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PASSIVE PROJECT STRATEGY: GIVONI DIAGRAM

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Abstract

This article discusses the issues arising from irregular and excessive consumption of energy resources in cities across Uzbekistan, particularly in the context of overloaded infrastructure systems such as water supply, heating, and electricity. The authors introduce a new regulatory document focused on passive building strategies, which aim to utilize natural processes like solar insolation for heating and cooling, helping to mitigate the effects of climate change. The article proposes a novel approach for passive building design using the Giovanni diagram, a tool that aids in the development of bioclimatic zones. The study analyzes data from 2005 to 2022, collected from a meteorological station in Fergana, Uzbekistan, to map bioclimatic zones and optimize energy efficiency in buildings. The authors also present data models on solar heating and cooling systems, emphasizing the importance of natural ventilation, evaporative cooling, and high thermal mass for maintaining indoor comfort.

Keywords: passive building design strategies, climatic and actinometric data, bioclimatic zone, bioclimatic indicators, Givoni diagram, passive solar heating, evaporative cooling, natural ventilation zone, comfort zone, artificial intelligence, energy management.

1. Introduction

It is known that currently in the cities of the republic's territories during harsh winter and hot summer days as a result of irregular and excessive consumption of energy resources in buildings and structures, as well as as a result of gross violations of the load indicators of the existing infrastructure structure (energy systems and networks) of construction works (drinking water supply, hot water supply and sewerage, heating systems, electricity and gas supply) in the system cause disruptions in the power grids of buildings and structures on a large scale [1-3].

In the context of regular climate change, passive development strategies are characterized by long-term and sustainable consequences. Such approaches based on the use of natural processes and resources provide reliable solutions to reduce the adverse effects on the climate. One of the main advantages of passive development strategies is an integrated approach to adaptation to climate change, which uses climate-resistant architecture and other natural processes [1,3].

For the first time, the authors developed a normative document on the passive construction strategy in Uzbekistan – SNK 2.08.08.22. "Passive buildings: residential", which provides for the development of master plans for residential buildings that take into account heating and cooling through the use of solar insolation. Also, when choosing technologies and materials for structures, it is envisaged to take into account climatic parameters and physic-geological data of artificial climate education systems. The measures provided for in this regulation have a clear environmental aspect. On the one hand, they contribute to improving the air quality in our cities, and on the other hand, they add elements to the fight against climate change. At the same time, the authors have prepared:

- database on changes in actinometric and climatic data of the republic for the period 2005-2022 based on satellite and ground-based observations for the preparation of forecast calculations for the use of solar heating and cooling insolation systems in the republic;
- scientifically based initial data on the choice of optical, weight-dimensional and thermal engineering

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indicators of energy-active translucent fences for use in Passive houses with solar heating (cooling) insolation systems.

In the above-mentioned normative document, for the first time, the application of the Giovanni diagram for the passive design of buildings based on the characteristics and indicators of the climatic conditions of the region is proposed, since this diagram is one of the tools for the development of bioclimatic maps and indices, which is based on the assessment of comfortable temperature inside the building and offers design strategies for adapting architecture to the climate [4].

In this regard, in this report, the authors present the results of the development of a draft map of bioclimatic zones for the formation of the Giovanni diagram in the region, using the results of research conducted on the analysis of data from climatic and actinometric observations of the meteorological station for the period 2005 and 2022, located in the city of Fergana, Fergana region, from the regions of the republic between.

2. Materials and Methods

Based on information about solar radiation, temperature, humidity, precipitation and wind speed, an improved model of the bioclimatic zone of the comfort region is being created, taking into account the bioclimatic conditions. [5-7]. These models are the basis for optimizing the energy efficiency of buildings, reducing the need for artificial heating and cooling. The months with fully and partially favorable heating conditions are analyzed, as well as the importance of natural ventilation at high temperatures and humidity. At the same time, the assessment includes an analysis of summer periods with high thermal mass, which require special regulation of the internal temperature of the building. The heating (cooling) season is also analyzed separately, during which a passive heating and cooling system can be used. [5-7].

Giovanni diagram

Passive building design strategies are based on climatic conditions, since it is the difference between climatic conditions and favorable operating conditions, as well as the reasons for this difference, that necessitate appropriate measures in building design. In this case, the goal is to minimize the existing difference as much as possible without using artificial heating or cooling systems. One of the tools for developing passive design strategies is the Giovanni diagram (bioclimatic map), which is based on an assessment of the favorable temperature inside the building and offers design strategies for adapting architecture to the climate [6, 11]. Based on the above, a psychrometric chart is used as the basis of Giovanni's bioclimatic map, which shows temperature and humidity data (monthly, daily or hourly) for a specific area. The most reliable way to use Giovanni's bioclimatic map is to plot data on it every hour, since daily and monthly averages actually determine temperature and humidity to a large extent, and the most adverse conditions are not recorded, even if they occur frequently. For example, with large daily fluctuations, the average daily or monthly values of temperature and humidity in the climate incorrectly reflect the initial climatic conditions, which affects the subsequent level of comfort and, accordingly, design strategies. Giovanni's bioclimatic map determines the method of cooling or heating, respectively, depending on the climatic conditions of the outdoor air.

There are several types of Giovanni diagrams that are adapted to specific climatic conditions and include many strategies. Together with the climate database, the chart displays temperature and humidity values as a graph, suggesting the best strategies and demonstrating the improvement of favorable conditions in accordance with each strategy. The Giovanni diagram identifies six zones for passive design strategies (see Figure 1):

1. Comfort zone;
2. Natural ventilation area;
3. Evaporative cooling zone;
4. High thermal mass;
5. High thermal mass and night ventilation;
6. Passive heating.

Climate data (ambient temperature and relative humidity) can be plotted directly on the diagram, which can be used to check which of the six zones of the diagram these conditions fall into. The zones are defined in the diagram as follows.

1. Comfort zone: in the conditions defined for this zone, it is assumed that a person is in thermal comfort conditions indoors. According to Giovanni, it can be noted that people can be in thermal comfort conditions within different limits of relative humidity (from 20% to 80%) and air temperature (from 20°C to 26°C). When the indoor air temperature approaches 20°C, it is necessary to prevent exposure to wind, as this can cause discomfort. If the air temperature approaches 26°C, it is necessary to control the ingress of solar radiation into the room in order to avoid overheating.

2. Natural ventilation zone: if the room temperature exceeds 26°C or the relative humidity is high enough, natural ventilation can improve thermal comfort. Giovanni assumes that the maximum allowable indoor air velocity is about 2 m/s, so

ventilation maintains comfort up to the maximum outdoor temperature of 32 °C. When the temperature significantly exceeds 26°C and the relative humidity is below 50%, night cooling is more appropriate than daytime ventilation. This can happen in hot, arid regions where daytime temperatures range from 30°C to 36°C and nighttime temperatures are below 20°C. In these conditions, daytime ventilation is not suitable, as this would lead to heating of the building. The best strategy is to limit ventilation during the day to reduce the intake of hot air, and use night ventilation, using colder air to cool the interior space.

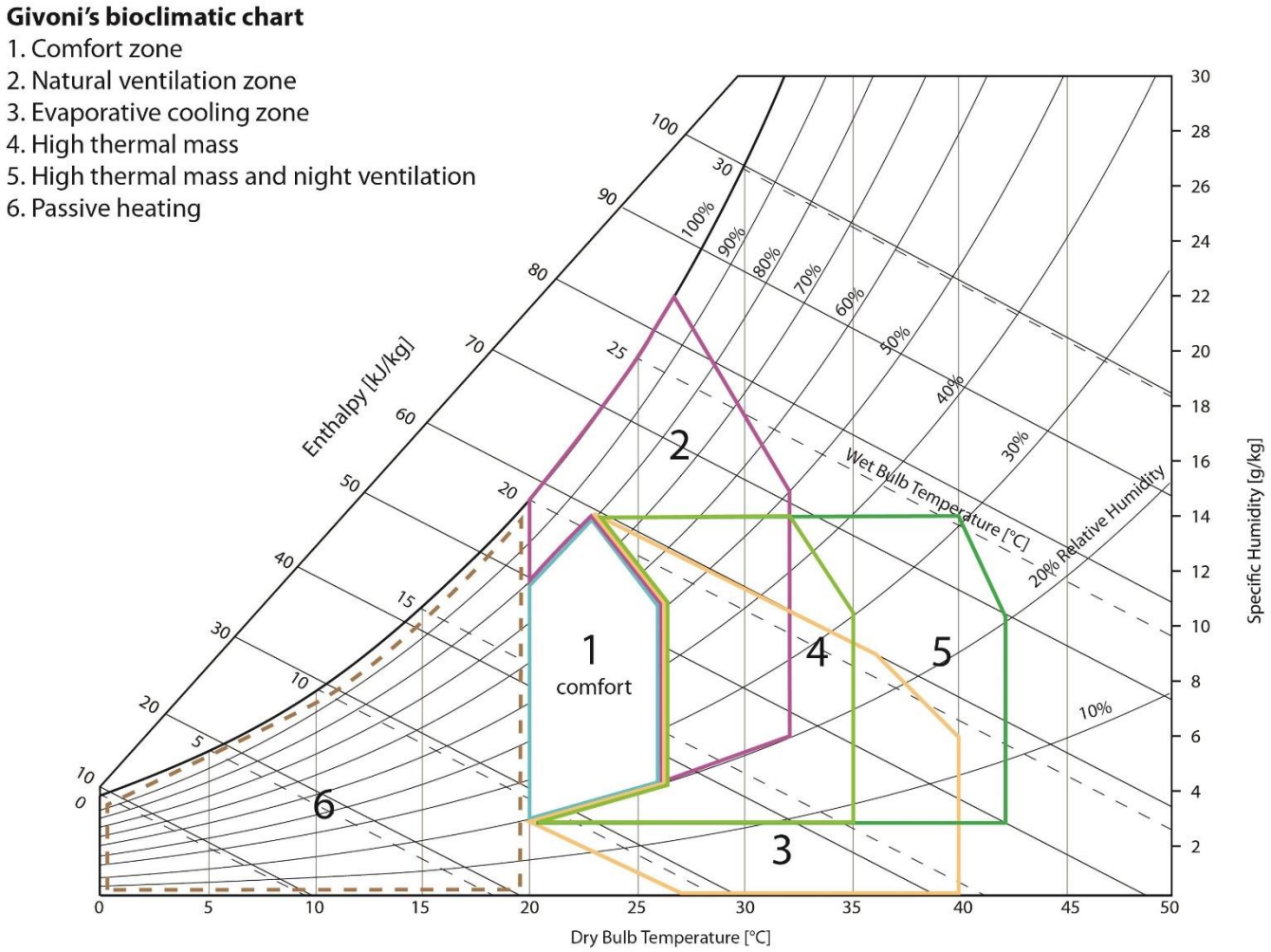


Figure 1. Bioclimatic zones based on the Giovanni diagram.

3. Evaporative cooling: this method can reduce the air temperature and at the same time increase the relative humidity of the living room. Direct cooling of the interior using evaporative cooling requires good ventilation to avoid the accumulation of water vapor. During the evaporative cooling process, both the temperature and humidity of the air change in accordance with the constant humid temperature of the bulb and the enthalpy. The heat content does not change, and the energy is simply converted from tangible energy to latent energy.

4. High thermal mass: The use of high thermal mass in a building can reduce indoor temperature fluctuations compared to outdoor space, reducing peaks. This solution can be successfully used in places where the temperature and relative humidity are within the thermal mass zone. Room temperature equalization occurs due to:

- accumulated heat in the building structure during the day is released into the interior at night, when the outdoor temperature decreases.;
- In addition to this, the thermal design cools down during the night and stays cool for most of the day, lowering the daytime indoor temperature. In addition to using the thermal mass of the shell, the thermal mass from the ground can also be used.

5. High thermal mass and night ventilation: Thermal mass can be used in combination with night ventilation to provide passive cooling. During the night, outside air circulates through the building, cooling the building fabric. Cooling, which is retained in the structure, is available to compensate for heat

generation the next day and keep the temperature closer to comfortable limits. Night ventilation is most effective in hot-arid climates, where daily temperature fluctuations are high and the night temperature drops below 20°C. Thermal mass combined with night ventilation can be used to minimize or eliminate the need for mechanical cooling. This solution can be applied in places where temperature and relative humidity conditions are within this zone.

6. Passive solar heating: The use of passive solar heating is more suitable for places where seasonal air temperatures are below 20°C. Thermal insulation of the building is recommended due to heat loss and glazed windows of the appropriate size facing the sun during the coolest period.

The Giovanni diagram method was employed in this study due to its versatility and flexibility as a tool for ventilation design, surpassing other methods such as CFD (Computational Fluid Dynamics), the Central Ventilation Shaft (CVS) method, the dimensionless graphs method, the air exchange calculation method, and others. While the CFD method necessitates substantial computational resources and time, particularly for large-scale structures (Ferrucci et al., 2018), the Giovanni diagram method facilitates rapid evaluation of air exchange processes without the need for complex calculations or high computational demands.

The CVS method, typically applied in natural ventilation systems for high-rise buildings and public structures, relies on integrated ventilation shafts as a core component. However, it is predominantly suited for large multi-story buildings and requires detailed design during the architectural planning phase (Yang et al., 2014). Moreover, it does not always account for dynamic environmental changes, unlike the Giovanni diagram, which is a more flexible approach applicable to buildings of various scales, from small to large. This method also enables the evaluation of the impact of variable factors, such as air temperature and humidity, which cannot be adequately addressed through the standard CVS method.

The dimensionless graph method is known for its efficacy in quickly determining the influence of parameter variations, such as air leakage or wind turbulence, on ventilation performance. Nevertheless, it may be overly generalized for buildings with complex geometries or under specific climatic conditions (Etheridge, 2002). Furthermore, it lacks adaptability to real-time changes in environmental conditions. In contrast, the Giovanni diagram method offers greater adaptability, allowing for the incorporation of parameters such as temperature fluctuations or external humidity, enabling dynamic ventilation assessments based on current conditions.

In conclusion, the Giovanni diagram method provides a fast and intuitive evaluation of ventilation performance while accounting for multiple factors (temperature, humidity, wind direction), making it an optimal choice for buildings of varying complexity and types.

3. Calculations of the psychrometric table

The equations used in the compilation of the psychrometric table are based on the proximity of the vapor-air mixture to ideal gases [12-15]. In this approximation, the ambient air is considered as a mixture of two main components: dry air and water vapor. The thermodynamic properties of this mixture can be determined by two other properties. But due to the high nonlinearity of the correlation of equations with these parameters, numerical methods are useful when performing psychrometric calculations. The following set of functions is built depending on the temperature according to the dry thermometer *(T: °C)* and absolute humidity *(d: kg H_2O//kg* dry air). The order of these functions is optional, each function is separate. *d=f(T)* is a set of points, that is, each function can be expressed analytically or numerically as *d=f(T).* First, the indoor temperature (t_i) is determined. This, in turn, depends on the outdoor temperature (t_0, which is the temperature of a dry thermometer), and relative humidity (φ).

$$t_i = t_0 + \frac{5}{9}\left(6.112 \cdot \varphi \cdot 10^{\frac{7.5 \cdot t_0}{235+t_0}} - 10\right) \quad (1)$$

The absolute humidity *d* deposited on the ordinate axis is largely due to the partial release of water vapor (P_{wv}), which is defined as:

$$d = \frac{0{,}6221 P_{wv}}{P - P_{wv}} \quad (2)$$

$$d = \frac{0{,}6221 \varphi P_{wv}}{P - P_{wv}} \quad (3)$$

where P is atmospheric pressure (Pa), φ is relative humidity (%).

In turn, P_{wv} can be determined depending on t_0 as follows [14].

$$P_{wv} = 610{,}48 \cdot \varphi \cdot 10^{\frac{7.5 \cdot t_0}{235+t_0}} \quad (4)$$

The dew point temperature t_{dp} is also one of the parameters of the air condition, which is calculated using the following expression, formed after

performing several steps according to expressions (3) and (4):

$$t_{dp} = 235 \cdot \frac{lg\varphi + \frac{7.5 \cdot t_0}{235 + t_0}}{7.45 - \left(lg\varphi + \frac{7.5 \cdot t_0}{235 + t_0}\right)} \quad (5)$$

Enthalpy i (kJ/kg) can also be determined by t_0 and d:

$$i = 1{,}006 \cdot t_0 + d \cdot (2501 + 1{,}86 \cdot t_0) \quad (6)$$

or, substituting expression (2) into expression (6), we get the following expression:

$$i = 1{,}006 \cdot t_0 + 0{,}6221 \cdot (2501 + 1{,}86 \cdot t_0) \cdot \left(\frac{P}{P_{wv}} - 1\right)^{-1} \quad (7)$$

The indicator of the wet thermometer T_w, (6) is determined using the following approximating formula for the case when the atmospheric pressure is P=715 mmHg

$$T_w = \begin{cases} -9.3542 + (0.0016 + 0.0199 \cdot A) \cdot A, \cdot If\ 10 \le i \le 37 \\ -30.8238 + 1.3051 \cdot A,\ if\ 37 \le i \le 112 \\ -26.1548 + 1.2081 \cdot A,\ if\ 112 \le i \le 175 \end{cases} \quad (8)$$

in this case, $A = \sqrt[3]{i}$.

Using the Newton-Raphson numerical solution method, expressed as a function of t_0 and φ of the resulting expression, it is possible to determine the values on the axes of the diagram shown in Figure 1 [16, 17].

4. Results

As part of this research work, a draft map of bioclimatic zones was developed to form a Giovanni diagram in the region (Figure 2), using the results of studies conducted on the analysis of data from climatic and actinometric observations of a meteorological station located in the city of Fergana, Fergana region, from the regions of the republic between 2005 and 2022 [18].

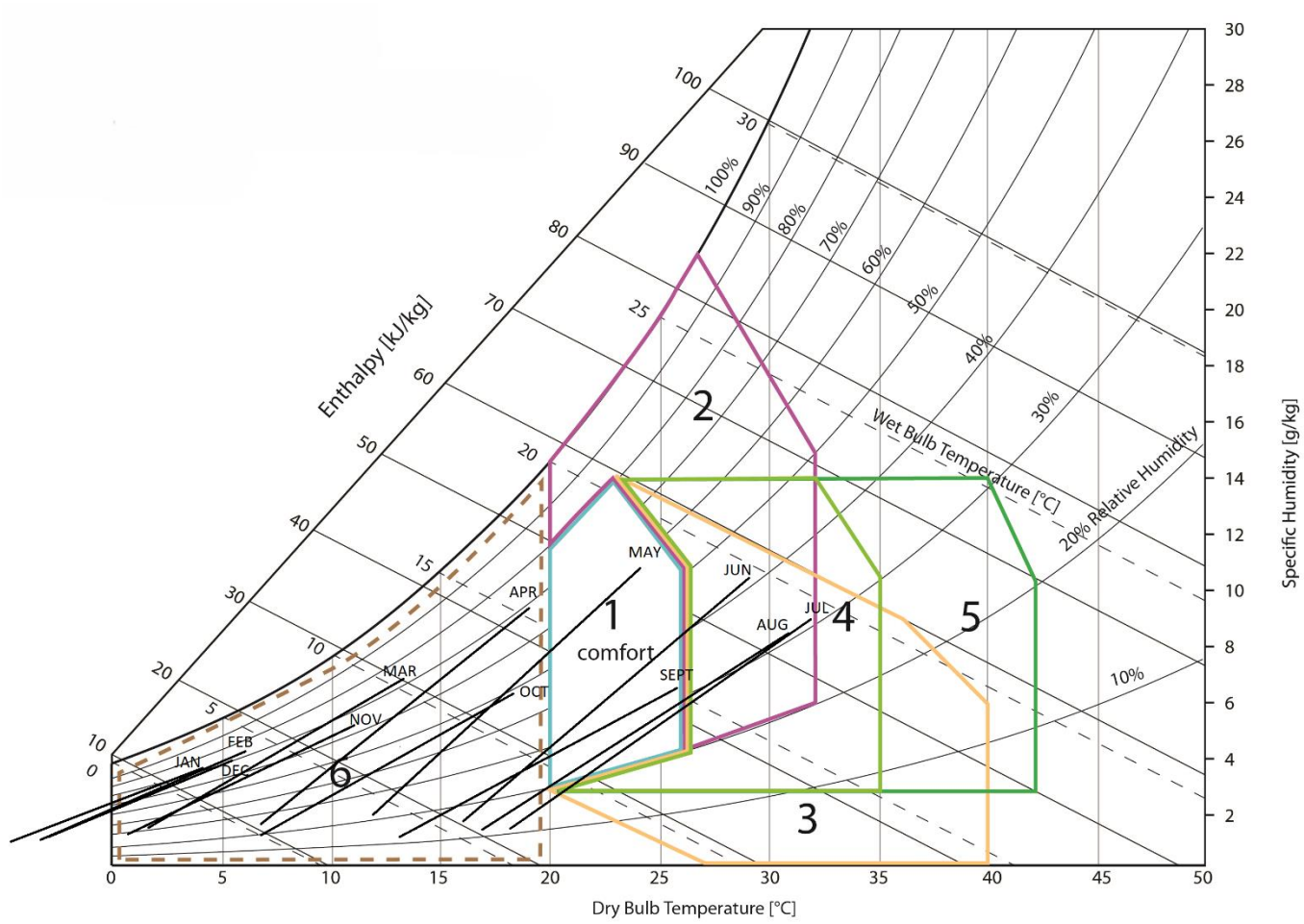


Figure 2. Map of bioclimatic zones for the city of Fergana, Fergana region.

The analysis of Figure 2 shows that:

1. For the city of Fergana, the comfort zone covers the months of May and September, as well as partially in the month of June, July, August, in which a person is in a state of thermal comfort indoors, which is typical for the region under consideration.

2. The natural ventilation zone for Fergana has a similarity to the comfort zone, if the room temperature exceeds 26 °C or the relative humidity is high enough,

natural ventilation can improve thermal comfort. As can be seen from Figure 2, it can be argued that natural ventilation corresponds to some days of the months of June, July and August in time frames.

3. The evaporative cooling zone for Fergana, as shown by Giovanni's diagrams, includes separate days of the months of June, July and August where evaporative cooling is required so that the relative humidity of the habitat does not decrease.

4. Periods with high thermal mass for Fergana are the months of June, July and August.

5. Periods with high thermal mass, where night ventilation is required (night temperatures fall below 20 °C), correspond to some days of June, July and August.

6. The use of passive solar heating systems is effective, as can be seen from Figure 2, in the period from October 15 to November 30 and from March 1 to April 15 in full, and also includes the months of December, January and February partially [11-14].

To validate our results on passive building design in the Fergana region using the Giovanni diagram, we conducted a comparative analysis by inputting our key climatic parameters into the open-access Online Interactive Psychrometric Chart (flycarpet.net) [19].

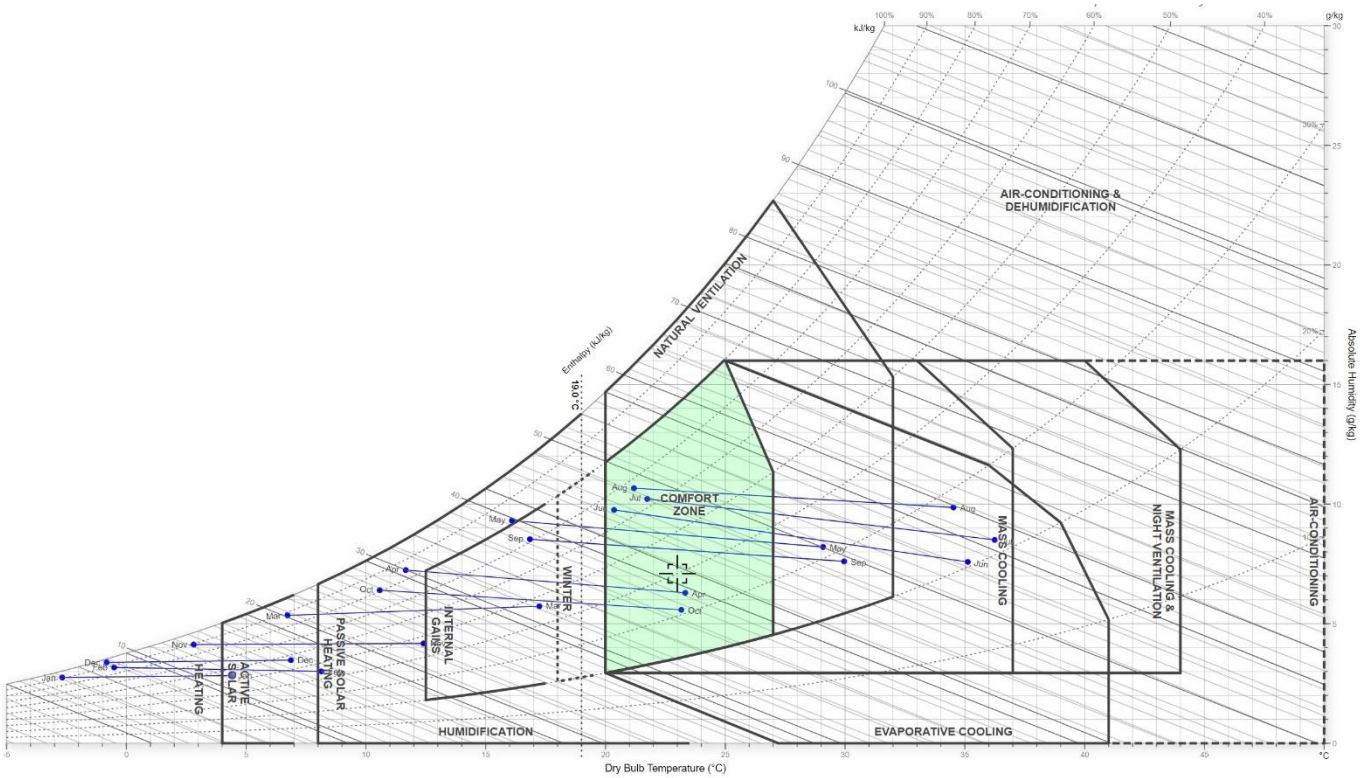


Figure 3. Map of bioclimatic zones for the city of Fergana from Online Interactive Psychrometric Chart (flycarpet.net) [19].

The comparison of both diagrams shows that our calculations align with the results obtained from the psychrometric chart tool. For instance, June and August in both diagrams fall within the expected comfort zone, indicating effective cooling through natural ventilation and mass cooling. The diagrams also demonstrate that the evaporative cooling zone includes specific days in June, July, and August, when evaporative cooling is required to prevent a decrease in relative humidity in the living environment. Additionally, the periods of high air temperature in Fergana are evident in June, July, and August. This alignment between our Giovanni diagram results and the psychrometric chart results validates our methodology.

With proper design and construction of buildings located in the passive heating zone, it is possible to provide comfortable conditions in the winter months without using traditional heating systems, which in turn can lead to significant energy savings and lower greenhouse gas emissions.

To ensure effective passive heating of buildings in the cold season, it is necessary to use structural elements and materials such as stone and concrete that can accumulate and retain heat. Architectural planning should include the correct orientation and location of windows to maximize sunlight, as well as high-quality thermal insulation to reduce heat loss. In addition, a smart approach to ventilation is needed, which allows you to keep warm and ensure good indoor air quality.

5. Conclusions

The analysis of the climatic conditions of Fergana reveals several key aspects and based on this, the following conclusions can be drawn:

- optimal conditions of thermal comfort prevail in the months of May and September of the year, while the summer months (June, July, August) are characterized by partial comfort, which indicates the seasonal variability of the climate of the region;

- natural ventilation, especially important at temperatures above 26°C and high humidity, is effective in the summer months. Research also highlights the need for evaporative cooling on certain summer days to maintain comfortable humidity.;

- attention is drawn to periods with high thermal mass in the summer months, which require a special approach to regulating indoor temperature;

- passive solar heating, as the analysis shows, is effective from October 15 to November 30 and from March 1 to April 15, as well as partially in the winter months, providing an alternative source of heat.

-passive construction strategies provide a significant reduction in energy consumption in buildings, which contributes to achieving environmental goals and reducing operating costs. The standardization of such strategies at the legislative level supports the widespread adoption of energy-efficient technologies in the construction industry.

Finally, the study highlights the importance of using structural elements capable of storing heat, such as stone and concrete, in passive heating systems. This includes architectural planning to maximize the input of solar radiation and high-quality thermal insulation, which helps to increase energy efficiency and reduce dependence on traditional heating systems.

The above, as part of the study of bioclimatic conditions in the regions of the country, taking into account the effects of climate change, strategies for designing passive buildings in order to minimize artificial heating and cooling, at the same time, it is necessary to plan the use of passive heating and cooling systems. heating is seasonally adjusted to ensure sufficient heating in winter, which in turn prevents buildings from overheating during the transition period.

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