

Rainwater harvesting for stormwater management and building climatization

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Abstract Environmental changes in urban areas include reduced evapotranspiration of the precipitation and the transformation of up to 95% of the radiation balance to latent heat. As a result, air temperatures inside buildings also rise and lead to discomfort or increased energy consumption for climate management. 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. The evapotranspiration of greened roofs and greened facades has a high potential to reduce the urban heat island effect.

Additionally, the retention of stormwater successfully reduces the peak load into combined sewer systems and prevents combined sewage release into surface waters.

The Institute of Physics in Berlin- Adlershof is a research and office building that features a combination of sustainable water management techniques, including the use of rainwater.

Compared to urban areas where rainwater disappears into sewer systems, all of the

precipitation from the roof will be used to cool the building and for the infiltration into the groundwater in one of the courtyards. The project includes ongoing monitoring of water consumption by different plant species and the cooling process of evapotranspiration which influences the energy balance of the building. This allows the transposition of experience to future projects, main target for the Department of Ecological City Construction of the Berlin Senate for organizing and financing this innovative project.



Figure 1 façade greening system, Institute of Physics, Berlin

Keywords green building architecture, green façades, evapotranspiration, evaporative cooling, rainwater harvesting, stormwater retention

Introduction

Worldwide, the reduction of energy consumption for cooling and ventilation installations is becoming increasingly important. The increased use of air conditioning systems, in particular, forces energy conservation strategies on the building sector (Schmidt, 2003). A new European parliament directive on the energy performance of buildings (2002/91/EC), strongly encourages the implementation of passive cooling techniques to improve indoor climatic conditions as well as the immediate microclimate.

The Institute of Physics, a project of the Architects Augustin and Frank (Berlin), is a research and office building that features several measures of sustainable architecture. The building combines sustainable water management and reduced energy consumption for cooling and ventilation. Rainwater is used to supply a façade greening system and ventilation units.

The building is a result of an architectural competition held in 1997. Construction of this experimental building for the Humboldt- University of Berlin started in the year 2000, and ended in 2003. The building has a total floor area of 19 000 m² . It was honored by the Berlin Architectural Award in the year 2004.

Methods

At the request of the Berlin Environmental Ministry, researchers at the Technical University of Berlin, the Humboldt University, and University of Applied Sciences Neubrandenburg have monitored the overall benefits of this building. This research has three foci: reduction of operating costs, the functionality of the water management systems and future applications.

The project includes permanent monitoring of the water consumption of different plant species of the façade greening system and of evapotranspiration and its effect on the energy balance of the building. In this project, irrigation is controlled and monitored by a internet-integrated computer system (for more detailed information see <http://www.gebaeudekuehlung.de>). Temperature and radiation measurements are intended to identify the economic and ecological benefits of these measures. Data collected from this project is incorporated into simulations designed to understand the transferability of these techniques to different climatic conditions and to determine benefits for future projects.

The investigated measures are to be divided into three main topics:

- Rainwater harvesting and decentralized stormwater management
- Passive and active building climatization, reduction of operating costs for energy
- The façade greening system

The general project structure is divided into 5 different phases:

- Phase I : Optimization of the planning assumptions (2001-2002)
- Phase II : Construction Management (2002-2004)
- Phase III : Monitoring (2004-2007)
- Phase IV : Optimization of the project (2005-2007)
- Phase V : Model construction, Performance Prediction for future projects (2007)

Rainwater harvesting and decentralized stormwater management

A main goal of rainwater harvesting in Berlin is the retention of rainwater to reduce stormwater flows into combined and separated sewer systems during rain events. This reduces the peak load and avoids an overload of the systems, which could cause flooding and serious health problems (Diestel, Schmidt, 2004). The Institute of Physics has no connection to any rainwater sewer. Rainwater is stored in 5 cisterns in two courtyards and will be used for irrigating the facade greening system and an adiabatic cooling system in 7 climatization units. Stormwater events with heavy rainfall will be managed by an overflow to a small constructed lake in one of the courtyards inside of the building. 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.



Figure 2, 3 constructed lake with natural surface infiltration inside of a courtyard

Passive and active building climatization

Impermeable surfaces like roofs and streets influence urban microclimates through radiation changes. As a result of these changes, air temperatures inside buildings also rise and lead to discomfort or increased energy consumption for climate management. A logical solution to create more comfortable air temperatures inside and outside of buildings is to green their façades and roofs, thereby „consuming“ this energy by evapotranspiration (Schmidt, 2005).

According to measurements taken at the UFA Fabrik in Berlin, extensive green roofs transfer 58% of radiation balance into evapotranspiration during the summer months. The annual average energy consumption is 81%, the resultant cooling-rates are 302 kWh/(m²*a) with a radiation balance of 372 kWh/(m²*a) (Schmidt, 2005).

A more demanding solution is a façade greening system which has a higher direct effect on the energy performance of a building than a greened roof. Green façades were implemented at the Institute with two objectives: 1) to passively climatize the building through shading and solar radiation and 2) to harness evapotranspiration to improve the microclimate inside and around the building.



Figure 4 façade greening system, Institute of Physics, Berlin-Adlershof

Plants provide shade during summer, while during the winter, when the plants lose their foliage, the sun's radiation is able to pass through the glass-front of the building. Energy savings will be extrapolated through radiation measurements at the institute.

Although in the natural landscape most precipitation is evaporated or transpired, in urban areas, evapotranspiration is greatly decreased and rainwater is instead swiftly directed into the sewer system and to receiving waterbodies. At the institute stormwater runoff is collected and used to irrigate 150 planters on nine different façades. The planters, which are located at each floor of the building, are irrigated by a water content maintained at a constant level. Evapotranspiration of the plants has an immediate feedback to the water consumption.

Rainwater based adiabatic cooling systems

Air conditioning in the Institute of Physics is achieved through seven adiabatic climatization units. These units use rainwater to cool air through the process of evaporation. This is a two step process. First, the rainwater is evaporated to reduce the temperatures of the air leaving the building. In a second step, fresh air entering the building is cooled as it passes across a heat exchanger with cooled air on its way out. This process is sufficient to maintain indoor temperatures of 21-22 °C with outside temperatures of up to 30 °C. Higher outside temperatures are maintained by a conventional cooling system which is supplied with cold water from two absorption chillers, provided with hot water by a combined heat and power unit (CHP).



Figure 5 adiabatic exhaust air cooling in seven air conditioning systems

Results

Table 1 Estimated results of a simulation for the planning process, Adlershof project

Institute of Physics, HUB, Berlin- Adlershof	
Storage capacity:	40 m ³ (9 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)

The retention pond in Adlershof has a size of 1,5% of the annual precipitation. This is quite a 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 provides information on these subjects that can be used for the planning of future projects.

Table 1 shows the estimated results of a simulation for the planning process. Up to now the real water consumption was much less than the estimated values. Main factor is the underdeveloped vegetation of the façade greening system in the first years of its implementation. In the summer month July until September the water consumption for the quite well developed *Wisteria sinensis* increased up to 420 liter per day for 56 planter boxes. This represents a cooling value of 280 kWh per day.

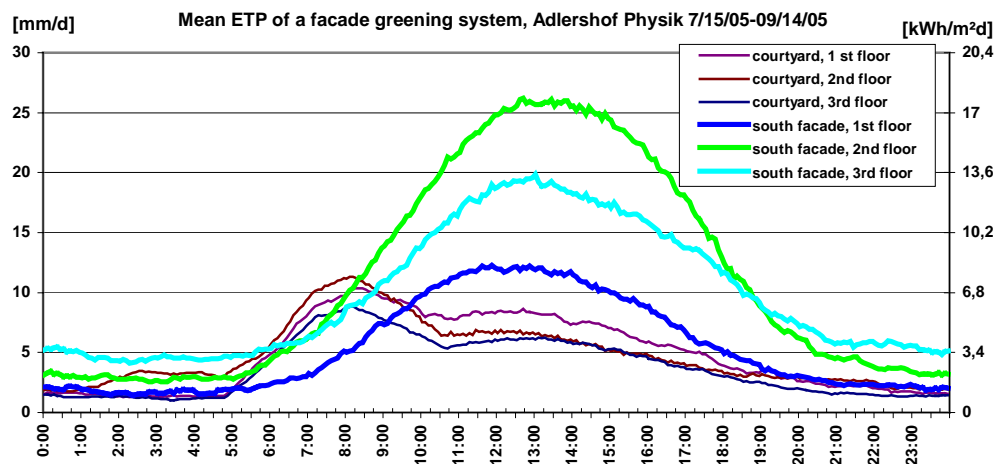


Figure 6 mean evapotranspiration of the façade greening system in mm/day and correspondent cooling rates

The mean evapotranspiration between July and August 2005 for the south face of the building was between 5.4 and 11.3 millimeters per day, depending on which floor of the

building the planters were located (Figure 6). This rate of evapotranspiration represents a mean cooling value of 157 kWh per day.

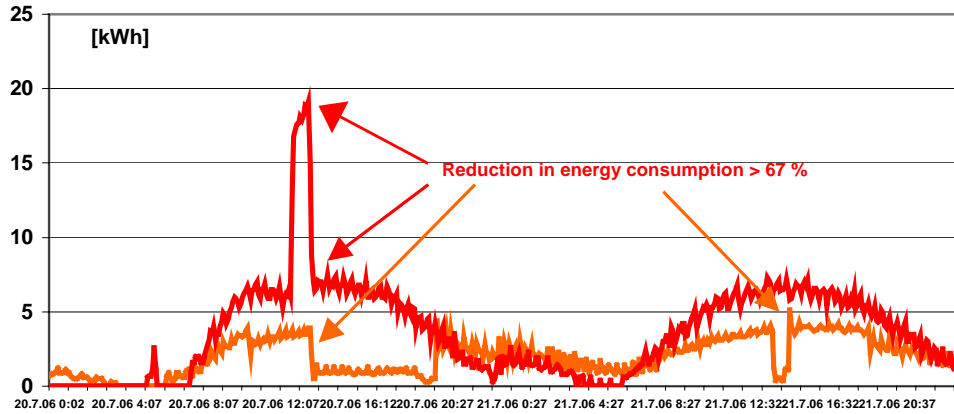


Figure 7 difference in energy consumption with and without adiabatic cooling climatization

Figure 7 shows the difference in energy consumption of two adiabatic exhaust air cooling systems switched on and off at highest outside air temperatures of up to 35 °C. Energy consumption increased from 6.0 to 19 kWh. Up to 30°C outside air temperature no additional energy is used.

Conclusions

Passive and active evaporation of water is an inexpensive and effective means to climatize a building. The evapotranspiration of a cubic meter of water consumes 680 kWh of heat. Greening a building's roof and façades results in significant additional evapotranspiration, which has a high potential to reduce the building's surface temperatures and to improve the climate inside and around the building. Both the potential and the real evapotranspiration are high due to high temperatures caused by the urban heat island effect and the low humidity of urban areas.

Evapotranspiration is the most important factor of the environmental benefit of green roofs and green façades in urban areas. It influences urban hydrology, reduces surface temperatures and improves stormwater management.

The combination of rainwater harvesting with the climatization of a building has been successfully implemented. The adiabatic cooling systems have a higher efficiency than expected. Goal for future projects will be the transposition of experience to completely substitute technical cooling facilities with rainwater based climatization systems.

5. References and Links

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Lead Institution:

Department of Green Building Architecture, Berlin Senate

The department of green building architecture initiates, monitors, and supports innovative measures of sustainable architecture. Main departmental foci include: the reduction of operating costs for water and energy, the improvement of green site development, the reduction of waste, and the use of sustainable building materials. Scientific monitoring is used to guide the development of local regulations and legislation, develop guidelines for future projects, and contribute to the body of knowledge supporting green building architecture. The work of this group over the last 25 years has resulted in modifications of the common building legislation and guidelines for innovative architectural competitions (SenStadt, 2002, 2003).

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