GDF – green density factor and GCF – green cooling factor. A specific calculation method to integrate green roofs, green facades and their evapotranspiration cooling rate into the general planning procedure of architects and planners.

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Dissertation

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Abstract

This Ph.D. thesis will develop a calculation framework that relates the vegetation cover of a building to the area of the paved footprint of the building. In a second step, the cooling effect of the building vegetation on the surrounding microclimate is estimated. The introduced factors can be used in terms of town planning regulations in order to standardize environmental parameters for buildings.

The introduced factors are called the Green Density Factor (GDF) and the Green Cooling Factor (GCF).

The aim of this work is to develop the above factors (GDF and GCF) as a quantitative and a qualitative measure of the green volume. These new factors will enable an easy to use tool in

urban planning questions. Adequate, for example, to the factors GFZ or GRZ, used in nowadays German city planning. GRZ is the “Grundflächenzahl”, a measure for the sealed footprint in relation to the property size (for example: GRZ = 0.4 means that 40% of the property size can be covered/paved with buildings). GFZ is the “Geschossflächenzahl” which informs about the allowance of total number of floors (for example, VII means the building can be constructed with 7 floors maximum).

The factors GDF and GCF, introduced in this work, will address architects (since roofs and façade surfaces will be affected), developers/planners (detailed decisions based on the predictions) and decision makers (politicians) – as well as a variety of specialists working in the fields of water management, city climate and sustainability. The factors allow to adjust/optimize the entire building regarding its shape, the energy systems and the exterior greenery towards environmental buildings and cities**.** Furthermore, the factors will allow cities to set guidelines for upcoming construction projects.

The GDF relates the amount of exterior greenery on façades and roofs to the paved footprint of the building. The more exterior areas are vegetated the higher the GDF. Following this approach, the negative effects on the city climate as a result of paved areas can be (over)compensated by exterior vegetation, including other positive consequences that follow. It should be noted, however, that there are other negative effects resulting from paved city surfaces (e.g. on the soil and ground water) that cannot be recovered by vegetated buildings alone.

Based on the GDF, the Green Cooling Factor (GCF) will allow to calculate the cooling impact of the building vegetation. The cooling effect is a result of evapotranspiration of the plants. The cooling capacity measured in kilo-Watt-hour (kWh) per year will be compared to the building energy used in heating, ventilation and air condition (HVAC), as well as the electrical components of the building installation. The HVAC systems produce mainly heat that so far is released into the city spaces. This released heat will be compared with the cooling capacity. Again, overcompensation can be achieved as consequences of the vegetation. An overcompensation can directly be read from the calculated GCF value: For example, GCF = 1.5 means, that for each 100kW from HVAC heat load injected into the micro-climate, an amount of 150kW of cooling capacity (150%) are added to the micro-climate by the building vegetation.

The factors are applied to different example buildings located in the climate zones of Hamburg (Germany) and Hong Kong (China) in order to illustrate their general capabilities – since both city require a different focus in terms of sustainable city planning. In these cases, a 25% vegetation cover of facades and an 80% vegetation cover of roofs is assumed. It is shown, that in both cases the amount of local rain precipitation is sufficient to feed the evapotranspiration of the vegetated facades and vegetated roofs to achieve a cooling that overcompensates the heat load injected by the building into the micro-climate. Furthermore, the factors are used to estimate the potential to compensate the heat load caused by the energy consumption of the whole cities of Hamburg and Hong Kong. Therefore, the factors allow to easily predict cooling energy capacities for different regions and different sized areas.

Both, the GDF and the GCF will be factors that provide specialists with a clear framework at the very beginning of the planning procedure. Architects and city planners (e.g. governmental city planning agencies) can determine the degree of exterior greening and the expected cooling using these factors. Therefore, all the benefits for each city quarter can be

included/predicted individually. Using this approach, architects and city planners are able at a very early stage to include it into a life-cycle-assessment of the building and increase its value through the benefits of the exterior greenery. An outlook for a potential implementation of the factors into the city planning process is discussed based on the example of the “Hafen City” Hamburg at the end of the thesis.