ENERGY SAVING STRATEGIES THROUGH THE GREENING OF BUILDINGS THE EXAMPLE OF THE INSTITUTE OF PHYSICS OF THE HUMBOLDT-UNIVERSITY IN BERLIN- ADLERSHOF

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Abstract - The energy consumption for cooling and ventilation units in buildings can be reduced by passive cooling techniques like the greening of roofs and facades. Greened roofs consume a yearly average of 81% of all radiation balance by evapotranspiration of the precipitation. A new project in Berlin will feature a combination of stormwater management with energy saving through the greening of facades and the integration of adiabatic cooling systems. Both systems will be supplied with rainwater. A scientific monitoring will determine the overall benefits of the project.

Keywords: energy saving; stormwater management, facade greening, roof greening, rainwater harvesting

1. Introduction

Urbanization is increasing worldwide. Urban centers are characterized by negative environmental impacts including escalated flood risks, polluted surface waters, modification of the urban climate and increased water and energy consumption.

The risk of flooding is increasing in many cities due to the increase of impermeable surfaces such as buildings, asphalt and concrete. Annual floods of three German rivers: the Rhine, the Mosel and the Main, show that high priority should be placed on decentralized measures of rainwater retention. Land use practices that reduce the retention, infiltration, and evaporation of rainwater throughout a watershed are a main cause of the floods which periodically damage settlements and infrastructure built along rivers. The most recent flood in Germany in September 2002 caused damages of more than 9 Billion Euros (Fig. 1 and 2) (see: http://www.umweltbundesamt.de/index-e.htm).

Fig. 1, 2: Flood in Germany 9/2002 (www.focus.de)

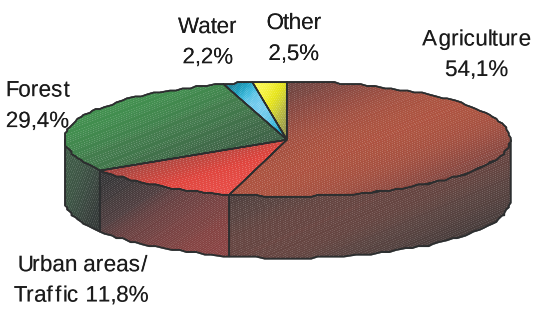

Fig. 3: Land use in Germany; 1997

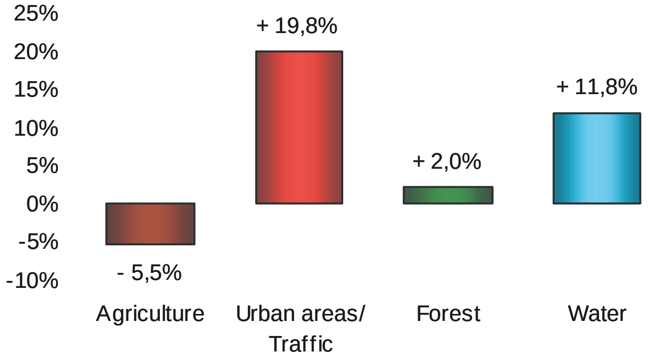

Fig. 4: Germany 1981-1997: 19.8% increase of urban areas, 5.5% loss of agricultural areas

The increase of impermeable surfaces (see Fig. 3, 4) additionally influences the microclimate by creating a different energy balance than is found in greened areas. Most of the precipitation in the natural landscapes is evaporated. For example, in naturalistic landscapes in the Spree and Havel watershed in Germany, approximately 80% of precipitation is evaporated or transpired by plants. Energy is required for the evapotranspiration of water to proceed. This physical process generates the so-called “evaporation-cooling” of 2450 Joules/g H_2O evaporated. According to research in Hamburg, Germany in 1957, greened areas like meadows consume a yearly average of 86% of all radiation balance [Collmann, 1958]. This energy is used to transpire water and create biomass. The consumed energy will be transformed again as water condenses in the atmosphere.

2. Research

Environmental changes in urban areas include reduced evapotranspiration of the precipitation and the transformation of up to 95% of radiation balance to latent heat (Fig. 8). Additionally, there is an increase of thermal radiation caused by higher surface temperatures of hard materials like concrete and the ability of such surfaces to store heat (Fig. 5).

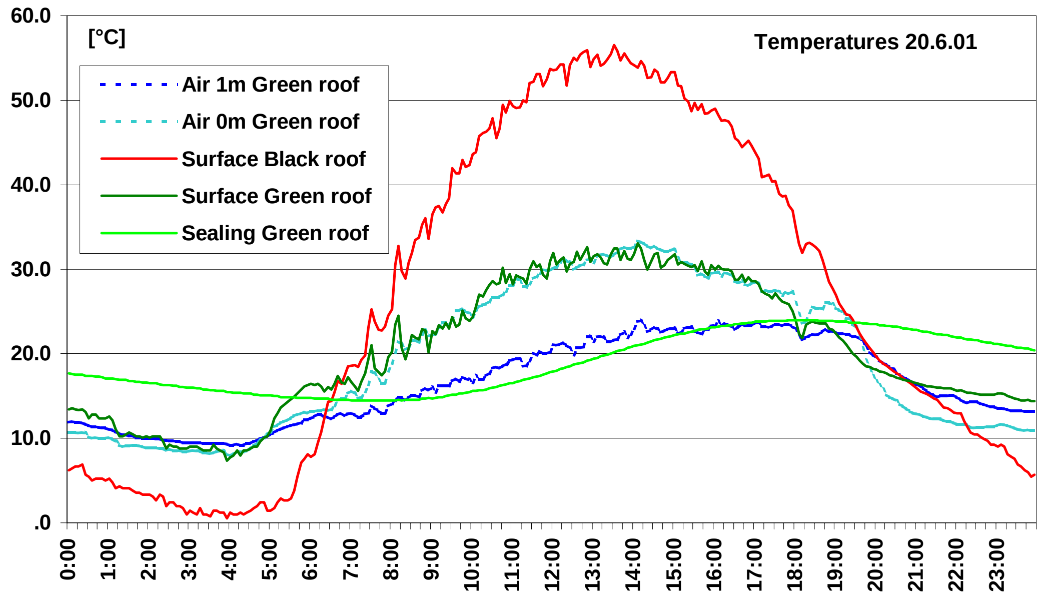

Fig. 5: Reduced surface temperatures of a greened roof compared to a conventional flat roof (Infrared measurements) [Köhler, Schmidt 2002]

As a result, air temperatures inside buildings also rises and leads to discomfort or increased energy consumption for climatization. A logical solution to create more comfortable air temperatures inside and outside of buildings is to green their facades and roofs, thereby „consuming“ this energy by evapotranspiration.
According to measurements we have taken at the UFA Fabrik in Berlin, extensive green roofs transfer 58% of radiation balance into evapotranspiration during the summer months (Fig. 9). The annual average consumption of energy is 81%, the resultant cooling-rates are 302 kWh/(m²*a) by a radiation balance of 372 kWh/(m²*a) (average of 1987-89, see Tab. 1). In tropical countries, much higher cooling values are expected due to higher precipitation and evapotranspiration rates [Köhler et al., 2001].

Fig. 6 (left): In 1984 greened roof in Berlin's city center (Paul Lincke Ufer 44, Berlin Kreuzberg)

Fig. 7 (right): Climatological station on an extensive green roof, where hydrologic and energetic measurements are taken, UFA-Fabrik in Berlin-Tempelhof

Tab. 1: Precipitation, runoff, potential and measured evapotranspiration, and the evaporation cooling rate of green roof plots, measured in Berlin [Schmidt, 1992, Köhler et al., 2001]

Year	**Precipitation**	**Runoff**	**Runoff**	**potential ETP**	**measured ETP**	**Cooling rate**
	[mm]	[mm]	[%]	[mm]	[mm]	[kWh/(m²*a)]
1987	702	179	25.5	641	523	356
1988	595	157	26.4	696	437	298
1989	468	98	20.9	750	370	252
average	**588**	**145**	**24.6**	**696**	**443**	**302**

3. New Approach

The energy consumption for cooling and ventilation units in buildings is a factor of growing importance. With the new directive of the European parliament on the energy performance of buildings (2002/91/EC) passive cooling techniques should be implemented that improve indoor climatic conditions and the microclimate around buildings. Additionally, the rise of costs for air conditioning systems has been a factor to promote energy saving efforts in the buildings sector. The Institute of Physics in Berlin-Adlershof, a project of the Architects Augustin and Frank, Berlin, is a research and office building that will feature a combination of sustainable water management techniques, including the use of rainwater to cool the building. There are three main goals of rainwater harvesting in this project. The first goal is to substitute drinking water. The second is the retention of rainwater which reduces *…(cont.)*

Energy balance of a greened roof compared with a black bitumen roof

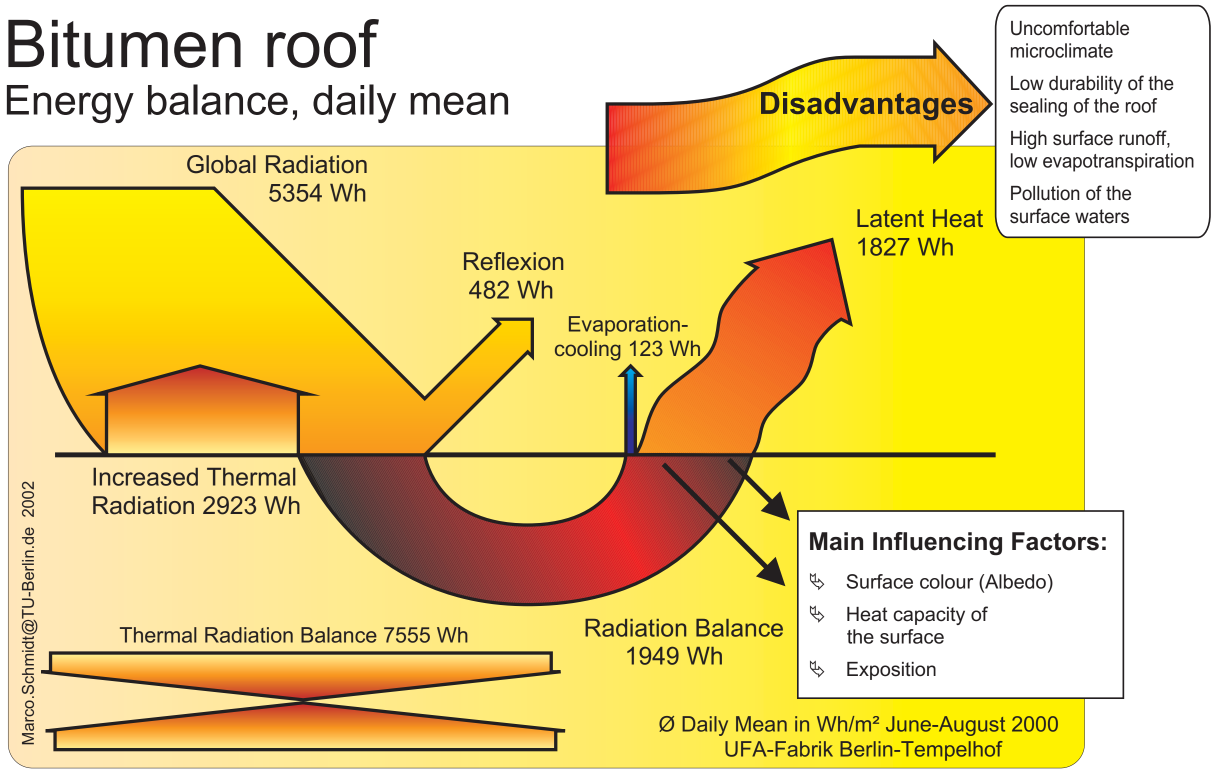

Fig. 8: Reduced evapotranspiration in urban areas converts up to 95% of radiation balance to latent heat and increases the thermal radiation

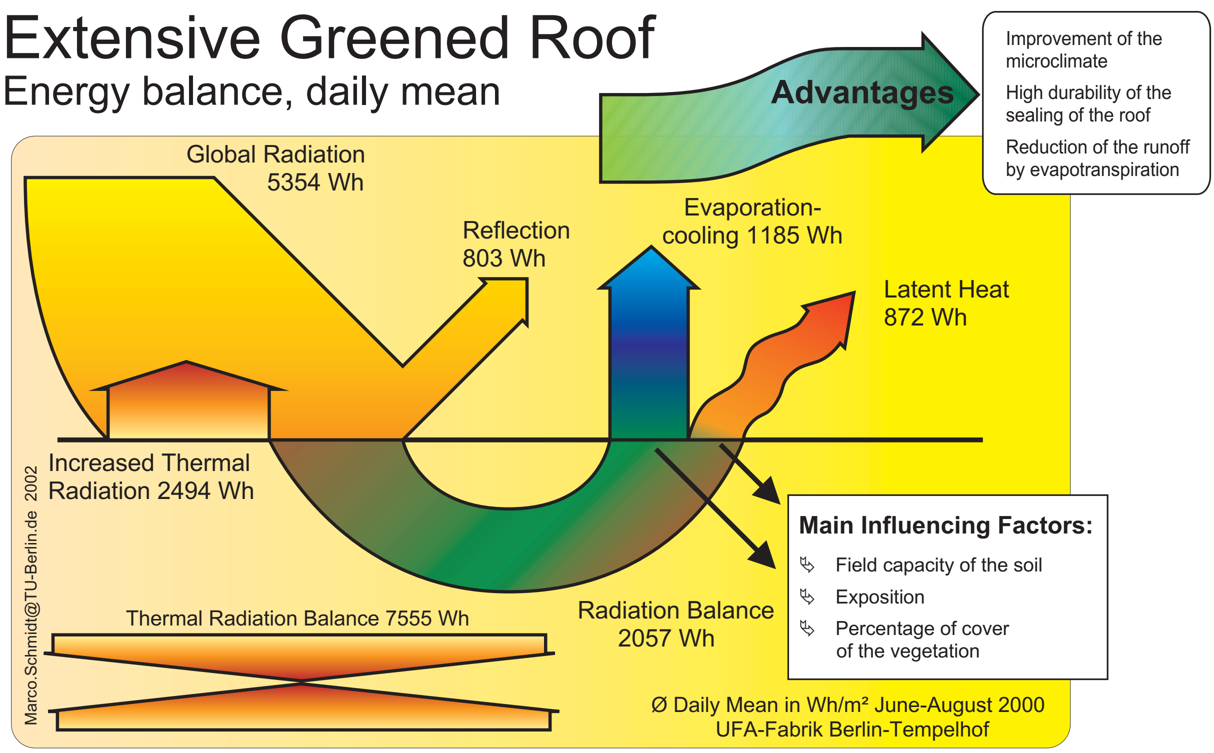

Fig. 9: Extensive greened roofs transfer 58% of radiation balance into transpiration during the summer months, UFA Fabrik in Berlin, Germany

(cont.)… stormwater flows in combined sewer systems during rainfalls. This reduces the peak load and avoids an overload of the system, which could cause flooding and serious health problems. Third goal is to reduce energy consumption during the summer month through evapotranspiration and shade.

Fig. 10 and 11: Climbing plants provide shade and cooling by evapotranspiration (left: in construction 10/2003)

Rainwater will be stored in 5 cisterns in two courtyards of the building and will be used for the irrigation of a facade greening system and adiabatic cooling systems. The green facade with its different types of climbing plants has been designed to demonstrate the four seasons. The plants will provide shade during the summer, while in the winter, when the plants loose their leafs, the sun's radiation will go through the glass front of the building. This project will include ongoing water consumption monitoring of different plant species comprising the green facade and the adiabatic cooling system. Both the shade created by the plants and the cooling process of evapotranspiration will influence the energy balance of the building.
Stormwater events with heavy rainfall will be managed by the overflow to a small constructed lake in one of the courtyards. The institute is located in a groundwater protection area close to groundwater uptake wells of the city's drinking water supply station. To protect the ground water quality, only natural surface infiltration is allowed

Tab. 2: Project data of the new building of the Humboldt-University in Berlin (HUB)

	Institute of Physics Berlin HUB - Adlershof	
Connected Area	Air conditioning systems with adiabatic cooling:	7 units
	Irrigated Greened Containers:	152 plots
	Connected roofs:	4700 m²
	Pond in the courtyard:	225 m²

Fig. 12: Constructed lake with natural surface infiltration

Tab. 3: Estimated results of a simulation for the planning process, Adlershof project

Estimated project data	Storage capacity:	64 m³ (15 mm)
	Drinking water supply	> 30 % (Simulation)
	Rainwater for adiabatic cooling:	12 % (Simulation)
	Rainwater for green facades:	26 % (Simulation)
	Rainwater for irrigated courtyards	6 % (Simulation)
	Infiltration into the underground	> 35 % (Simulation)

All data represented are results of a simulation and were generated during the planning process (Tab. 3). Scientific monitoring to determine the overall benefits of the project are beginning immediately. The retention pond in Adlershof has a size of 2.5% of the annual precipitation. This is a quite low percentage, especially considering its role in water storage for both irrigation and cooling purposes. Many unknown factors – including the amount of water which will be used by the green facade and the adiabatic cooling systems - meant that assumptions had to be made in the planning process. Monitoring of this project will provide information on these subjects that can be used for the planning of future projects.

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