principios científicos y operados desde plataformas informáticas para evaluar el rendimiento térmico en interiores de edificaciones. Con las simulaciones matemáticas se conocen los niveles de transferencia de calor de los exteriores a los interiores de las edificaciones y, con ello, se puede recomendar y evaluar algunas medidas de ahorro energético; para reducir el consumo y ayudar a contener los problemas ambientales o de energía. Este trabajo tiene como objetivo recoger datos de tiempo en algunas regiones de nuestro país, a partir de los sistemas de datos especializadas para la simulación térmica como viviendas residenciales, edificios de oficinas, o cualquier tipo de construcción en México. El estudio se realizó en el periodo de 2010 a 2012.

Palabras clave: análisis de temperaturas, ahorro de energía, eficiencia energética.

1. Introduction

The electrical energy consumption of air conditioning equipment represents an increase of over 50% in demand for electricity in the residential housing in areas that require it, in office buildings, hotels, shopping malls and stores department. This is in order to get a comfort during the summer months ranging from May to October in this zone of the northwest of Mexico, where some regions are identified as hot zones, as Baja California, Baja California Sur, Sonora, Sinaloa, Chihuahua, Coahuila, Nuevo León, Durango and Tamaulipas. In these zones of Mexico, are two major climates identified as very dry, dry and semi dry areas, represented by high temperatures during the summer months, reaching 45°C and near of 0°C in winter, with levels higher than 50% of relative humidity. Thermal simulators operate with climatological data of the region in which the property is located. The simulation results are as good as the data that have fed, so it is important to have reliable climatological information and processed the way they require simulators. Thermal simulators operate with climatological data of the region in which the property is located [1]. The simulation results are as good as the data that have fed, so it is important to have reliable climatological information and processed the way they require simulators. There are a lot of studies conducted to evaluate the temperatures and their relationship to the energy consumption. An example may be the Federal Electricity Commission (FEC), which supply, regulates and control the electricity in the northwest of Mexico principally. FEC evaluates the temperatures by regions where climates are hot, and presents an increase of the consumption by air conditioning or coolers evaporative and increasing the economic costs to the families. For this reason, this study is focused on decreasing cost per kilowatt hour below their normal price in the Mexicali city where the cost of electricity is very high. Also in this zone of Mexico, the electricity system lacks a formal technical analysis methodology for estimating prices that can be discussed by experts on the subject and subjected to other types of analysis. In Mexicali, exists the Engineering Institute at the Autonomous University of Baja California (UABC), which has developed a simulator which using thermal calculations for hourly temperatures showing that they can be estimated skills. This can be, with cooling system functions and the electricity consumption, of any construction building with the climatological information of the cities, where can be possible realize analysis, of efficiency of energy [2],[3].

Specialized thermic systems

The commercial simulators to realize thermal calculations regularly are developed by companies engaged in selling of used computing systems to calculate the temperatures cities and determine of the cooling systems capacity in buildings. But most, have only climatological information of USA and provide estimates of thermal loads in buildings that are not used in our country, and furthermore the presence of heat can provide a different reality. The biggest problem of designers of these systems is when they face to thermal calculations of the 11th temperature level, solar radiation and relative humidity, principally; in hourly periods, and each place represents a custom analysis. The study aims to show, the possibility to group the principal climatic regions and demonstrate how can behave the reality of a thermal climatic region as a very similarly to another region, and set the conditions where possible. It will also be possible to establish criteria for groups of temperatures in different cities in Mexico.

Efficacy of energetic systems

The importance of efficient use of electric energy is today a topic of utmost importance for all economic, political and social sectors. The companies dedicated in the generation, transmission and distribution of electricity systems

Have shown that it is much better to save or stop using electricity when it is not needed. Exists alternative campaigns implemented on the importance of turning off a light bulb when it is not needed and benefit of present and future to save electricity. In Mexico, the use of electricity in the domestic sector is 26%, distributed in the air conditioning, the lighting, refrigeration and the appliances. Additionally, it should be mentioned that in Mexico, are an average of 8 lamps to the lighting systems in houses and 19 in commercial and industrial activities. If the normal lamps are replaced with saving lamps, would be savings of 80%, and emissions to the environment would be in the order of 31 million tons of CO₂. By other hand, this work aims to provide systematic information of climatic variables of interest such as temperature, solar radiation and relative humidity, hour by hour, trying to cover the widest extension of the territory of the Mexican Republic. This is as a reliable source for mathematical modeling, simulation and thermal energy behavior in the building systems, especially geared towards residential housing, buildings and commercial and public sector. Most of the data is provided by the Sistema

Meteorológico Nacional (SMN-Mexico) with automatic stations monitoring, of climatic parameters mentioned above located in different places of the country. Also, the Meteorology Department of the Engineering Institute in the University of Baja California, California, working with the Department of Engineering of the University of Sonora and Comisión Nacional del Agua (CANA-Mexico) in Baja California, have supported information from their respective stations. The SMN agency under the CNA, has monitoring systems in the Automatic Weather Stations (AWS), with registers every 10 minutes of the following information to studies of this topic showed in table 1.

Once obtained and processed the information of the climatic factors in hourly times, the data can be analyzed to obtain a representative regionalization of climates, average temperatures, and most importantly the variable used in studies of energy efficiency (degree-hours). This indicates, the effect of local temperature, representing the time duration of the temperature obtained in the period of analysis to be used in the thermal simulation program developed by the Institute of Engineering, UABC. With this, can get a realistic characterization of the energetic behavior and establish conditions of conservation and efficient use of energy for all types of buildings in the regions evaluated.

Heat transfer mechanism

Heat transfer occurs mainly when there is a difference of temperatures between two bodies. The heat gain occurs when a body temperature increases relative to another and heat loss, when a body temperature decreases relative to other. The laws of thermodynamics indicate that all physical systems tend to the thermal equilibrium [4], when there is a temperature difference between bodies and it is a phenomenon that occurs

Table 1. Climatic factors monitoring by the meteorological stations.

Climatic parameters monitored
Wind speed and direction
Room temperature
Barometric pressure
Solar radiation
Relative humidity and precipitation

Data from CNA-Mexico

consistently. The second law of thermodynamics states that energy having a direction and sense, has a heat flow in a direction and this, and is from a lower level to a higher level of temperature. When there is a temperature difference between two objects in proximity to each, the heat transfer can't be stopped; and it can only become slower. The thermal conductivity coefficient expresses the magnitude of their ability to conduct heat through unit area of a sample of material of infinite extent. This coefficient varies with conditions Material (moisture content, temperature at which the measurement is performed), by what conditions to do so are fixed, usually for dry material is in some times of 15°C (mean temperature of building materials) and in other times of around 27°C. Heat gain is the rate at which energy is transferred to a space or rate at which energy is generated inside this. Heat gain has two components sensible heat and latent heat, which must be calculated separately [5], [6]. Heat gains usually occur in the following forms:

1. Solar radiation through the windows.
2. By heat conduction through the boundary and by radiation and convection from the inner surface into space.
3. Sensible heat convection and radiation from the internal objects.
4. By introducing external air, either by cooling or by infiltration.
5. Latent heat gains within the space generated.

Thermal calculation

Is expressed through mathematical models how energy is transmitted in as heat between different systems, surfaces, materials, etc.; whenever there is a temperature difference [7], [8]. There are several factors to consider for thermal calculations, and to understand this is important to know how to find heat transfer that can occur, taking into account the main mechanisms as conduction, convection and radiation processes, as is showed in Fig. 1, as the thermal gains can be inside a house.

Heat balance

Generally, the thermal conditions of a building depend of the magnitude of heat gains and losses instantly. The building will tend to heat up when heat gains have the greater losses and the cooling process in the opposite situation. In either both cases, can easily reach the interior conditions of discomfort which, in extreme situations, require artificial cooling systems (cooling and / or heating) to be countered [9], [10]. A heat

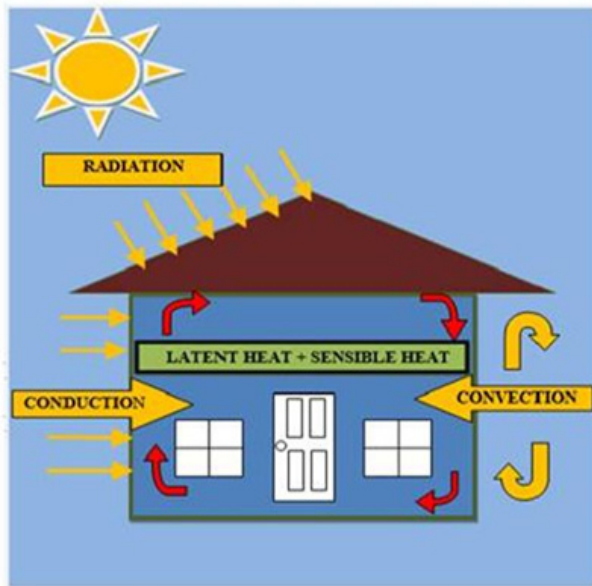


Fig. 1. Transference mechanisms of heat in a normal house.

balance considers internal heat gains and external, described below:

- Internal Earnings: People, lighting, equipment, material flow.
- External Earnings: Absorption of solar radiation by surfaces exterior windows, skylights, ventilation.

The American Society of Refrigeration and Air Conditioning (ASHRAE), recognized the validity of four methods for calculating the thermal loads to select the capacity of air conditioning equipment, that is mentioned follows:

1. The Method of Transfer Functions (MTF). Is a simplified version of this method with applications for different types of construction, being published in the ASHRAE handbook fundamentals 1977 [11]. This method was founded to estimate the cooling loads in hourly periods and to predict conditions space for several systems, control programs and establish programs operation. The method of transfer functions is applied to calculate unidirectional flow of heat transfer walls and ceilings sunny.
2. The second method is to calculate the thermal charges and differential temperature and the cooling load factors. It is a method that can be applied to be considered as the first alternative calculation procedure manual [12]. This method

is considered a simplified method by using a factor U to calculate the cooling load for roofs and walls, the basic equation for cooling load on outer surfaces is: $Q = UA$.

The Load Calculation Method for Differential Temperature (LCDMT) is based on the assumption that the flow of heat through a wall or ceiling can be obtained by multiplying the (indoor-outdoor) temperature differential by overall heat transfer coefficients [13], which can be found as tabulated values U from ceilings and walls, respectively.

3. The third method is used for the calculation of thermal stress, being the Equivalent Differential Temperature Total and Average Time (EDTT/AT). The first presentation of this method was made in the manual ASHRAE fundamentals 1967, and is recommended for specialized users. To calculate the cooling load of a space using the convention EDTT/AT specialized software, and are utilized the same general procedures employed to apply the MTF.
4. The fourth method was used to calculating the residential loads [14]. There are several packages in the market of commercial calculation, which facilitate the determination of the cooling load on buildings, for example in the USA, are the follows:
 - a) Residential Load Calculation. This software can estimate the gains and heat losses of buildings of 1900 cities in the United States, but does not specify the methodology used.
 - b) Software Design for HVAC Professionals (www.commercial.carrier.com). The name of E20-II software and its methodology used to calculate the heat gains and losses, is by the method of transfer functions proposed by ASHRAE and can only be used within the United States.

One of the most accepted methods is the transfer function given by ASHRAE in 1997, which is described in the Fundamentals of the manual, containing information of the time required temperature instantly, during the whole year and information needed several years [15]. However simulators, that use this methodology has databases of states and cities of the United States, not possible apply in Mexico. The commercial use simulators based on climatological information, based to the room temperature of the Meteorological Station nearest to the evaluated city, but is not applied to the hour-grade criterion. This can lead to unrealistic results. For example, if desired the simulation of the temperature of a building in San Felipe and not has

registers, can use the record of the city or town which exists nearby information and could be the Mexicali city. Clearly, despite of nearby areas to determine energy behavior is not the same as the climates of both sites and may be significantly different. The simulator developed by Engineering Institute of UABC, uses the methodology transfer functions given by the ASHRAE, and also adding the hour-grade criterion for determining cooling systems, rapid removal of heat and power consumption of an indoor building conditioning. This simulator has been used quite reliable for 22 thermal calculations performed in houses of Mexicali, Hermosillo and Cd. Obregon in Sonora, Culiacan, Sinaloa and diverse cities as Cienfuegos, Moa and Sancti Spiritus, in Cuba, among others. Their database has degree-hour information of these cities and regions. Currently still working to expand the information base available to the simulator for other regions and cities and be used in any part of our country.

Geography of Mexico

Mexico is divided into 31 states and the Federal District, and has a land area of 1,964,375 square kilometers. The geographic location within the map Global is North Latitude $32^{\circ} 43' 6''$ on the border with the United States of America, which is located on the right bank of the Colorado River between The Algodones, Baja California and Andrade, California. West longitude $118^{\circ} 22' 00''$ west longitude; Elephant Rock at Guadalupe Island, located in the Pacific Ocean. North Latitude $14^{\circ} 32' 27''$ and at the mouth of the river Suchiate border with Guatemala. The latitude is 86° West $42' 36''$ at the southeast end of the island women. Mexico has a total population recorded in the census of the year 2005 with 103 million and in the population census of 2010 was 112 million inhabitants that is an increase of 7%. It mention that the study began conducting the census data in 2005, however the increase in population does not significantly affect results.

The climates in Mexico

Climate types identified by the National Weather Service in our country showed in Fig. 2. In Mexico the climate is determined by several factors, among which find the altitude above sea level, geographical latitude, the various weather conditions and the existing distribution of land and water. The country has a great diversity of climates, which can be classified according to their temperature in warm and temperate; and according to the moisture in the middle, being dry, semi dry and very dry, and in humid and sub-humid environments.



Fig. 2. Climates in Mexico.

Dry and semi dry weather

It is found in most of central and northern Mexico, in a region that includes the 28.3% of the country; and is characterized by the circulation of winds caused by low cloudiness and rainfall 300 to 600 mm per year, with average annual temperature 22°C to 26°C in some regions, at 18°C to 22°C . This corresponds to states located geographically in the North, Northwest and Northeast zones that are principally Aguascalientes (86%), Zacatecas (73%), San Luis Potosi (71%), Nuevo Leon (68%), Coahuila (49%), Sonora (48%), Durango (40%), Sinaloa (40%), Chihuahua (33%) and Baja California (24%). These percentages are the predominant climate in their territory.

Very dry climate

Registers temperatures average 18°C to 22°C , with extreme cases of more of 26°C ; presenting annual rainfall of 100-300 mm on average, 20.8% in the country, and is characterized to be located geographically in the North and Northwest areas covering the states of Baja California (69%), Lower California Sur (92%), Chihuahua (40%), Coahuila (46%) and Sonora (46.5%). these percentages are the predominant climate in their territory.

Warm climate

This is divided into sub-humid warm moist warm. The first of it occupies 4.7% of the national territory and is characterized by

a temperature 25°C annual average between 22°C and 26°C and rainfall of 2000 to 4000 mm annually. Meanwhile, the warm sub-humid climate is found in 23% of the country; it is recorded rainfall between 1000 and 2000 mm per year and temperatures ranging from 22°C to 26°C, with regions where 26°C exceed.

Mild climate

It is divided into sub-humid and humid; and the first, was recorded temperatures between 18°C and 22°C and average rainfall of 2 000 to 4 000 mm per year; comprising 2.7% of the national territory. Regarding the sub-temperate wet, is 20.5% in the country, mostly observed temperatures between 10 ° and 18°C and 18°to 22°C, however in some areas may decrease to less than 10°C; recorded rainfall of 600 to 1 000 mm in average during the year.

2. Methodology

The analysis of climate in Mexico was to obtain information of the geographic zones with different environments and can determine the factors about of the activities in each region of this country. In this study was made some steps: (1) compilation, organization and analysis of information of climates in Mexico, (2) Selection of cities with habitants higher than 100 000 habitants, (3) determine maximum and minimum temperatures in the cities of step 2 with the type of climates, (4) select houses to make a thermic simulation and (5) identify houses with high consumption of electricity as shown in Fig. 3.

3. Results

Mexico exhibits throughout its territory six main climates and subclimates classified and grouped by the National Weather System as show in figure 3: (1) warm humid and sub-humid, (2) Dry and semi-dry, (3) temperate humid, (4) warm humid, (5) very dry and (6) warm sub-humid.

Figure 3 was made in accord of three principal climate factors based in population, cities and territory, mentioned next:

1. What is the climate that has largest population in Mexico?
2. What is the climate that has the largest number of cities?
3. What is the climate that has greater coverage in our country?

To answer these questions, was decided to first analyze all cities a larger population of 100 000. The diversity of climate in Mexico explained above was showed by distribution in table 2 and next information.

Classification of climate related with population

For urban populations over 100 000, it was found following:

1. Temperate and sub-humid with the largest number of habitants 24 501 964.
2. Warm and sub-humid in second place with 14 207 920.
3. Dry and semi dry with 13 318 566.
4. Very dry climate in the fourth position with 8 009 361.
5. Temperate and humid with 155.253.
6. Warm in humid with 78 989.

Total of 59 955 484 people, representing 46% of the population of Mexico. Assuming the rest of people lives in towns with less than 100 000 populations.



Fig. 3. Analysis of climates and climates in Mexico.

Table 2. Distribution of climates in Mexico.

Núm.	Type of climate	Habitants	Cities	Territorial extension (km ²)
1	Warm and sub-humid	14,207,920	37	562,129
2	Dry and semi-dry	13,318,566	34	521,676
3	Temperate and sub-humid	24,501,964	39	229,754
4	Very dry	8,009,361	33	332,593
5	Warm humid	155,253	20	136,155
6	Temperate humid	78,989	2	27,093

- a) Climates representing higher temperatures throughout the year are the warm humid and warm sub-humid. These are located in the areas geographical of the southeast of Mexico.
- b) The very dry, semi-dry and dry climates found on the geographic area northern Mexico and have the highest temperatures during summer (May-October). The climate is the most populous sub-humid temperate with 24 501 964 inhabitants it accounts for almost 20%. The weather in more cities is the warm sub-humid with 39 representing 22%. And finally the warm sub-humid climate is the most coverage our territory with 562.129 km², this represents almost 28%.

Classification of climate by cities

Cities with more than 100000 inhabitants were 165 and exhibit the following characteristics.

1. Temperate and sub-humid with a total of 39.
2. Warm sub-humid with 37 cities.
3. Dry and semi dry with 34 cities.
4. Very dry with 33 cities.
5. Warm humid climate with 20 cities.
6. Temperate humid with 2 cities.

Classification of climate related with territory

The country has a total area, including our islands 1 964 375 square kilometers. Also, based on the information analyzed was found the following:

1. Warm sub-humid with 562.129 km².
2. Dry and semi dry with 521.676 km².
3. Very dry with 332.593 km².
4. Temperate and sub-humid with 229.754 km².
5. Warm humid with 136.155 km².
6. Temperate humid with 27093 km².

Climates and impact in the energy

Climate greatest impact on consumption and energy demand is one imposes greater demands of HVAC (Heat-Ventilation-AirConditioning) and corresponds to warmer throughout the year and in the summer season. This also implies greater economic burden on consumers of electric power consumption due to extra for the air conditioning required:

Simulation of thermic energy

The three principal climates are analyzed with a software mentioned above, and showed the simulation analysis in Fig. 4, Fig. 5 and Fig. 6. The different environments are classified next:

- a) Warm climate. It has higher temperatures year round and are found mainly in the southeast and southwest areas of Mexico, as showed in Fig. 4 with the principal characteristics.

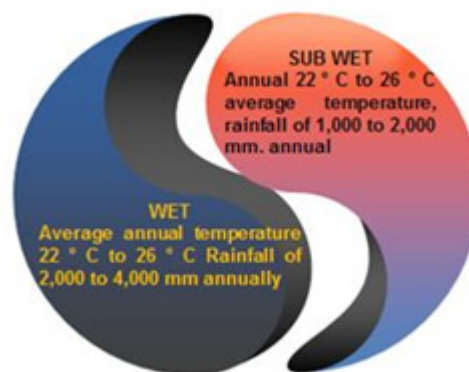


Fig. 4. Simulation analysis of warm climate in Mexico.

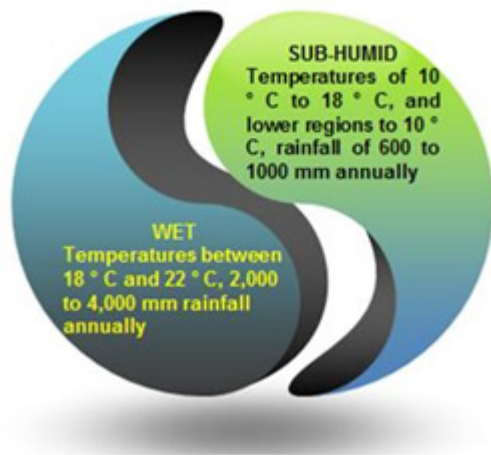


Fig. 5. Simulation analysis of temperate climate in Mexico.

- b) Temperate climate. It presents the lowest temperatures throughout the year is located in the center of Mexico areas, as showed in Fig. 5 with the principal characteristics.
- c) Dry climate. It presents the highest temperatures in the summer period (May to October) and are in the north, northeast and northwest areas of Mexico.

4. Discussion

The humid and sub-humid climates are associated with higher average temperatures through the year the climate and was

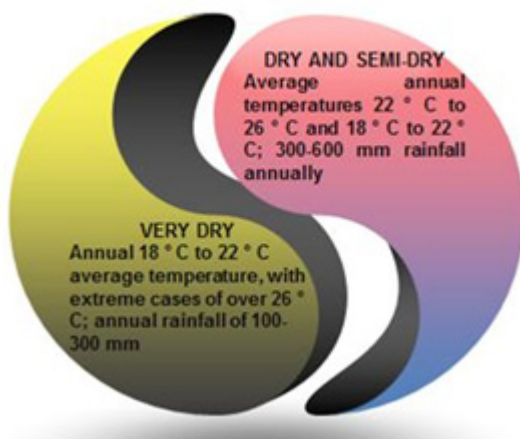


Fig. 6. Simulation analysis of dry climate in Mexico.

identified in the summer and winter, with a difference of no more than 2 degrees Celsius. Very dry, dry and semi dry weather was observed with the highest hourly temperatures during the summer season in Mexico, in contrast, in the winter period temperatures are low. The difference in the average summer temperature over winter is up to 13 degrees Celsius. This indicates that it is an area with extreme weather heat in summer and cold in winter. Temperatures in the humid and sub-humid temperate climates are very similar and relatively low throughout the year.

5. Conclusions

The study foundations to have a systematic regionalization thermo energetically building systems characterize most of the country. Grouped three temperature ranges were selected: 30 to 25°C, 15°C to 25°C and 10°C to 28°C. Cities and regions that belong to a temperature profile can be used to propose actions for saving and efficient energy use, these actions may include official standards in buildings, electricity tariffs, environmental legislation and health among others.

Acknowledgments

Authors want to grateful to University Program of Postgrad that the support and provide to the evaluations the information analysis and the specialized software to make the analysis simulations.

References

- [1] R. A. Taylor, "Socioeconomic impacts of heat transfer research," *Journal of Heat and Mass Transfer*, vol. 3 no. 1, pp. 15-23, 2012.
- [2] J. Walton, C. Hicks, and D. Wilson, *Fundamentals of Momentum, Heat, and Mass Transfer, Handbook*, 2nd ed., New Jersey: Wiley, 2011.
- [3] J. Wilmore, and D. K. L. Costill, "Materials used in the heat transfer systems," *Journal of Engineering and Climatic Topics*, vol. 8 no. 1, pp. 89-102, 2012.
- [4] J. M. Smith, M. M. Abbott, and H. C. Van Ness, *Introduction to engineering thermodynamics, Handbook*, 7th ed., New York: McGraw-Hill, 2005, pp. 125.
- [5] Y. A. Cengel, and J. A. Ghajar, *Heat and Mass Transfer: Fundamentals & Applications*, New York: McGraw-Hill, 2011, pp. 48-64.
- [6] Y. A. Cengel, *Heat Transfer. A practical approach*, 2th ed., New York: McGraw-Hill, 2005, pp. 67-82.

- [7] P. A. Tipler, and G. Mosca. *Physics for Scientists and Engineers*, 6th ed., New York: Worth Publishers, 2008, pp. 666-670.
- [8] J. R. Senft, *Mechanical efficiency of heat engines, Handbook*; Cambridge: University Press, 2007.
- [9] F. McQuiston, and J. Splitter, *Cooling and Heating Load Calculation Manual*, 2nd ed., New Jersey: Wiley, 2010.
- [10] A. Faghri, Y. Zhang, and J. Howell, "Advanced heat and mass transfer," *Journal of Thermic Processes*; vol. 9 no. 4, pp. 57-63, 2010.
- [11] *Fundamentals of American Society of Heating, Refrigeration and Air-Conditioning Engineering*, ASHRAE Handbook, ASHRAE, 1999.
- [12] J. H. Lienhard V, and J. H. Lienhard IV, "A heat Transfer. An overview", *Journal of Heat Applications*, vol. 6 no. 3, pp. 28-40, 2008.
- [13] A. Mojiri, R. Taylor, E. Thomsen, and G. Rosengarten, "Spectral beam splitting for efficient conversion of solar energy. A review," *Renewable and Sustainable Energy Reviews*, vol. 28, pp. 654-663, Dec. 2013.
- [14] X. Xiaoming, and J. W. Chang, "Smart materials to increase the heat transfer," *Journal of Materials and Engineering*, vol. 7 no. 1, pp. 34-45, 2013.
- [15] M. Wend, and T. Henderson, "Theoretical features of conduction and convection heat transfer," *American Journal of Heat*, vol. 9 no. 1, pp. 80-95, 2012.

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