Cooling Effect of a Green Area

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outdoor thermal comfort | façade greening | evapotranspiration | shading

1. Introduction

Due to the assumption that two thirds of the world population will live in urban areas by 2050 [1] the issue of urban greening is becoming increasingly important. The climate of cities is known to be very different compared to that of surrounding rural areas and a clear temperature difference is observable. This phenomenon is called the "Urban Heat Island" (UHI) effect. One of the main reasons for its occurrence is the sealing of permeable surfaces—as it happens, for example, when constructing buildings and infrastructure on previous open, green spaces. Furthermore, vertical building surfaces cause a reflection of the sun rays and thus heat up the environment. Vertical greening is a strategy to counteract this effect [2][3][4].

One of the measures in the "Urban Heat Island Strategy Plan" by the Vienna Environmental Protection Department is the protection and expansion of green and open spaces, as they provide a cooling effect through shading and evapotranspiration [4]. However, according to the report "Global warming of 1.5 °C" by the Intergovernmental Panel on Climate Change (global material resource) [5], a general increase in surface temperature has been observed worldwide and not only in cities. This makes the issue of cooling in summer of rising importance. Façade greening can contribute to this as an effective cooling measure.

The microclimate of a city is influenced by various urban characteristics, such as building density, the nature of its open spaces, the orientation of buildings in relation to solar radiation and wind movements, as well as the surface materials and colors of roofs, façades, courtyards and streets. The synergistic effects of planning decisions that have an impact on the microclimate can lead to a significant improvement in the residents' sense of comfort [6].

Green façades have a cooling effect on the building and the surrounding climate [7][8]. Furthermore, the cities are becoming increasingly dense, which makes the space-saving characteristic of vertical greening an optimal solution. Façade greening represents an interface between buildings and urban planning. In addition to the previous, conventional tasks of buildings, a greened building takes over one more with a façade greening.

Façade greening also has numerous other advantages, including air quality improvement, sound reduction through adsorption, supply of oxygen and of course the aesthetic aspect [9][10].

There are various categories of façade greening. Among the ground-based are the climbing plants, which are divided into self-climbers and scaffold climbers. They take root in the soil in front of the building. The self-climbers, such as ivy and wild vine can hold themselves to the wall by means of roots and adhesive discs. Scaffold climbers need climbing aids such as ropes or trellises.

Facade-bound greeneries are structures that are attached directly to the building. These curtain wall elements are either plant troughs that are attached to rails or vertically suspended elements from which the plants grow out horizontally [11].

The microclimate in a street canyon is strongly influenced by the surrounding buildings and their structure, color, construction, insulation and surface temperatures [3].

The building envelope is heated up by sun rays. However, a green surface intercepts the rays and thus prevents their reflection, which leads to the reduction in temperature in the immediate surroundings. In consequence, the surface temperatures of a building are significantly reduced by vertical greening, which is also proven by a number of studies [7][12].

2. Comparison of the Cooling Capacity with a Beech Tree

It is difficult to represent and value the total cooling effect of a green area caused by evapotranspiration. Therefore, in the following a comparison of the cooling capacity with a beech tree is made and a method for the monetary evaluation of the cooling effect is presented.

A beech tree has an approximate average transpiration capacity of 30 L per day [13].

The studied vertical greening system with an area of 58 m^2 has an average evaporation capacity of 101.38 L per day in summer.

Thus, it can be said that the façade greening is equivalent to about 3.4 beeches in terms of evaporative capacity. Nevertheless, it should be noted that the façade greening must be artificially irrigated. The water consumption of this trough system without tank in the outdoor area is 0.35 m^3/m^2/year. [12] For the entire system, this would be 18,550 L per year. However, at places with insufficient space for trees, especially in the context of dense urban areas, vertical greening is a good alternative. A façade greening is an elaborate concept compared to a self-growing tree, but it has a time advantage if it has to be done quickly, as a tree needs decades to become fully grown.

Tudiwer et al. [14] determined the cooling costs for the economic evaluation of a façade greening. The presented method was used to qualitatively assess the economic effects of greening buildings. In particular, it deals with the evaluation of the evaporation energy in urban areas. The production costs are influenced by evaporation capacity, the total costs for the greening system, and the number of summer days. These cost models are usually used in the energy industry to compare different electricity prices. It is based on the ratio of the total cost of electricity generation to the electricity generated. The costs are incurred at different times and using the net present value method, they are to be discounted and calculated at time t = 0 to have a direct comparison.

In [14], the formula for the electricity production costs is adapted and the cooling production costs of the façade greening, located in Vienna, are calculated.

Considering several influencing factors, such as the number of summer days (desired cooling effect), the amount of heat extracted and the total costs, the cooling production costs were calculated to be 0.80 €/kWh. This indicates that with an investment of 0.80 € in this façade greening 1 kWh of thermal energy can be extracted from the environment. It should be noted that the calculations were made in 2019 and the current costs may differ.

The reduction in the surface temperatures of the exterior façade due to greening is clear. The south façade of a 5-storey administrative building in a university campus in Shanghai showed a maximum temperature difference of ~9 °C between the non-greened and greened façade, and up to 4.2 °C for the north façade.

A study conducted in the vicinity of the city center of Ljubljana, Slovenia showed a temperature reduction in a south façade of up to 34 °C.

References

1. Brockerhoff, M.; United Nations. World Urbanization Prospects: The 1996 Revision. Popul. Dev. Rev. 1998, 24, 883.
2. Tudiwer, D.; Höckner, V.; Korjenic, A. Greening Aspang-Hygrothermische Gebäudesimulation zur Bestandsanalyse und Bewertung unterschiedlicher Szenarien bezogen auf das Innenraumklima. Bauphysik 2018, 40, 120–130.
3. Hollands, J.; Tudiwer, D.; Korjenic, A.; Bretschneider, B.B. Greening Aspang—Messtechnische Untersuchungen zur ganzheitlichen Betrachtung mikroklimatischer Wechselwirkungen in einem Straßenzug einer urbanen Hitzeinsel. Bauphysik 2018, 40, 105–119.
4. Brandenburg, C.; Damyanovic, D.; Reinwald, F.; Allex, B.; Gantner, B.; Czachs, C. Urban Heat Islands–Strategieplan Wien; Wiener Umweltschutzabteilung–Magistratsabteilung 22: Wien, Austria, 2016.
5. Orr, G. Global warming. Struct. Eng. 2007, 85, 34.
6. Bretschneider, B.; Korjenic, A.; Höckner, V.; Tudiwer, D.; Pitha, U.; Scharf, B. Greening Aspang/Entwicklung eines Verfahrens zur Gesamtenergetischen Optimierung von Stadtgebieten am Beispiel der Aspangstraße: Final report; FFG: Roseville, MI, USA, 2017; Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjViNCwmOb6AhVJaN4KHY2GAaEQFnoECBUQAQ&url=https%3A%2F%2F content%2Fuploads%2Fsites%2F3%2FBGR8_2018_KR15SC7F13040_Greening-Aspang-1.pdf&usg=AOvVaw0bu54JtugbCeyPCU9J--Ve (accessed on 26 April 2020).

7. Dahanayake, K.K.C.; Chow, C.L. Studying the potential of energy saving through vertical greenery systems: Using EnergyPlus simulation program. Energy Build. 2017, 138, 47–59.
8. Acero, J.A.; Koh, E.J.Y.; Li, X.; Ruefenacht, L.A.; Pignatta, G.; Norford, L.K. Thermal impact of the orientation and height of vertical greenery on pedestrians in a tropical area. Build. Simul. 2019, 12, 973–984.
9. Sternberg, T.; Viles, H.; Cathersides, A.; Edwards, M. Dust particulate absorption by ivy (Hedera helix L) on historic walls in urban environments. Sci. Total Environ. 2010, 409, 162–168.
10. Pérez, G.; Coma, J.; Cabeza, L.F. Vertical Greening Systems for Acoustic Insulation and Noise Reduction. Nat. Based Strateg. Urban Build. Sustain. 2018, 3, 157–165.
11. Pitha, U. Leitfaden Fassadenbegrünung; ÖkoKauf W, Nr. Wien; 2013.
12. Hoelscher, M.T.; Nehls, T.; Jänicke, B.; Wessolek, G. Quantifying cooling effects of facade greening: Shading, transpiration and insulation. Energy Build. 2016, 114, 283–290.
13. Pitha, U.; Scharf, B.; Zluwa, I.; Pelko, C.; Korjenic, A.; Tudiwer, D.; Salonen, T.; Mitterböck, M. Der Fassadengarten der MA 31, Bepflanzung und Dämmung–Wirkung und Funktion einer nachhaltigen Neugestaltung. Informationsbroschüre zur thermischen Sanierung und Begrünung des Amtsgebäudes in der Grabnergasse 4-6. 2019, p. 12. Available online: https://www.obt.tuwien.ac.at/uploads/media/Folder_Der_Fassadengarten_der_MA_31.pdf (accessed on 26 April 2020).
14. Tudiwer, D.; Hollands, J.; Korjenic, A. Berechnung der Kühlgestehungskosten von fassadengebundenen Begrünungssystemen im städtischen Raum. Bauphysik 2019, 41, 120–124.