Journal for Geometry and Graphics
Volume 29 (2025), No. 1, 89–99

Geometric Aspects of Heat Income Energy to Facades of Buildings

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Abstract. The climate of Ukraine, which is located in several climatic zones, provides hot periods in summer and autumn-spring times and periods of heating houses in winter and off-season. An important factor influencing the energy saving of buildings is solar energy, from which it is necessary to protect against overheating during periods of overheating and use its heat during the operation of the heating system. Green spaces are actively used in modern cities to form the microclimate of streets, protect facades from overheating, create shading for windows, terraces and balconies. This is aesthetic and ecological. In winter, plants that shed their leaves open access for solar radiation to enter the premises, which contributes to energy saving. Modern architecture of cities and individual buildings provides for a variety of uses of green spaces: individual trees, rows of trees along facades, plants on facades as overhangs, side edges or green curtains. This publication analyzes shading from edges, overhangs and curtains.

Key Words: insolation, solar devices, solar maps, energy efficiency, solar energy

MSC 2020: 92F05 (primary), 51N05

1 Introduction

Modern architecture increasingly uses green spaces not only to decorate city streets, but also to decorate facades. Plants on facades also have practical significance. During periods of overheating, they protect against heat, during the heating period, if plants shed their leaves, they do not prevent the penetration of solar energy through the windows, thereby reducing the cost of heating buildings. The publication [9] examined in detail the calculations of shading from rows of trees. If we consider facade plants from the point of view of sun protection, the following types can be distinguished: Overhang, edge to the right of the window, edge to the left of the window, green curtain and their combinations. Each of them has its own geometric

ISSN 1433-8157/

calculation model. The initial data for the calculation depend on the climate zone, outdoor air temperature, overheating and heating period, and facade orientation.

Analysis of literary sources shows various methods for determining the heating and cooling periods of buildings [10]. The territory of Ukraine is divided into five architectural and construction climatic regions [1]. With a central heating system, the heating period for residential buildings and most public buildings begins at an average daily outdoor air temperature below 8 °C [1], and overheating of premises occurs at an outdoor air temperature in the shade above 21 °C [2]. According to the principle of the extreme outdoor temperature, complex solar maps were constructed, which display the overheating and heating zones [7]. Such maps are advisable to use for selecting the type and optimizing the geometry of sun protection devices (SPDs).

To calculate the energy efficiency of the SPD, energy solar maps have been proposed [8]. They can be obtained by plotting 100 points on the solar map for a plane of the corresponding orientation, which are distributed over the map in accordance with the contribution of elementary sections of the sky to the energy illuminance of this plane under the condition of a completely open sky. Energy solar maps are constructed separately for periods of cooling and overheating for vertical planes of facades oriented to eight cardinal directions: N, N-E, E, S-E, S, S-W, W, N-W. The construction was carried out on the basis of the PPP “Atmospheric Radiation” [6] with real cloudiness of the sky for five cities: Kyiv (I architectural and construction climatic region), Zaporizhzhia (II region), Ivano-Frankivsk (IIIa region), Uzhhorod (IIIb region), Simferopol (IV region).

2 Energy Points in a Spherical Coordinate System

To calculate the coordinates of energy points on the celestial sphere, the Grasshopper parametric modeling program was used. The program allows you to build a model of the celestial sphere with energy points in 3D. The initial data for construction are complex solar maps with energy points, which are a projection of the celestial sphere onto a horizontal plane with the projection center at the nadir. The task is to obtain the angular coordinates of energy points projected onto the celestial sphere. The projection lines are a bundle of rays drawn from the nadir and passing through 100 energy points (Figure 1). The intersection points of these rays with the celestial sphere will be the desired points. The first row of coordinates γ_n is obtained as the angle between the vertical plane of the facade and the vertical plane passing through the z-axis and the energy point. The construction of a bundle of planes gives the desired meridian coordinates of each point.

The second series of coordinates δ_n is defined as the angle between the horizontal plane of the celestial sphere and the plane passing through the energy point on the celestial sphere and the horizontal line on the facade to which the calculated point belongs. The function from Grasshopper called *Panel* provides the coordinates of each point as a set of angles. The program helps to graphically automate the constructions to obtain a large array of data of the desired angular coordinates, namely two coordinates for 100 points, 5 cities of Ukraine, 8 directions, separately for the heating and sun protection periods. An analytical description of the obtained coordinates can be presented as follows. Based on the fact that the solar map is a projection of the celestial sphere through the nadir onto the horizontal plane, the coordinate γ_n on the map is displayed in natural. The coordinate δ_n is determined by the

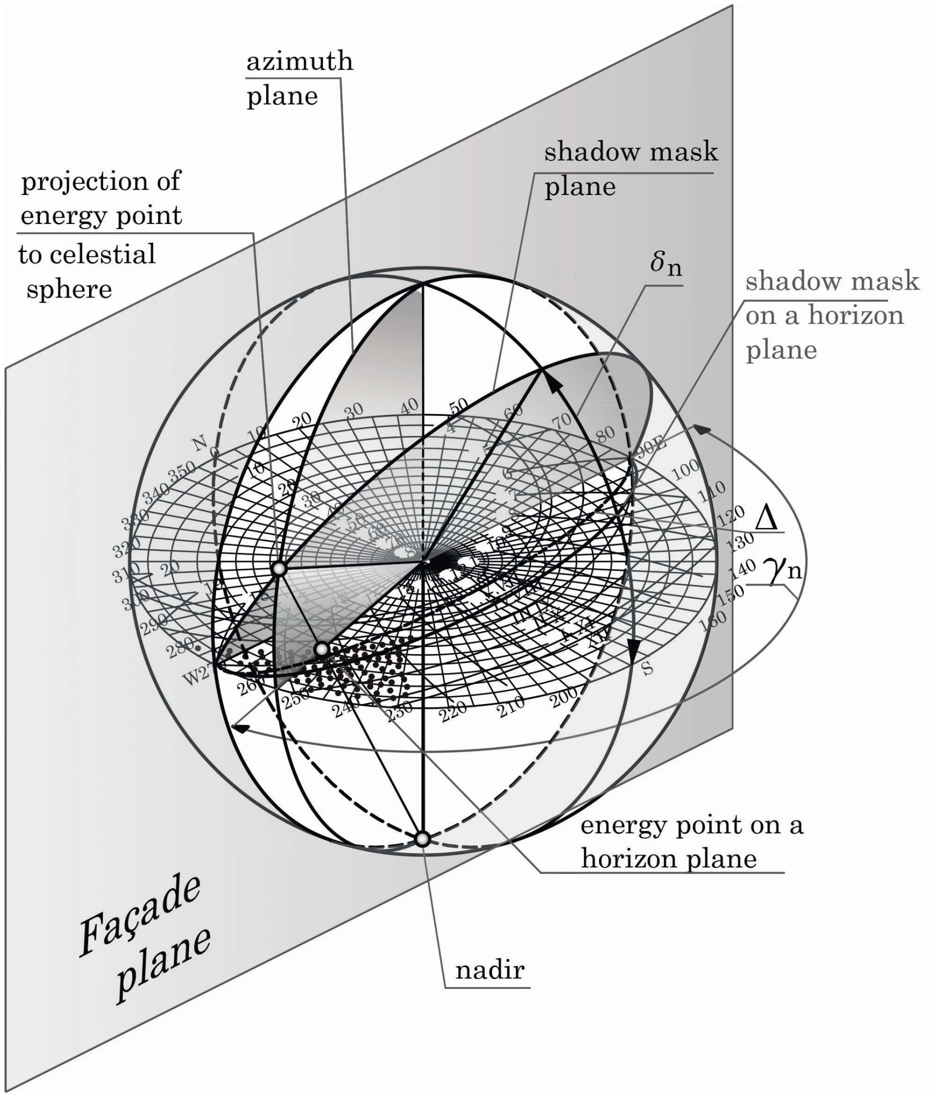

Figure 1: Axonometric image of determining the spherical coordinates of an energy point

formula:

$$\delta_n = \arctan\left(\frac{(-\frac{r}{2R} + \frac{R}{2r})}{\sin\gamma_n}\right) \tag{1}$$

where R is the radius of the celestial sphere, r is the distance from the center of the solar map to the energy point.

Further calculations are performed only with numerical values of point coordinates in spreadsheets.

3 Shading Calculation

The proposed methodology for calculating the energy characteristics of shading from overhangs, edges, and curtains from green spaces is considered in this article using the example of the climatic parameters of Kyiv city. Similar calculations have been made for cities representing other climatic regions.

3.1 Determination of the Partial Correction Factor for Horizon Shading from Overhangs

The overhang of green spaces (Figure 2*a*) is a conventional plate, cantilevered from the plane of the facade with a given transparency characteristic. The overhang shades the facade at an angle α. On the energy solar map, the shading area is limited to a section of the shadow mask circle and covers a certain number of energy points. The plane Δ, in which the sun's rays pass through the leaves of the overhang to the calculation point (Figure 1) is the shadow mask line, dividing the shaded energy points in half. By numerical methods, this angle δ_{med} can be obtained by numerical methods in a spreadsheet as the median of a series of point coordinates using the function `{=MEDIAN(IF(C6:CX6>0; C6:CX6))}`.

Standards [3, 4] for calculating energy consumption for heating and cooling buildings take into account the shading reduction factor $F_{\text{sh,O}}$, when calculating the impact on the energy efficiency of buildings, according to the formula

$$F_{\text{sh,O}} = \frac{I_{\text{sol,ps,mean}}}{I_{\text{sol,mean}}} \tag{2}$$

where

- $I_{\text{sol,ps,mean}}$ – average energy illuminance by solar radiation of the surface under consideration, shaded by external objects, W/m^2;
- $I_{\text{sol,mean}}$ – average energy irradiance by solar radiation of the same surface in the absence of shading, W/m^2.

The transparency of the green overhang is calculated using the exponential extinction law[1], from which the optical density of the overhang μ is obtained from the formula:

$$\mu = \frac{\ln f_{\angle}}{d_{\angle}} \tag{3}$$

where

- $f_{\angle}$ – light transparency of the tree crown, measured at the calculated angle of incidence of the sun's rays,
- $d_{\angle}$ – path length of the ray in the crown.

Publications [5, 11], which provide instrumental studies of the percentage of shading from climbing plants used for decoration and shading on facades, give the value of the transparency of the plant array in front of the windows as 0.64 with an array thickness of 400 mm. Whence $\mu = 1.116 \times 10^{-3}\text{mm}^{-1}$ in the presence of leaves during the cooling period and $\mu = 9.6 \times 10^{-6}\text{mm}^{-1}$ in the absence of leaves.

The transparency of the green overhang depends on the distance of the ray through the thickness of the overhang. In the plane Δ, the rays travel different distances to the calculation point. Thus, with the thickness of the overhang b and the angle α_{med} of the plane Δ to the horizon, the length of the ray through the overhang in the normal plane of the facade at the design point will be:

$$d_{\perp} = \frac{b}{\sin \alpha_{\text{med}}}. \tag{4}$$

Other rays in the Δ plane will follow the path

$$d_{\alpha,\beta} = \frac{d_{\perp}}{\sin \beta} \tag{5}$$

[1] `https://en.wikipedia.org/wiki/Beer-Lambert_law`

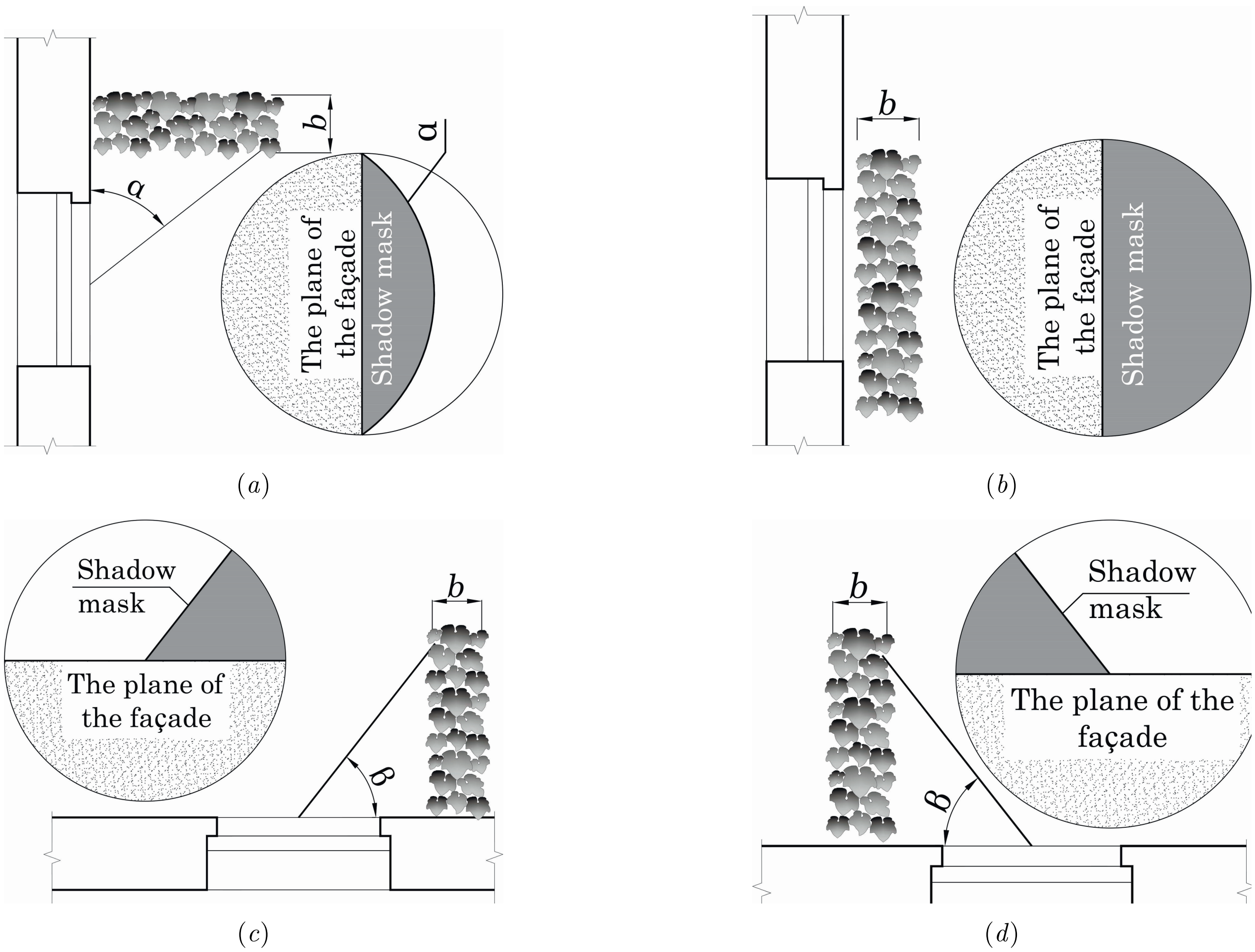

Figure 2: Schemes for determining the shading angles from green facade structures: a – vertical angle α of overhang shading and thickness of green block; b – vertical angle α of curtain shading and thickness of green block; c – horizontal shading angle β of the right edge and thickness of green block; d – horizontal shading angle β of the left edge and thickness of green block

where β – angle of the ray plane relative to the facade.

The value of transparency $f_{\alpha,\beta}$ ($0 \leq \alpha \leq 90\,^\circ$C and $0 \leq \beta \leq 180\,^\circ$C with step $10\,^\circ$C, where α – vertical shading angle, β – horizontal angle to the plane of the facade, determined by the formula:

$$f_{\alpha,\beta} = \mathrm{e}^{-\mu d_{\alpha,\beta}}. \tag{6}$$

To determine the percentage of direct solar energy transmission through a green overhang for eight facade orientations and five representative cities, the formula is used:

$$P_\alpha = 100 - \sum_{b=0}^{18}\Big(\sum_{k=0}^{9-a} N_{90-10k,10b}\Big) \cdot (1 - f_{10a,10b})). \tag{7}$$

where $N_{\alpha,\beta}$ – number of points in a cell α, β between the shadow mask shading and the meridian planes. α is a family of lines of horizontal shading, β – family lines of vertical shading, that are being considered as $10^\circ \times 10^\circ$ mesh, so $\alpha = 10a$, $\beta = 10b$.

Number of points $N_{\alpha,\beta}$ is also determined from spherical coordinates γ_n, δ_n in a spreadsheet using logical formulas. Coordinates are separated into ranges 0–5, 5–15, 15–25, 25–35,

Table 1: Example of automated calculation of the number of points in the cells of the energy solar map for the northern location of the facade during the cooling period for Kyiv

	angle from the wall counterclockwise																		
height	0-5	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	105-115	115-125	125-135	135-145	145-155	155-165	165-175	175-180
<0																			
0-10																			
10-20																			
20-30																			
30-40																			
40-50																			
50-60				2	2	2	4	2	5	6	5	3	2	4	2	2			
60-70		1	3	4	5	4	3	3	2	2	2	2	3	4	5	3	4	1	
70-80		3	1														1	3	
80-90																			
Σ																			100

Table 2: Example of calculating the percentage of solar radiation transmission by facade orientation for Kyiv

Height	N	N-E	E	S-E	S	S-W	W	N-W
0°	11.65	28.61	40.14	45.64	45.54	45.51	40.59	29.50
10°	20.84	38.07	44.77	45.64	45.54	45.51	45.06	36.12
20°	35.55	49.73	55.73	47.33	45.54	47.00	56.82	49.53
30°	50.01	62.92	68.63	53.19	45.54	54.25	68.60	62.10
40°	61.84	72.30	79.20	66.27	45.54	67.36	79.43	72.43
50°	69.81	81.15	81.01	81.22	45.54	81.85	86.39	80.07
60°	77.42	86.85	92.24	90.00	64.87	91.03	93.00	87.03
70°	88.70	93.32	96.59	96.00	92.93	96.80	96.71	93.51
80°	99	100	100	100	100	100	100	100

35–45, 45–55, 55–65, 65–75, 75–85, 85–95, 95–105, 105–115, 115–125, 125–135, 135–145, 145–155, 155–165, 165–175, 175–180 along the meridians and 0–10, 10–20, 20–30, 30–40, 40–50, 50–60, 60–70, 70–80, 80–90 at the corners of the shadow mask (Table 1).

Formula (6) allows us to obtain the percentage of solar energy transmission, taking into account shading from zero value when the sun is on the horizon to the maximum when the sun is at the zenith. The result is a table of the percentage of solar radiation transmission by facade orientation (Table 2).

As is known, solar radiation arriving at the facade consists of direct, diffuse and reflected radiation. Diffuse radiation in the regulatory literature [3] already takes into account reflection from the ground. Partial correction factor for horizon shading F_{ov} determined by the formula:

$$F_{\mathrm{ov}} = \frac{0.01 \cdot S \cdot P_\alpha + D}{S + D} \tag{8}$$

where S – average monthly sum of direct solar radiation, $\mathrm{MJ/m^2}$, is determined by [3]; D – average monthly amount of scattered month radiation, $\mathrm{MJ/m^2}$, is determined by [3]; P_α – percentage of direct solar energy transmission, calculated by formula (7).

Thus, according to DSTU [1], for Kyiv, the heating period includes I–IV and X–XII months, and the overheating period includes VI–VIII. The final tables of the values of the partial correction factor for the shading of the horizon by the overhang F_{ov} for Kyiv are given in Table 3.

Table 3: Partial correction factor for horizon shading from overhangs during heating period and cooling period for Kyiv, F_{ov}

Shading angle α	N	N-E	E	S-E	S	S-W	W	N-W
Heating period/Cooling period								
I architectural and construction climatic region								
10°	$\frac{1.00}{0.90}$	$\frac{0.99}{0.78}$	$\frac{1.00}{0.73}$	$\frac{0.99}{0.72}$	$\frac{0.99}{0.74}$	$\frac{0.99}{0.73}$	$\frac{0.99}{0.74}$	$\frac{0.99}{0.78}$
20°	$\frac{1.00}{0.91}$	$\frac{0.99}{0.82}$	$\frac{1.00}{0.78}$	$\frac{0.99}{0.72}$	$\frac{0.99}{0.74}$	$\frac{0.99}{0.73}$	$\frac{1.00}{0.80}$	$\frac{0.99}{0.83}$
30°	$\frac{1.00}{0.93}$	$\frac{0.99}{0.87}$	$\frac{1.00}{0.85}$	$\frac{1.00}{0.76}$	$\frac{1.00}{0.74}$	$\frac{1.00}{0.77}$	$\frac{1.00}{0.86}$	$\frac{0.99}{0.87}$
40°	$\frac{1.00}{0.95}$	$\frac{0.99}{0.90}$	$\frac{1.00}{0.90}$	$\frac{1.00}{0.82}$	$\frac{1.00}{0.74}$	$\frac{1.00}{0.83}$	$\frac{1.00}{0.90}$	$\frac{0.90}{0.87}$
50°	$\frac{1.00}{0.96}$	$\frac{0.99}{0.93}$	$\frac{1.00}{0.91}$	$\frac{1.00}{0.90}$	$\frac{1.00}{0.74}$	$\frac{1.00}{0.91}$	$\frac{1.00}{0.93}$	$\frac{1.00}{0.93}$
60°	$\frac{1.00}{0.97}$	$\frac{0.99}{0.95}$	$\frac{1.00}{0.96}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.83}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.96}$

3.2 Determination of the Partial Correction Factor for Horizon Shading from Curtains

The shading from the curtain has its own geometric features (Figure 2*b*). The transparency of the curtain according to Formula (3) will have the same values. Formula (4) will take the form:

$$d_{\perp} = \frac{b}{\cos \alpha}. \tag{9}$$

The length of the path of the rays through the curtain and the transparency value are determined by Formulas (5), (6). When determining the percentage of direct solar radiation transmission through plants, it is calculated by (7), taking into account that in the case of a curtain of green plantings all energy points are in the shadow zone.

$$P_{\alpha} = 100 - \sum_{b=0}^{18}(\sum_{a=0}^{9} N_{10a,10b}) \cdot (1 - f_{\alpha,10b})). \tag{10}$$

The partial correction factor for horizon shading F_{cur} is determined by Formula (7), using the same initial data as in the previous example (Table 4).

3.3 Determination of the Partial Correction Factor for Horizon Shading from Edges

Shading from the side edges of the building facade is calculated using the same algorithm, but with adjustments to the calculations according to the geometry of the passage of sunlight through the side obstacles. For example, the angle of shading from the side edges does not

Table 4: Partial correction factor for horizon shading from curtains in the heating and cooling period for Kyiv, F_{cur}

Shading angle α	**Orientation**							
	N	N-E	E	S-E	S	S-W	W	N-W
Heating period/Cooling period								
I architectural and construction climatic region								
10°	$\frac{1.00}{0.90}$	$\frac{0.99}{0.82}$	$\frac{1.00}{0.80}$	$\frac{0.99}{0.77}$	$\frac{1.00}{0.75}$	$\frac{0.99}{0.78}$	$\frac{1.00}{0.81}$	$\frac{0.99}{0.82}$
20°	$\frac{1.00}{0.90}$	$\frac{0.99}{0.81}$	$\frac{1.00}{0.79}$	$\frac{0.99}{0.76}$	$\frac{0.99}{0.75}$	$\frac{0.99}{0.77}$	$\frac{1.00}{0.80}$	$\frac{0.99}{0.82}$
30°	$\frac{1.00}{0.89}$	$\frac{0.99}{0.80}$	$\frac{1.00}{0.78}$	$\frac{0.99}{0.75}$	$\frac{0.99}{0.73}$	$\frac{0.99}{0.76}$	$\frac{1.00}{0.79}$	$\frac{0.99}{0.81}$
40°	$\frac{1.00}{0.89}$	$\frac{0.99}{0.78}$	$\frac{1.00}{0.76}$	$\frac{0.99}{0.73}$	$\frac{0.99}{0.72}$	$\frac{0.99}{0.74}$	$\frac{1.00}{0.77}$	$\frac{0.99}{0.79}$
50°	$\frac{1.00}{0.88}$	$\frac{0.99}{0.76}$	$\frac{1.00}{0.73}$	$\frac{0.99}{0.70}$	$\frac{0.99}{0.69}$	$\frac{0.99}{0.71}$	$\frac{1.00}{0.74}$	$\frac{0.99}{0.77}$
60°	$\frac{1.00}{0.88}$	$\frac{0.99}{0.73}$	$\frac{1.00}{0.68}$	$\frac{0.99}{0.65}$	$\frac{0.99}{0.65}$	$\frac{0.99}{0.66}$	$\frac{1.00}{0.70}$	$\frac{0.99}{0.75}$
70°	$\frac{1.00}{0.87}$	$\frac{0.99}{0.69}$	$\frac{0.99}{0.62}$	$\frac{0.99}{0.58}$	$\frac{0.99}{0.59}$	$\frac{0.99}{0.59}$	$\frac{0.99}{0.64}$	$\frac{0.99}{0.71}$
80°	$\frac{1.00}{0.87}$	$\frac{0.99}{0.65}$	$\frac{0.98}{0.53}$	$\frac{0.98}{0.51}$	$\frac{0.98}{0.54}$	$\frac{0.98}{0.52}$	$\frac{0.98}{0.56}$	$\frac{0.99}{0.67}$
90°	$\frac{1.00}{0.87}$	$\frac{0.99}{0.65}$	$\frac{0.98}{0.53}$	$\frac{0.98}{0.51}$	$\frac{0.98}{0.54}$	$\frac{0.98}{0.52}$	$\frac{0.98}{0.56}$	$\frac{0.99}{0.67}$

make sense to make more than 60°. Shading of energy points is carried out along the meridian lines of the solar map. Accordingly, the median β_{med} is determined for this group of points from 0° to 60° for the edge on the right and from 120° to 180° for the edge on the left. The length of the distance of the ray passing through the edge at zero height of the sun for the right edge is determined by the formula:

$$d_0^{\text{right}} = \frac{b}{\cos(180^\circ - \beta_{\text{med}})} \tag{11}$$

For the left edge by the formula:

$$d_0^{\text{left}} = \frac{b}{\cos \beta_{\text{med}}}. \tag{12}$$

The length of the ray passing through the edge at a non-zero sun altitude for the right and left edges is determined by the formula:

$$d_{\alpha,\beta} = \frac{d_0^{\text{right}}}{\cos \beta} \tag{13}$$

$$d_{\alpha,\beta} = \frac{d_0^{\text{left}}}{\cos \beta} \tag{14}$$

To determine the percentage of direct solar energy transmitted by the right green edge, we use the Formula (15).

$$P_\alpha = 100 - \sum_{a=0}^{9} \sum_{k=0}^{b} N_{10a,10k} \cdot (1 - f_{10\alpha,10b}). \tag{15}$$

Table 5: Partial correction factor for horizon shading from the edges on the right side in the heating and cooling period for Kyiv (I architectural and construction climatic region), $F_{\text{fin right}}$

Shading angle α	**Orientation**							
	N	N-E	E	S-E	S	S-W	W	N-W
Heating period/Cooling period								
10°	$\frac{1.00}{0.90}$	$\frac{1.00}{0.82}$	$\frac{1.00}{0.80}$	$\frac{1.00}{0.99}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
20°	$\frac{1.00}{0.98}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.99}$	$\frac{1.00}{0.99}$	$\frac{1.00}{0.97}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
30°	$\frac{1.00}{0.97}$	$\frac{1.00}{0.94}$	$\frac{1.00}{0.98}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.99}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
40°	$\frac{1.00}{0.97}$	$\frac{1.00}{0.91}$	$\frac{1.00}{0.96}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.93}$	$\frac{1.00}{0.97}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
50°	$\frac{1.00}{0.97}$	$\frac{1.00}{0.86}$	$\frac{1.00}{0.94}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.94}$	$\frac{1.00}{0.90}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
60°	$\frac{1.00}{0.97}$	$\frac{1.00}{0.82}$	$\frac{1.00}{0.90}$	$\frac{1.00}{0.93}$	$\frac{1.00}{0.88}$	$\frac{1.00}{0.90}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$

Table 6: Partial correction factor for horizon shading from the edges on the left side in the heating and cooling period for Kyiv (I architectural and construction climatic region), $F_{\text{fin left}}$

Shading angle α	**Orientation**							
	N	N-E	E	S-E	S	S-W	W	N-W
Heating period/Cooling period								
10°	$\frac{1.00}{0.98}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.98}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$
20°	$\frac{1.00}{0.98}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.99}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.96}$
30°	$\frac{1.00}{0.96}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.98}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.97}$	$\frac{1.00}{0.98}$	$\frac{1.00}{0.93}$
40°	$\frac{1.00}{0.96}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.96}$	$\frac{1.00}{0.92}$	$\frac{1.00}{0.96}$	$\frac{1.00}{0.95}$	$\frac{1.00}{0.89}$
50°	$\frac{1.00}{0.96}$	$\frac{1.00}{1.00}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.92}$	$\frac{1.00}{0.89}$	$\frac{1.00}{0.94}$	$\frac{1.00}{0.93}$	$\frac{1.00}{0.85}$
60°	$\frac{1.00}{0.96}$	$\frac{1.00}{1.00}$	$\frac{1.00}{0.99}$	$\frac{1.00}{0.89}$	$\frac{1.00}{0.87}$	$\frac{1.00}{0.92}$	$\frac{1.00}{0.89}$	$\frac{1.00}{0.81}$

Same for the green edge on the left:

$$P_\alpha = 100 - \sum_{a=0}^{9} \sum_{k=0}^{b} N_{10a,180-10k} \cdot (1 - f_{10\alpha,180-10b}). \tag{16}$$

The partial correction coefficient for horizon shading F_{fin} is determined by Formula (7) based on the climatic conditions from the previous examples (Tables 5, 6).

4 Conclusions

Green plantings and constructions from them have recently been increasingly used in energy-efficient architecture. However, until now there are no methods for determining their shading coefficients, which does not allow taking into account their influence on the energy data during making energy certificates. The technique for determining the shading coefficients for solar protection devices from the green blocks proposed in the article is a continuation of studies on the effectiveness of green plants for passive regulation of solar radiation entering buildings. The effectiveness of green solar protection devices is calculated taking into account the geographical latitude and climatic features of the construction area. For windows oriented to the southern sector of the horizon, the most rational will be overhangs, north-west orientation – side edges on the left, northeast orientation – side edges on the right, for west and east orientations – curtains.

This technique is based on available field studies of the transparency of green structures. We realize that such studies are still not enough. In addition, calculations of shading coefficients are carried out only for five cities of Ukraine, which represent different architectural and construction climatic regions. Therefore, in the future, it will be necessary to specify the calculation coefficients of shading for different types of green plantings and different climatic conditions. The studies presented in the article were prepared for the publication of the state standard of Ukraine "Green structures. General regulations".

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Received February 23, 2025; final form May 10, 2025.