HCU HafenCity Universität Hamburg

in co-operation with

UNICAMP

Energy-Efficient Retrofitting of Buildings

Elective Module

HafenCity University Hamburg 2017

Office for Facades and Building Envelopes
Prof. Dr.-Ing. Frank Wellershoff

Introduction

"Energy-efficient retrofitting of buildings" is an elective module focused on refurbishment of buildings with emphasis on energy-efficiency, internal comfort and design strategies. Retrofit enables improvement of building performance, increases its useful life and meets current performance requirements (thermal, energetic, environmental, and economic). The module is based on three learning phases and included a study trip in Campinas, Brazil, where Training School as a part of the module was organized.

This booklet is a summary of the module and serves as an overview of the students activity and final outcome – design sketchbooks.

Phase 1
Pre-preparation prior to Training School through input lectures and analysis of local climate in Brasilia.

Phase 2
Project week at University of Campinas, Brazil, as a research cooperation between the University of Campinas (UNICAMP) and the HafenCity University in Hamburg (HCU).
In Training School "Design process for building retrofit" researchers dealt with the challenges we face in building design and refurbishment, both aiming at minimizing greenhouse gas emissions and energy demand, especially from non-renewable sources as well as reducing climate change impacts. A case study was initiated based on the existing ministry building in Brasilia, dating back to the 60's.

	Monday 05-06-2017	Tuesday 06-06-2017	Wednesday 07-06-2017	Thursday 08-06-2017	Friday 09-06-2017
9:00 – 10:00	Registration	Design process (Doris Kowaltowski)	Daylight and lighting systems (Claudia Amorim)	Workshop	Workshop NoPa: RIU
10:00 – 10:15	Coffee break	Coffee break	Coffee break		
10:15 – 11:15	Welcome	Rule-based design (Gabriela Celani)	Environmental performance of buildings (Joana Gonçalves)		
11:30 – 12:30	Research report instructions	Façade systems (Frank Wellershoff)	Workshop instructions		
12:30 – 14:00	LUNCH				
14:00 – 15:15	Research report session	Green technologies (Kelen Dornelles) (Leticia Neves)	Workshop	Workshop	Workshop NoPa: RIU
15:15 – 16:15		Retrofit case study (Luciana Fernandes)			
16:15 – 16:30	Coffee break	Coffee break			Final presentation
16:30 – 17:30	Research report session	Retrofit and sustainable architecture (Wolfgang Willkomm)			
17:30 – 18:00					
Night					

Program of Training School "Design Process for Building Retrofit"

An international group of researches was gahtered to present and lecture about state-of-the-art in sustainability, energy-efficiency, design process and technological advancement.

Lecturers of Training School

Introduction to the programe

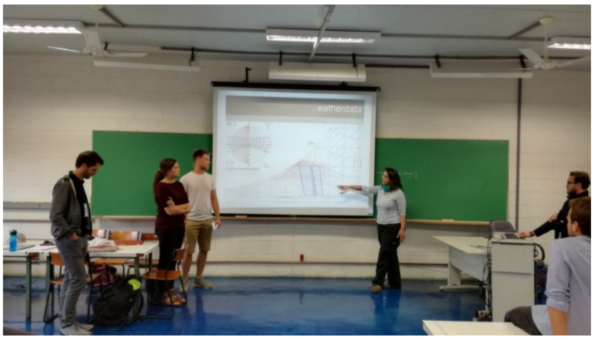
Around 30 participants actively participated in the School, of which 14 from HafenCity University in Hamburg. After the impulse lectures, 5 workgroups were formed with intention to derive new innovative designs and to encourage international cooperation.

Students from Engineering Department	Sina Petersen Dennis Lüke Tobias Wölke Christoph Thiede Janna Widmaier Marcel Marbes
Students from Architecture Department	Björge Köhler

Students from REAP	Wulan Diah Puspitowati
Research Associates	Matthias Förch, Dipl.-Ing. Roman Baudisch, Dipl.-Ing Matthias Friedrich, M.Sc. Matija Posavec, M.Sc.
Lecturers	Prof. Dr.-Ing. Frank Wellershoff Prof. Dr.-Ing. habil. Wolfgang Willkomm

Phase 3

As a mandatory task for students enrolled in the module, a final preparation of the workshop results is presented in a form of a design sketchbook. The conceptual design prepared in Campinas is subsequently analysed and evaluated at HCU Hamburg. The efficiency of technical methods and systems applied is pre-dimensioned and discussed.



The School's Workshop and students from HCU

The booklet consists out of 5 design sketchbooks with various design options. The sketchbooks are presented subsequently.

Design concept for retrofit of the ministerial building in Brasilia

Group 1
Wulan Diah Puspitowati, Lars Plath

HafenCity University Hamburg 2017

Office for Facades and Building Envelopes
Prof. Dr.-Ing. Frank Wellershoff

Abstract

The main objective is to improve the building's thermal and energetic performance with the emphasis on improving the user comfort. The main idea is to break free and not limiting the design to the heritage protection issues and former design proposal for the same project. The façade design is bold, yet still preserving the style of the architect by using clean vertical and horizontal lines and the outline shape of the building. The main guideline was the recommendations pointed out in the lectures and simulations from Climate Consultant.

The distinctive feature would be the social spaces and mixed use functions in order to change the perception of the formality of the building function, while addressing also the isolation and strict zoning issues. The design of social spaces also shape the façade design by incorporating loggia with vegetation inside the building as well as greening the surrounding environment. Taking macro scale and addressing the influence of microclimate is also one of the main concern and is included in the proposed design.

The design emphasis is on implementing passive measures to a large extent before moving on to a high-solution that depended on building automation. However, the combination of both active and passive measures is still necessary due to the climatic condition.

The objective is to change the paradigm of modernism to have a mixed use, more social and fluid spaces and a work-and-life balance philosophy; whereas at the time the city was planned, modern means rational and distinct separation of functions, such as how Le Corbusier's "Charter of Athens" described of an ideal city. Brasilia is a landmark in the history of town planning, however there are also some shortcomings that needs to be addressed. The challenge will be not only to change the paradigm on urban planning and energy efficiency on historical buildings, but also to revise the implementation of preservation guidelines that needs to be followed.

Based on the analysis on climate, location, building and the site of the building case study, a retrofit plan is developed to improve the existing situation in this building. The analysis of the proposed interventions will show the possibility of improving the user comfort as well as the building's energetic performance by using passive measures and straightforward interventions.

The final outcome will improve the overall working climate inside the building, as well as a more sustainable and energy efficient building. By putting emphasis on the user comfort, acceptance and satisfaction the expected result would be a happier, healthier and a more productive occupants that consequently will be more effective in raising awareness and driving positive transformation in Brasilia.

Keywords: *façade retrofit, historical building, user comfort, thermal and energetic performance*

1. Status Quo

1.1 Location Analysis

In 1960 Brasilia has formally became the capital of Brazil replacing Rio de Janeiro in order to make the capital closer and more accessible to other regions. Located in the central part of the country, Brasilia was created from nothing; it was a planned city, following the Modernist Movement ideals of clean lines, rational planning and clear separation of functions. The Pilot Plan (*Plano Piloto*) of Brasilia was a winning entry designed by Lúcio Costa, the principal urban planner that gained the privilege of designing the city. Together with architect Oscar Niemeyer who designed many of the city's famous structures, Brasilia has become a landmark in the history of urban planning and has been awarded World Heritage Site by UNESCO in 1987.

However, aside from its prominent design the city has its shortcomings. It lacks the complexity of a normal city as the functions are segregated and there is also insufficient mass transportation system and a lack of human scale, which makes it difficult for pedestrian to move around. Furthermore, most of the inhabitants are the upper middle classes, which accounts for less than 10 percent of the population, so this resulted in massive amount of urban sprawling. Brasilia today is in need of revision, as it is not working out as a city and as the critics pointed out, "*The city has been both acclaimed and criticized for its use of modernist architecture on a grand scale and for its somewhat utopian city plan*." [1]

The design of the city resembles an airplane or a bird in flight (Figure 1).The monumental axis which runs from east to west is lined by public buildings and it is intersecting in the middle with the arched north-south residential axis. The division is intentional for the speedy completion of the project.

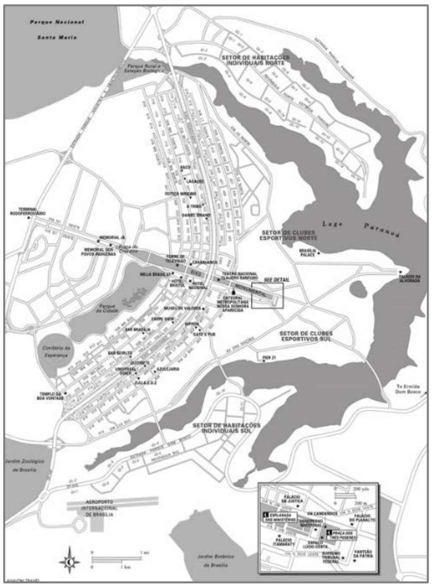


Figure 1: Pilot Plan of Brasilia [2]

The building used as a case study for the retrofit project is the Ministry of the Environment (MMA) and the Ministry of Culture (MinC), which is located in the ministries esplanade (*Esplanada dos Ministerios*), in the monumental axis, which is shown in Figure 2 and Figure 3.

Figure 2: Esplanada dos Ministerios [3]

Figure 3: MMA/MinC Building [5]

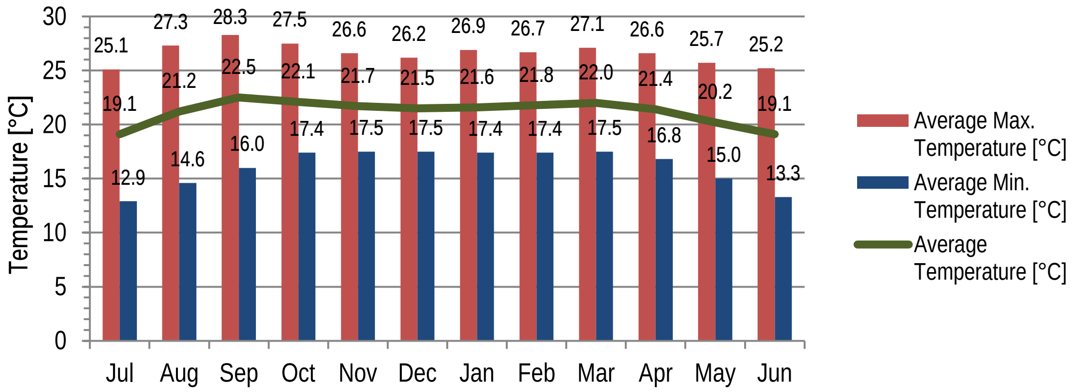
1.2 Climate Analysis

Brasilia is located on the Highlands in the heart of Brazil next to the Paranoá Lake. It is subject to special climatic conditions, which falls under the category Aw in Köppen Geiger climate classification system. In general Brasilia's climate is tropical wet and dry or savanna with an extended dry season during winter.

The primary cause for high precipitation in this region is ground-level low pressured areas next to the equator in the summer period. It resulted in possible thunderstorm with a lot of rain. Opposite to that these troughs move north in the winter period while simultaneously subtropical high-pressured areas reach Brasilia and dry the climate. Additionally the troughs strengthen the east winds. Following below is the analysis for relevant weather data, based on the International Weather for Energy Calculations for Brasilia [4].

1.2.1 Temperature

Figure 4 shows the average monthly temperature with minimum and maximum value throughout the year. It can be observed that the level of temperature varied only slightly between summer (October - March) and winter (April - September). The average annual temperature is about 21.2°C with almost steady values in the summer period. Only for a few days during winter that the temperature decreases below 10°C, while during summer there are more days that the temperature reaches above 30 °C. However the annual average temperature below 25°C is expected for tropical regions, considering also that Brasilia is at 1172 m above sea level.



1.2.2 Humidity

The average

Figure 4: Temperature Profile Throughout the Year

monthly relative humidity is displayed inTable 1. The level of humidity varies strongly between summer and winter with the difference range of about 30 %.

Table 1: Monthly Average Relative Humidity throughout the Year

Relative Humidity [%]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Yearly
	56	49	53	66	75	79	76	77	76	75	68	61	67,6

Summer period
Winter period

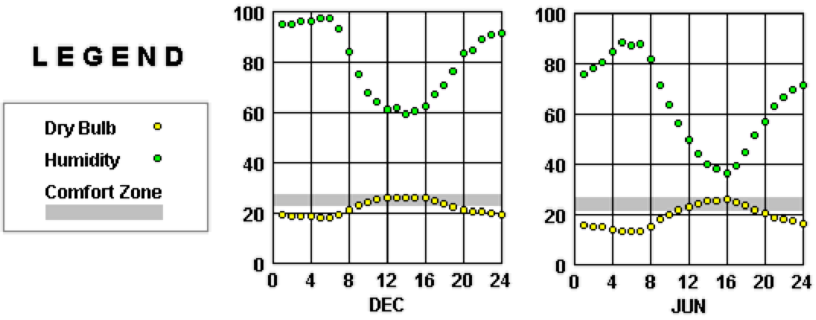


Figure 5: Average Monthly Dry Bulb and Relative Humidity throughout the Day in Summer and Winter

The difference of relative humidity between the summer and winter periods throughout the day can be seen in Figure 5. While the relative humidity could reach nearly 100% during the summer night, it decreases under the influence of the temperature during the day to 60%. The same variation can be observed in winter but with a relative humidity under 90% during the night and a decrease of nearly 50% to less than 40%. This indicates the influence of the Paranoá Lake on one hand and the tropical climate on the other hand.

1.2.3 Wind

The wind wheel throughout the year for Brasilia is shown in Figure 6. As mentioned above the location strengthened the east winds. 10% of the annual wind occurrences are coming directly from the east. In addition to that more than overall 30% are coming from east-southeast and east-northeast. In relation to that it can be observed that the eastern range has lower relative humidity than the western range because of the wind occurrences.

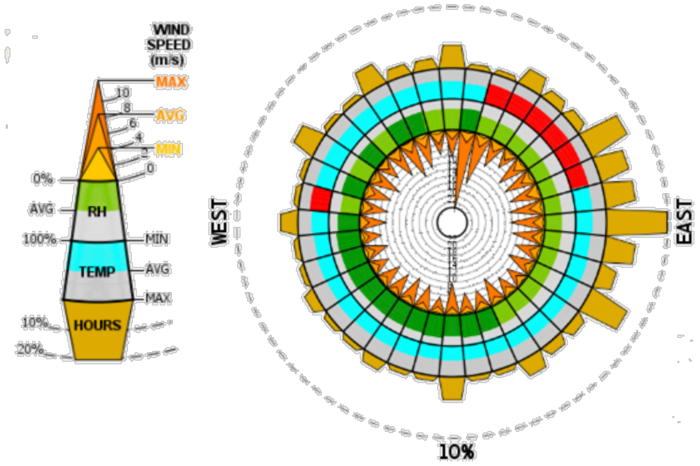


Figure 6: Wind Wheel throughout the Year

1.2.4 Precipitation

Figure 7 displays the annual precipitation in Brasilia separated into months and starting in July during the winter period. This dry season starts in May and lasts until September with very less precipitation under 60 mm (l/m²) and a low point at only 8 mm in June. In opposite to that the precipitation increases rapidly to over 200 mm during the summer period with a peak at 246 mm in December. The months from October to April are considered to be the wet season.

Together with the other weather data from the analysis above confirms the Köppen Geiger's classification for Brasilia as “equatorial savannah with dry winter” with distinct dry and wet seasons, nearly consistent temperature and high relative humidity.

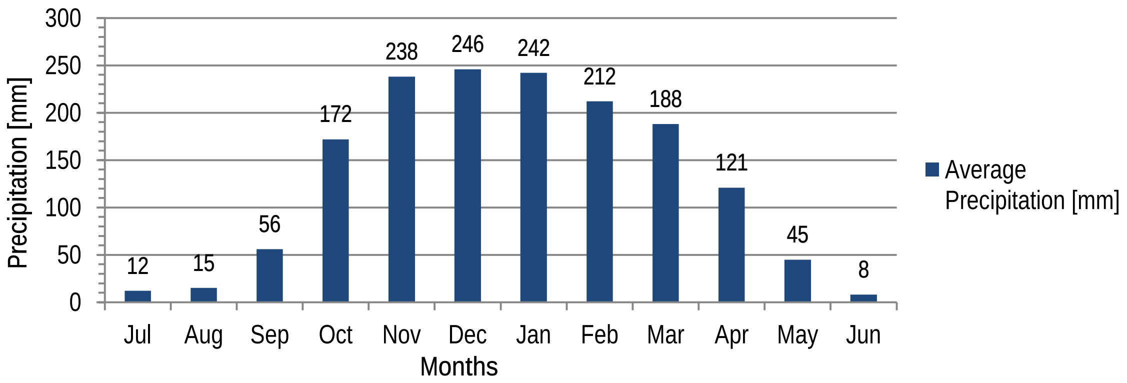


Figure 7: Precipitation throughout the Year

1.2.5 Solar Radiation

The solar radiation in Brasilia varies throughout the year between summer and winter period as shown in Figure 8. During the summer months the sun angle reaches nearly 90° as the sun is more or less rectangular orientated at noon.

Furthermore the sun path around the summer solstice is located next to the east-west axis with an impact towards the south. Different to that the sun angle decreases to only 50° at noon at the winter solstice. The direction is then orientated to the north with an nearly parallel sun path to the east-west axis.

The sunshine duration does not change strongly between summer and winter which can be seen in the sun chart as well as in Table 2. Based on the mean monthly sunshine hours per year the average per month is near 200 h. This means that the average annual sunshine hours per day is around 6.5 h, which is quite high.

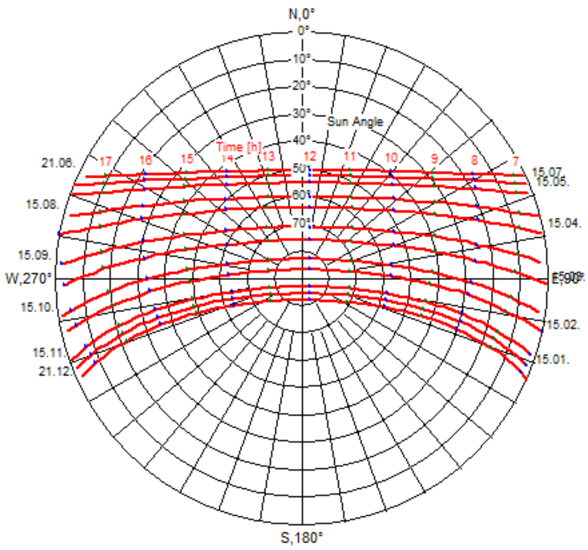


Figure 8: Sun Chart Brasilia, Brazil [6]

Table 2: Mean Monthly Sunshine Hours throughout the Year

Mean Monthly Sunshine Hours [h]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Year
	266.5	262.9	203.2	168.2	142.5	138.1	154.4	157.5	180.9	201.1	234.3	253.4	2,363

Summer period
Winter period

1.3 Building Analysis

All the ministry buildings in the esplanade have the same structural form and design. The floor plan is a simple rectangular with a long corridor in the middle and two external staircases on one side. The concrete skeleton construction enables the building for wide-span openings and fully-glazed facades using single-layer glazing with external metal film on both the east and west side.

Operable vertical metal lamellas are applied only on the external west façade (Figure 9) as well as internal blinds on both facades (Figure 11). The external wall is a ceramic brick construction plastered with mortar on both sides and covered with external beige ceramic tiles. In the interior, thermal acoustic ceiling with mineral fiber lining is used. The roof of the building is currently using concrete slab with white metallic roof. While it is effective to protect the upper floor from heat gain, the entire roof space is not being utilized apart from putting HVAC components and water tank.

The fully glazed façade in the east-west direction is causing user discomfort, as it generates high thermal gain, intense brightness and strong glare. This creates the behavioral response from the occupants to always close the internal blinds and turning on the HVAC system the entire day. Since the blinds are closed, the lights are always on during the day as well (Figure 12).

The office rooms are using opaque partition material; thereby daylight could not pass through the corridors. The occupants and the active lighting system along with the office electronic equipment is adding up the internal heat load, putting stress to the HVAC system and increase the energy consumption as well. The lack of adequate social spaces and the feeling of enclosed space create a dull formal space that is uninspiring and does not foster a good working environment (Figure 10).

Figure 9: West Facade with HVAC and Shading System [7]

Figure 10: Corridor with Interior HVAC at the Basement [7]

Figure 11: Outlook from Office in the West Façade [8]

Figure 12: Open Plan Office [9]

2. Main Design Criteria

2.1 Idea of Refurbishment

Based on the location, climate and building analysis, there are some possible interventions that can be applied to increase comfort as well as energetic performance. Figure 13 shows the analysis of the site and the concept for building retrofit, as well as site improvement. The building is oriented along the southeast and northwest axis, which exposed the east and west glazing façade to high sun radiation and glare. Therefore, shading device is necessary to reduce external heat gain and still allowing the occupant for unobstructed view of the outside environment. However, since the predominant wind direction is coming from the east, this orientation allows for the building to be naturally ventilated during winter months.

The rooftop can be utilized for harvesting rainwater, as well as generating renewable energy using PV panels. Some functions can be added to the rooftop and green roof can be implemented to make the rooftop accessible for the occupants. Sealed surfaces such as the rooftop and the massive amount of parking space in the south part of the building will cause Urban Heat Island effect and adding more heat stress to the environment. Implementing green roof and adding vegetation to the parking area will greatly improve the microclimate and cool down the surrounding area from the evapotranspiration effect.

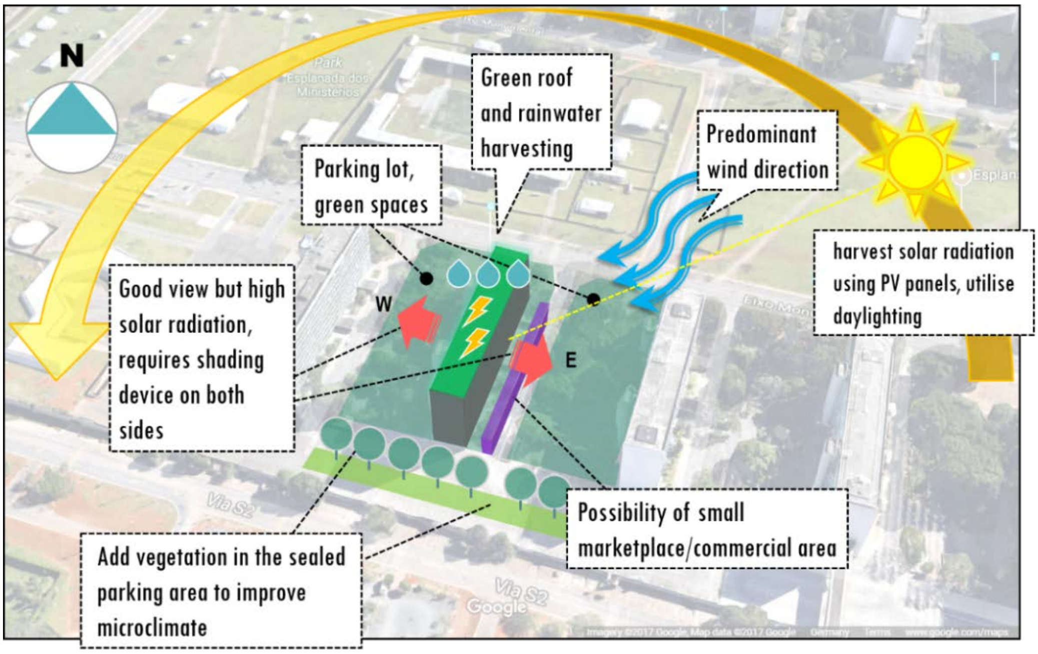


Figure 13: Site Analysis for the MMA/MinC Building

Lack of social spaces and the strict segregation and zoning of the four functions of living, working, recreation and circulation has left the buildings in the monumental axis without having a close proximity to simple commercial functions such as barbershop, cafe or convenient stores. These functions can also be implemented in the ground floor area, detached from the building to provide the occupants much-needed social spaces for work-life balance

2.2 Summary of Input

Lectures from experts during BRASS workshop in CAMPINAS (5-9 June, 2017) have given valuable input to consider in the design approach and retrofitting aspects. Not only did the participants gain some insight from the technical point of view, but also non-technical aspects such as the cultural heritage issue and the preservation policy. Under the United Nations Development Program (UNDP), a retrofit project has been done for the MMA and MinC building. The project obtained level A in the PROCEL Label, a Brazilian building certification system. However, for the purpose of the workshop the design teams have been advised to consider neither the cultural heritage issue nor financial cost-benefit of the proposed solutions. Furthermore the solutions applied in the actual project should not dictate or limit the design. Nevertheless, the information can be used to gain a better knowledge of the building.

Summary of the input that resonates to the following ideas and has influence on the design concept are:

1. *Fernandes, Luciana Oliveira*
    a. *Reports about the already-performed retrofitting design process on the Ministry building*
    b. *Improvements were applied to the HVAC, lighting and water systems of the building, the solutions were: New contract for energy provider, use shading devices and dimmers for lighting, setpoint of HVAC increased from 21 °C to 24 °C*
    c. *To improve the energy efficiency it is necessary to use articifical and natural lighting, also change the equipment to a more efficient ones*

2. *Kowaltowski, Doris*
    a. *A design and also a retrofit process always consist of input and output for improvements of the design, with exchange between all steps and connections between every part*
    b. *Retrofitting reviews architectural and engineering solutions, reduces consumption, reutilises, recycles, reuses*

3. *Neves, Leticia*
    a. *"Combining natural ventilation with mechanical ventilation and/or cooling in the most effective manner" = hybrid/mixed-mode ventilation*
    b. *"The size of windows on sun-exposed facades has by far the largest influence on room cooling needs; high-level small window: for cross-ventilation, night ventilation and background ventilation (automated)"*
    c. *"Shading devices: reduce the radiant temperature and solar gains"*
    d. *Using the building fabric as a thermal storage, with night cooling to take advantage of cooler night temperatures to enhance both radiant and convective cooling effect*

4. *Amorim, Claudia Naves David*
    a. *Improvement of the lighting situation increase user satisfaction*
    b. *Daylight, electric light and shading system must be considered together*
    c. *Direct sun and glare must be minimized or avoided, electrical lighting must be taken into account but with dimmers and sperarated areas*
    d. *Sun shading should be higher rated than mechanical cooling because the solar gain is reduced*

2.3 Design Criteria

Based on the input from the lectures as well as own analysis, criteria and key points that are crucial for the retrofit design are listed below:

Table 3 Design Criteria and Parameters

Criteria	Key points	Parameters
Energy	Shading and	The use of shading device should reduce external heat gain and in consequence reducing the building energy demand
	Daylighting	Natural daylight should be utilized without causing strong glare and discomfort; adequate daylighting should be able to reduce the use of artificial lighting to some extent
	Renewables	The use of on-site renewable energy should cover some of the building energy consumption
	Ventilation and Night cooling	Ventilation during night time should allow for night cooling so that during the day cooler, wet air is saved in the building by thermal mass
User Comfort	Visual comfort	Visual comfort is achieved when there is unobstructed view to the greater portion of the outside environment and also enough lighting to perform indoor activities
	Thermal comfort	Passive measures should be implemented to a great extent to achieve thermal comfort, therefore reducing the energy demand for active measures
	Transparency	Occupants should be able to orientate themselves and perceive their surroundings although in the enclosed spaces
Social space	Social area	Social area should be provided in the building to facilitate interaction and collaboration to foster brainstorming and innovative ideas
	Commercial area	Commercial area should allow a mixed use of functions within close proximity of the main office area
	Recreation/relaxation area	Recreation/relaxation area should be available in the form of lounges or green spaces inside the building
Vegetation and Water	Vegetation	Vegetation can be implemented inside the building as green roof/façade to add indoor comfort and on the site to improve microclimate and reduce urban heat island effect
	Rainwater harvesting	Rainwater is collected and used extensively to reduce the usage of potable water for non-drinking purposes

3. Conceptual Design

3.1 Design Concept

Figure 14: Building Facade Retrofit Design

The retrofit design is planned to work on small, medium and large scale. Small scale is done in the interior spaces such as changing the partition, lighting fixtures and lamps, while medium scale is on the whole building scale such as façade and shading design. Large scale is on the surrounding site of the building, in relation to other buildings as well in the ministries esplanade. The overall purpose is to improve the building energetic performance and to create a better working environment to improve user comfort. The design concept will cover four main criteria, which are energy, user comfort, social space and vegetation and water. The visualization of the design concept can be seen in Figure 14.

It needs to be noted that before implementing façade and retrofit design, the design prerequisites should be met. There should be a refurbishment of the outdated building elements to ensure the performance of the building is working as planned. The building should be airtight and the electrical wiring and plumbing should be checked and repaired if necessary. Once the passive design is implemented, active measures for indoor comfort such HVAC and lighting system should be retrofitted to a more efficient one as well.

3.2 Energy

The objective for energy retrofit is to reduce energy demand by passive and active measures to improve the building's performance. The main energy demand comes from the cooling load and lighting, therefore the retrofit concept will focus on these areas to improve the current situation. Renewable energy is also explored and implemented to a large extent to make the building more sustainable.

3.2.1 Shading & Daylighting

The current situation is that the façade on the east and west is fully glazed, causing the area in the vicinity of the window to have high thermal gain and strong glare. In this case, the area next to the window needs to be protected from direct sunlight. Currently the space between the column and the façade is not being utilized, as can be seen in Figure 15. Therefore the glass façade can be moved in by 0.9 meter next to the column to provide shade and reduce glare near the window area. The same windows can still be reused in this sense and will only need to be improved for airtightness by replacing the sealant.

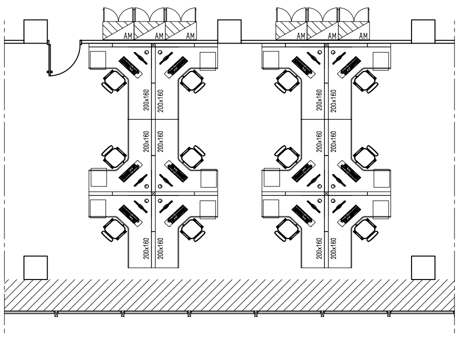


Figure 15: Extract of a Typical Room in a Floor Plan

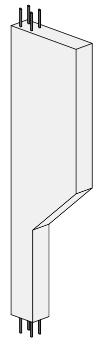


Figure 16: Design of Concrete Fins

Shading system is also implemented in the form of vertical concrete fins to further protect the building from low and angled sun (Figure 16). This will provide shading, while at the same time still giving the occupants enough unobstructed view to the outside environment. The fins are placed at an optimal angle based on the sun orientation analysis throughout the year, which will be further shown in the detail section. The design of the shading system can be seen in Figure 17.

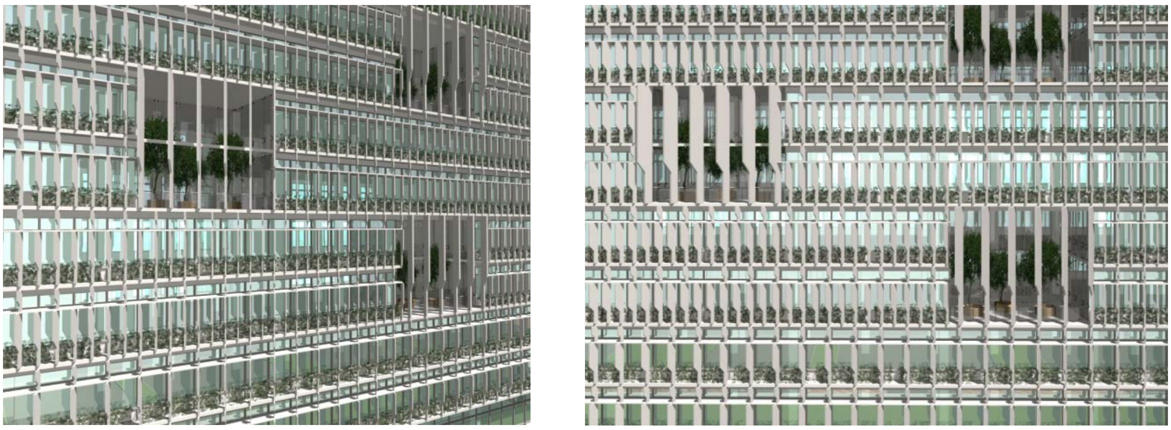


Figure 17: Design of the Shading System

Adding these fins for protection against heat and glare will consequently reduce the amount of daylight; therefore to balance it, the fins are divided in two parts. The upper part of the window will be covered in smaller fins at a distance of 1.7 meters, since the upper part is already shaded by the floor slab and also to allow daylight to come in. The bottom part is covered with bigger fins at closer distances to provide shading and glare protection to the working area.

To mount both fins it is necessary to add a horizontal slab, which will act as horizontal shading as well as can be further utilized as a light shelf to allow light to penetrate through the building. The ceiling should be removed to reveal the floor slab in order to reflect light deeper in the building and provide general illumination. The negative impact should also be considered as the element could heat up and transfer heat inside the building.

Taking daylighting into consideration, lighting retrofit is also necessary. The first step would be to change the lamps and fixtures into a more energy efficient ones. The next step would be to include daylighting sensors and divide the area into lighting zones. On the area where daylight is present the lighting should be able to be turned off or dimmed using daylight sensors and dimmers. Occupant sensors can also be implemented. Working light adjacent to the desks is more appropriate since it will directly illuminate the working area necessary to perform tasks and can reduce the need for general illumination. Additionally to increase the illumination of the whole floor and especially the corridors, partitions are recommended to be painted white and using transparent or glass walls towards the corridor to improve indoor quality and visual comfort.

3.2.2 Renewables

The possibility of using renewable energy is also explored and in this case there is a potential to use solar panels and to mount it on the rooftop Figure 18. The rooftop area is currently not being utilized effectively apart from using the space to put HVAC equipment and water tanks. The use of photovoltaic panels will help cover some of the energy demand. In general, the use of renewable energy will help reducing the building's carbon emission and lowering environmental impact.

Figure 18: PV Panels on the Rooftop

3.2.3 Ventilation and Night Cooling

In the current situation mostly mechanical ventilation is used in the building. The HVAC system is constantly set to 21°C. Consequently this is not energy-efficient since occupants can get used to higher temperature and the outdoor temperature is frequently comfortable. The concrete slab has a potential to have positive impact for cooling the building because of its thermal storage capacity, however in the current situation it is covered with acoustic ceiling.

To improve the situation the ceiling should be removed to reveal the concrete slab and therefore activating its thermal storage capacity. During the night, using natural ventilation the slab will be cooled down and store the cold humid air inside the building and will help to acclimatize the building during the day. Designing the loggia also helps with cross ventilation of night cooling and also natural ventilation during winter months.

Removing the ceiling will also have a positive impact on the lighting situation. When it is painted white, the high ceiling can be used to reflect light deeper in the building. This can also be supported with the help of light shelf to provide general illumination in the interior of the building. The horizontal element that acts as a reinforcement and shading device can also be used by extending it to the interior side and treated as a light shelf. Both the shading and night cooling diagram can be seen in Figure 19.

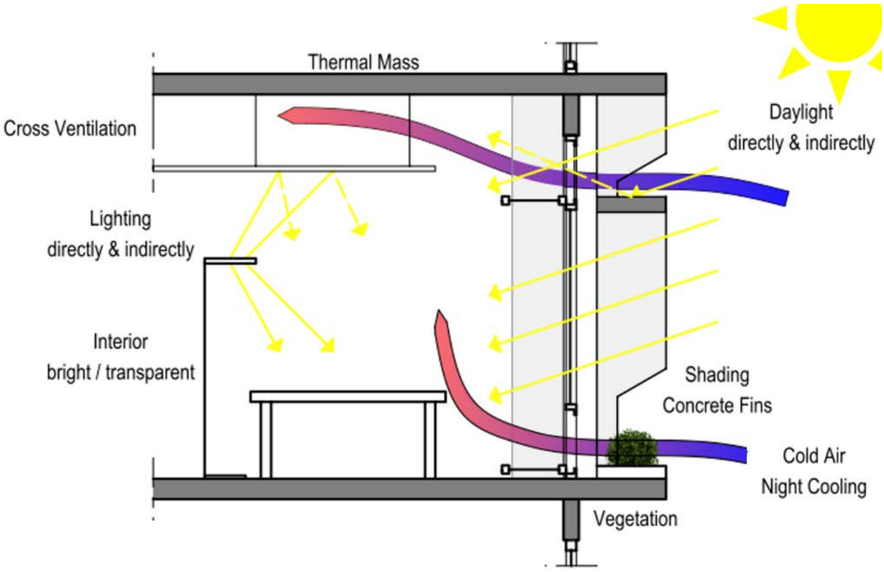


Figure 19: Schematic Diagram of Shading and Night Cooling

3.3 User Comfort

Buildings are not just an architectural showpiece, they are structures designed for people. In this case, it should be designed to support the occupants to work and perform necessary tasks for public services. The building should be able to make the occupants comfortable, safe and healthy. User comfort is one of the main objectives of this retrofit. Main key points that should be achieved are visual comfort, thermal comfort and transparency.

Visual comfort is achieved when there is unobstructed view to the outside environment and at the same time also having enough illuminance to perform indoor tasks and activity. The windows in the current situation are already big enough, however there is a problem with strong glare and heat gain. As explained above, the retrofit design has taken this into consideration by implementing shading device and moving the façade inwards to allow visual comfort without having strong glare and heat gain. The shading device shown in Figure 20 shows that the occupant can still have a relatively unobstructed view to the outside.

Thermal comfort is also achieved with shading intervention. Moreover, by removing the ceiling to reveal the floor slab and use it as a thermal mass for night cooling, the building can acclimatize better during the day. This will also have positive impact on the daylighting quality, to reflect more light deeper in the building. Reducing external heat gain will consequently reducing the cooling load and also energy consumption associated with it. By using less HVAC system will also have a positive health impact and avoid having sick building syndrome for the occupants.

Transparency is important for user comfort because occupants should be able to orientate themselves and relate with the outside environment. Changing some wall element with transparent material will also avoid the feeling of claustrophobic in the enclosed space of the building interior. This will also allow a better distribution of daylight. Figure 21 shows that with using transparent walls, the user have visual access to not only the corridor and the room across from it, but also the outside environment throughout the other office as well. The grill on top of the glass partition will support cross ventilation across the building.

Figure 20: View to the Outside Environment

Figure 21: View Across the Corridor

3.4 Social Space

3.4.1 Social Area

Social space is an important aspect to increase user comfort and productivity. In this case, the proposed façade design is incorporating loggia at certain places in every two floors (Figure 22).The loggia opens up to the next floor above and helps with the cross ventilation for night cooling and natural ventilation during winter months. These loggias also serve as social spaces, to foster interaction while also improving comfort and productivity.

Figure 22: Design of Loggias

3.4.2 Commercial Area

One of the social aspects that is lacking in the current situation is the availability of supporting facilities in the form of mixed-use function. Strict zoning in the urban planning of the city has left the public buildings in the monumental axis without a close proximity to simple supporting facility. The proposed marketplace (Figure 23) is designed to improve the situation by adding a one-story building in the main entrance area on the south side of the building for a mixed-use commercial area. This can be in the form of coffee shop, barbershop, convenience store, etc. By making these functions available, the occupants will save a long drive to be able to cut his hair or buy simple daily needs.

Figure 23: Design of Marketplace

3.4.3 Recreation Area

Areas that are used to implement the loggia design can be relocated to the rooftop, where green roof can be implemented to create a positive ambience as well as improving the microclimate by reducing heat island effect (Figure 24).

Figure 24: Green Roof and Rooftop Ambience

The roof from the new structure can be used to implement PV panel and to collect rainwater as well (Figure 25). The new structure is designed in the U-shape. The rooftop of the longer part is used to integrate solar panel. The rooftop of the shorter part on one side is used as a restaurant/viewing deck and the rooftop on the other part is used to put HVAC equipment.

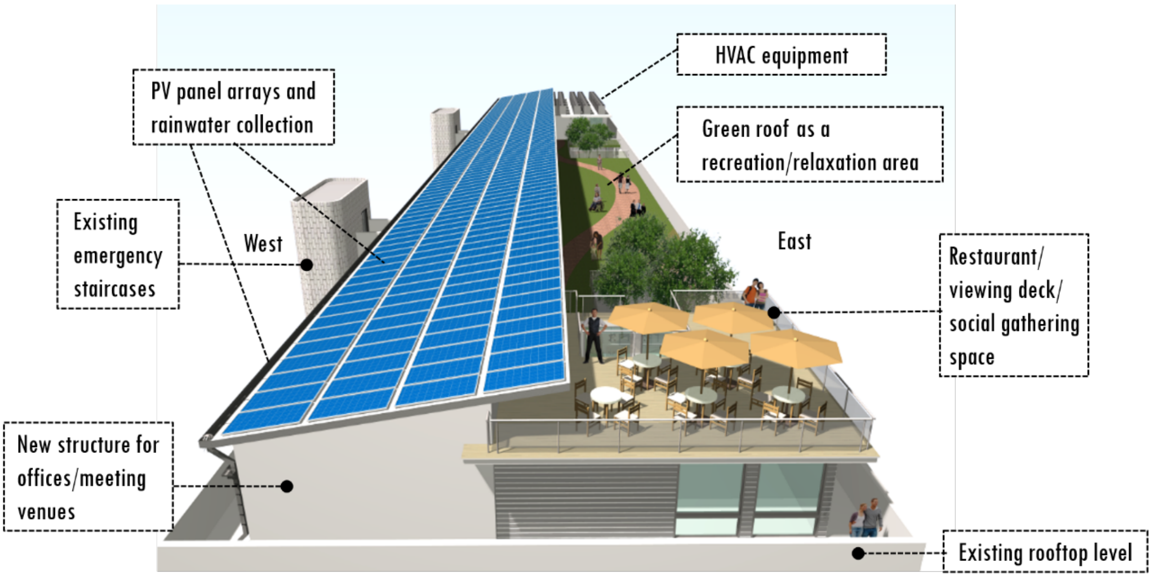


Figure 25: New Structure Design on the Rooftop

3.5 Vegetation and Water

Vegetation will always have a positive impact on people and environment. Having vegetation inside the building will soften the formal feeling of the place and have a pleasant mental and health impact for the occupants. Green roof will add protection to the immediate floor from heat gain and also reduce urban heat island effect. Green roof can be implemented on the rooftop of the marketplace and also in the rooftop of the main building as well. Vegetation can be included in the loggia to create a positive ambience.

Adding vegetation on the surrounding site of the building, especially on the south side where the parking lot is all covered with sealed surfaces will have a positive impact on the microclimate. By improving the microclimate of the surrounding site will consequently have a positive impact on the building and its occupants. Not only will it clean the air and serve as a noise buffer, it will also helps in cooling down the surface by adding shade and by the effect of evapotranspiration.

Water is another important aspect in the design. During the winter it is relatively dry and therefore there is an urgent need to collect and store water. Rainwater harvesting can be used to replace potable water for non drinking purposes. In this case, it can be used to irrigate the vegetation in the building. Water is collected on the rooftop and then stored in the water tank on the west side of the building.

3.6 Schematic Design Presentation

Figure 26 below concludes all the design intervention in the building in a schematic representation. Shading is implemented the east and west façade with vertical fins. Loggias are implemented in two locations every two floor, with the exception of ground floor, first and second floor.

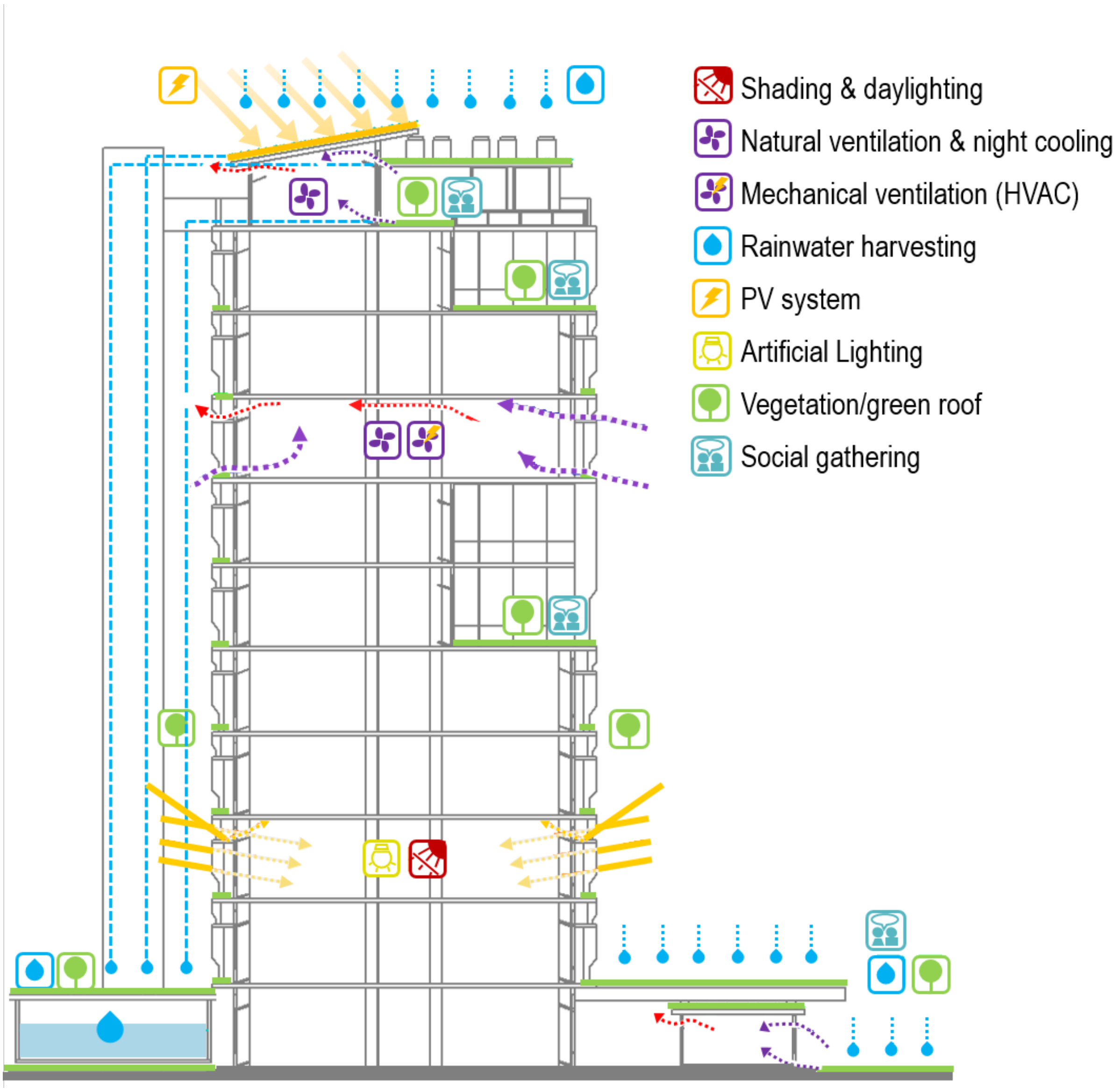


Figure 26: Schematic Presentation of the Conceptual Design

4. Details

4.1 Intervention Analysis

Interventions will be applied to the structure, façade and interiors as well as the lighting and cooling system. The proposed outcome should be less overheating through the fully glazed façade, thereby less use of HVAC to cool the offices and increased use of natural ventilation, more use of daylight throughout the working hours and thereby less use of artificial light. All these aspects are connected together and will also improve the energy-efficiency of the building.

Furthermore these topics cover the current state of art and practice. It is common to use the sun's heat to warm rooms and to use the wind as well as thermal mass to cool a building. That's why not only HVAC should be considered for thermal comfort but also surface temperature and moving air. Current lighting systems mostly consist of daylighting and additionally used artificial light with dimmers and motion sensors. The lighting system is in addition to that supported by bright colors of the opaque interior and transparent elements. Design strategies for air quality cover not only active systems like HVAC but also natural ventilation such as operable windows to not overrule the occupants.

4.1.1 Analysis of Sun Chart

By analyzing the sun chart it is possible to determine the angle, distance and shape of the shading system or rather the concrete fins. In general it is obvious that both façades need a shading system as it can be seen as at the building analysis as well as in the following table (Table 3). It shows that most of the time in summer and winter shade is necessary or would be beneficial. Only on few days solar radiation could be used for heating the building through the glazing. This conditions occurs on colder mornings but should not be considered as an important aspect due to the fact that the annual average outdoor temperature is above 21 °C.

Table 4: Sun Exposed Hours of the Building Calculated with Climate Consultant

	Warm / Hot > 27 °C (shade needed)	Comfort > 20 °C (shade helps)	Cool / Cold < 20 °C (sun needed)
Summer / Fall Hours exposed [h]	722	1441	359
Winter / Spring Hours exposed [h]	724	1358	444

For the final design further calculations for the angle, distance and shape of the concrete fins should be made with special software. For the basic design the sun chart is analyzed to define the range of the necessary angle and distance of the fins. The result is shown in Figure 27 for both façades with regards of the position of the sun for summer and winter solstice in the morning and the evening. The yellow area represents the positions lying in between these dates. With a range of 30° – 40° for the angle of the fins and a distance half of the width of the windows the shading system is preliminary designed.

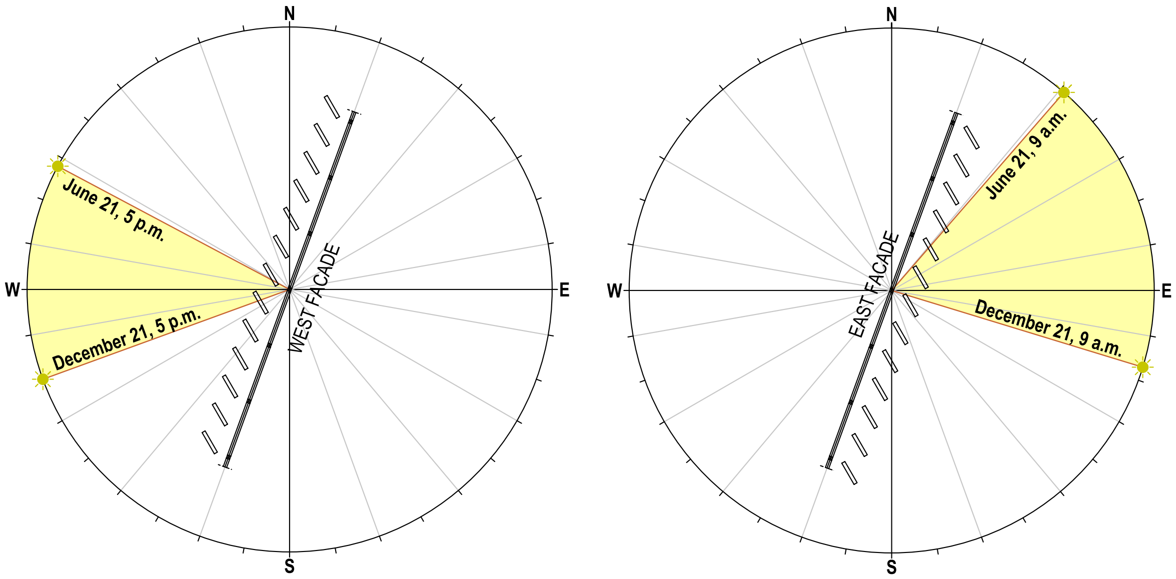


Figure 27: Angle and Distance of Fins on the Sun Charts for the East and West Facade

4.1.2 Analysis of Daylight Coefficient with PrimeroLicht

The daylight coefficient or factor is the ratio of the light level inside a room to the light level of the surrounding. In Figure 28 the change of the daylight coefficient is displayed by comparing the current situation (bottom) with the proposed design (top). The red line (daylight factor of 3%) indicates that the space is daylight-oriented if the values are above that. In general values between 3% and 5% indicate that the room is adequately lit but artificial lighting may be needed part of the time. Values under 2% are not acceptable and values above 5% indicate that the room is well lit but glare and solar gain may cause problems.

For the current situation it shows that it is much too bright at around the half of the room. This can also be observed in the building analysis since almost the whole day blinds and shading lamellas are closed. Different to that the proposed design shows that less area is too bright and nearly two-thirds of the room is adequately lit. In this calculation it was also taken into account that brighter interior will be attached.

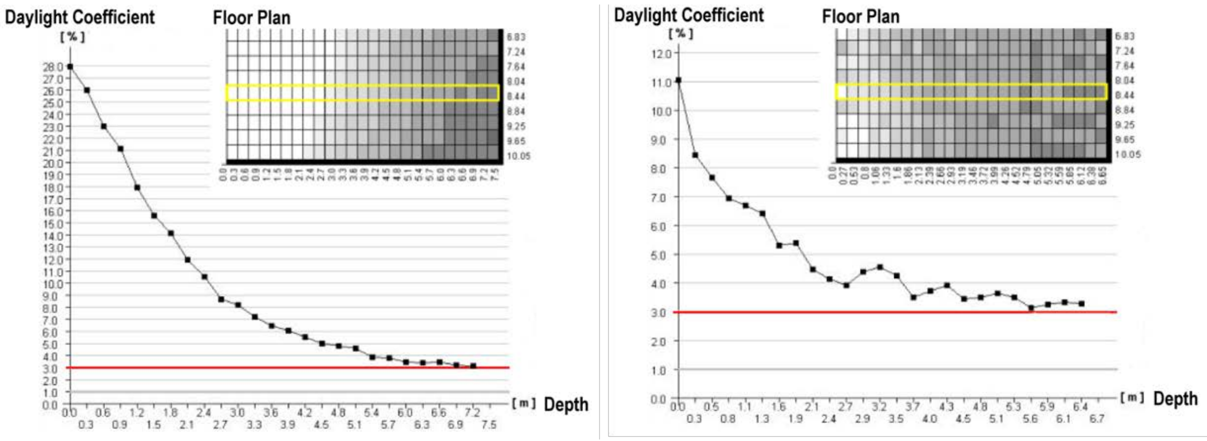


Figure 28: Analysis of Daylight Coefficient for Current Situation (left) and Proposed Design (right)

4.1.3 Cross Ventilation & Night Cooling

Especially at night the temperature is going down with a great difference to the day. This can be seen in Figure 29, which displays the monthly average temperature differences between day and night as well as daily values. The annual average difference is about 11.6 °C that indicates that only a few days have a temperature difference less than 6 °C. This value is known as limit for an effective night cooling. With these values it seems legit to expect an effective night cooling for most of the time. Because of that the windows should be open during the night to let the heated and used air out of the building. Consequently cooler air is induced and stored into the concrete slab and columns. During the day these components cool down the hotter air inside the offices.

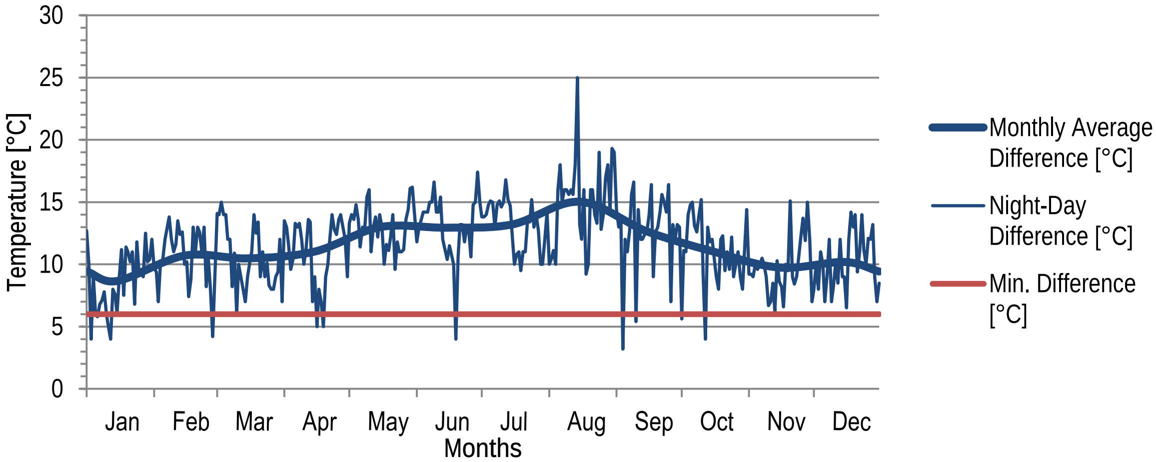


Figure 29: Day-Night Temperature Differences throughout the Year

To support the efficiency of the night cooling as well as to improve the ventilation during the day components for cross ventilation are applied to the corridor walls. Since the top window can be opened it can create an air stream between both façades. At the upper parts of the corridor walls passage openings must be applied. Then even during the day, if the outside temperature is lower than inside, the top windows should be open to improve the thermal conditions.

Nevertheless, the user could not manually operate this ventilation system in general. Electrical automation devices will be attached to the windows to ensure an efficient cooling. But as already mentioned the user will get the possibility to overrule the system. Furthermore additional mechanical ventilation must be taken into consideration because of the high occupancy inside the offices. This component might be necessary if the night cooling can't operate due to small night-day differences or for long heat periods.

4.2 User Comfort

4.2.1 Analysis of Room Comfort with PrimeroKomfort

The efficiency of every intervention mentioned above will be analyzed in a simulation with PrimeroKomfort. The software is able to evaluate user comfort as well as energy consumption at the actual location of the building. It considers shading, ventilation, lighting, construction and technical systems with the aim of high comfort and low energy requirement.

For the simulation one representative office based on the current situation is modeled. As utilization an open-plan office is presumed with dimensions of about 10.05 x 7.50 m since these are taken from the actual floor plan. It is assumed that twelve working people will occupy the room. All other relevant data like the properties of the construction, the energy demand of lighting and working equipment are taken from the information sheet of the Training School [5]. Based on this model all interventions are applied to the simulation step by step to see their impact to the room comfort.

The results can be seen in Figure 30 and Table 4. They are evaluated in accordance with the European standard for room comfort (DIN EN 15251) and with overheating hours. This standard defines four comfort classes for rooms based on the hours of satisfied occupants, which will be converted to the percentage of satisfaction. Because this is an already existing building and comfort class I is usually applied to hospitals and retirement homes comfort class II was chosen for the evaluation. Comfort class II means that the occupants are satisfied with the room comfort at least at 90% of the time. Overheating hours are calculated starting at 28°C and multiplied with rising gap to 28°C.

Table 4: Primero Simulation displaying Comfort Class and Overheating Hours

Ver.	Information	Comfort Class II DIN EN 15251		Overheating Hours [h]
		satisfied	exceeded	
basic	basic room with shading system and mechanical ventilation	1604 h / 56%	44%	3053
1	retrofitted design with moved façade and natural / mechanical ventilation	895 h / 31%	69%	7448
2	additional interior blinds	1338 h / 47%	53%	3808
3	additional horizontal element	1415 h / 49%	51%	3618
4	additional vertical fins	2339 h / 81%	19%	1102
5	additional upper vertical fins	2630 h / 92%	8%	489
6	additional sun protection glass	2613 h / 91%	9%	515

Obviously the recent situation inside the building is poor as it can be seen by only 56% of satisfaction and more than 3000 h overheating hours. By moving the façade towards the columns the satisfaction decreases and overheating hours increase although natural and mechanical ventilation are already applied. This is because no shading system was simulated and by that too thermal load is stored inside the building. By adding every proposed intervention the percentage of satisfied occupants can be increased to 92%. Simultaneously the overheating hours decrease to less than 500 h, which is the maximum in accordance with DIN 4108 for non-residential buildings. This standard is used for thermal simulations to evaluate their results.

This shows that the proposed interventions are efficient to improve the user comfort. Thermal, visual and air quality seem to be increased clearly. Furthermore it can be seen that the additional horizontal element, which divides the fins and glazing into a smaller upper part, do have a positive impact on the comfort. Nevertheless it is only a small improvement. This may indicate that this element has a negative impact due to the fact that it's been heat up by the solar radiation although it shades the room.

In addition another simulation was made to determine if the existing glazing could be reused. Version 6 was modeled like Version 5 but with additional sun protection glass instead of the existing one. Apparently adding this glass will slightly worsen the room comfort. With regards to the other evaluated results it seems reasonable to use the existing windows in the retrofit design to be more sustainable and to reduce the necessary costs.

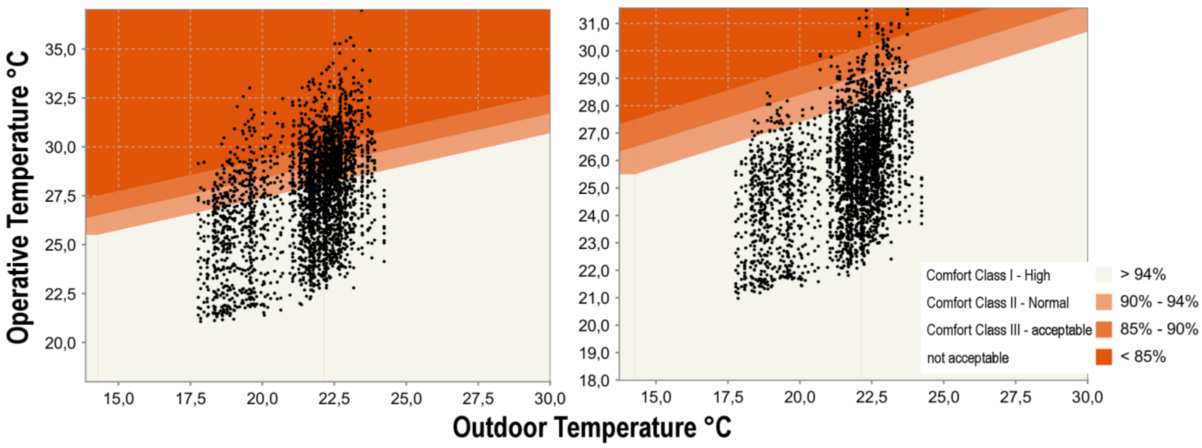


Figure 30: Results of Primero Evaluated by DIN EN 15251 for Basic Version (left) and Version 5 (right)

4.3 Vegetation & Water

In the current building vegetation wasn't part of Niemeyer's design. Although the surrounding area consists of some trees and other greenery none of this can be seen inside the building. Furthermore most of the area around the building is made of concrete or asphalt for parking lots. This should be reorganized in order to improve the depressing appearance of the surrounding and the building as well.

4.3.1 Vegetation as Part of the Thermal Concept

Nowadays it seems more and more common to use vegetation as a part of the design. But they also have an impact on the room comfort besides their pleasant appearance. By using vegetation as a façade or element in the façade and as a green roof improvement in temperature and humidity can be found. Several publications cover topics like the impact of vegetation on cooling, shading and ventilation ([10] – [12]). For example Pfoser [10] reports about the possibility to use vegetation for adiabatic cooling as well as Caetano [12] shows that plants can reduce indoor temperature and increase relative humidity.

For the design it was decided to add vegetation as a designing element in first place. Since it is not possible to prove definitely their impact on the thermal conditions besides the mentioned references it can only assume that they improve especially the needed cooling. This has to be investigated in the further design process.

4.3.2 Rainwater Collection

By adding vegetation to the building the water demand will be increased. In order to keep the water consumption at the same level as it is at the current situation a rainwater collection system will be applied. The purpose has been to set the dimensions of the rainwater storage to a size that at any time additional water from the public services is needed. In the following tables the assumptions for the calculation are displayed for the dimensioning based on the annual precipitation shown in Figure 7.

Table 6: Areas for Rainwater Collection

	Area [m²]	Return Coefficient [-]	Filter Efficiency [-]	Rainwater Yield [l/a]
Roof 10th Floor (Flat Roof)	~1,224	0,7	0,9	1,119,092
Roof Garden (Int. Green Roof)	~375	0,3	0,9	157,444
Roof Marketplace (Ext. Green Roof)	~969	0,5	0,9	678,058
			Σ =	2,034,593

Table 7: Assumption of Rainwater Consumption

	Area [m²]	Required Water [l/(a * m²)]	Water Demand [l/a]
Vegetation Loggias	~564	200	112,800
Vegetation Marketplace	~1807	200	361,425
Vegetation Windows	~880	200	176,000
		Σ =	650,225

Based on these calculations the storage volume is dimensioned with a dry season of 70 days. This value is calculated iterative in connection with the annual rainwater consumption. The volume of the tank is set to 125,000 l to reach efficiency of 100% throughout the whole year. Figure 31 displays the deficit of Precipitation during the dry season in which the water storage is necessary. From September to May the collected rainwater provides enough water to the vegetation. Only from June to August the vegetation will be provided by stored water out of the tank. By this the water demand of the building will not be increased. Furthermore this is a sustainable and efficient way to provide water.

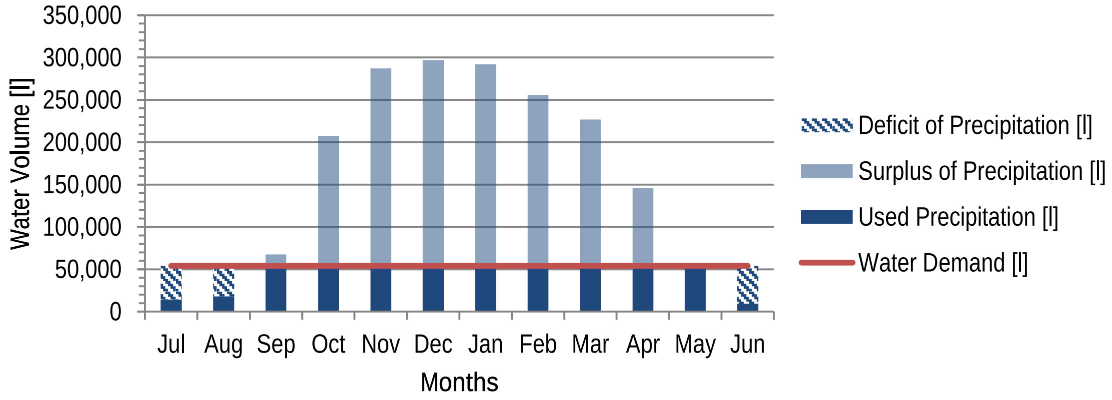


Figure 31: Dimensioning of Rainwater Collection and Precipitation Usage throughout the Year

4.3.3 Social Space

Because of the added loggias on the floors necessary spaces for offices get lost. To compensate these areas another floor with offices is added to the rooftop. Additional spaces will be in front of the building where also the marketplace is located. Alternatively the bank, that is currently located at the ground floor, could be relocated at the marketplace and their free space could be used for offices as well.

A rough calculation is shown in Table 7 to prove that the lost spaces will be added adequate to the places mentioned above.

Table 8: Comparison of Lost and Added Spaces

	Lost Space		
Loggia over two floors	6 x 2 x 70.5 m² =	846 m²	
Loggia at 9th floor	2 x 141 m² =	141 m²	
	Σ =	987 m²	
	Added Space		
Rooftop	7.5 m x 70 m =	525 m²	
Marketplace	7.5 m x 90 m =	675 m²	
	Σ =	1200 m²	✓

4.4 Energy

4.4.1 PV-System

Current state of practice shows that a PV-system is often used to increase the energy-efficiency of a building. For this project it is not possible to use a PV-system for the whole energy demand because of the dimension of the building. Due to this fact it seems useful to concentrate on one or two specific loads. By this it is possible to define a PV-system with an adequate dimension.

One component of this retrofit design is to optimize the lighting system by daylight and artificial light. Electronical devices will be applied to increase the energy-efficiency. Because of that the energy for the lighting will be provided by the PV-System. Analogous to the rainwater collection the PV-system will also provide the energy for the pumps of the rainwater system to water the plants.

The following tables display the basic data to dimension the PV-system. The daily average solar irradiance is taken from the Solar Electricity Handbook [13] for west north-west direction and 10° angle as this is the orientation and angle of the roof of the 10th floor.

Table 9: Daily Average Solar Irradiance throughout the Year for West North-West Direction and 10° Angle

Average Solar Irradiance [kWh/m²/d]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	4.68	4.72	4.62	5.09	5.28	5.49	5.60	5.74	5.35	4.73	4.48	4.42

Table 10: Monthly Solar Radiation Energy

Solar Radiation Energy [kWh/m²]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	145.0	132.2	143.1	152.7	163.6	164.6	173.5	177.8	160.5	146.6	134.4	137.1

For the calculation mono crystal silicon modules are assumed. The air can freely stream through the modules and the roof. As an area the nearly the whole roof is applied with PV-modules. With these assumptions the generation of energy shown in Figure 32 will be provided over the months. During summer period and three months in winter the PV-system generates more energy than necessary. In November, December and February additional energy is needed which could be provided by public service. Alternatively the surplus of generated energy could be saved into an energy storage system.

The displayed energy demand is based on average annual energy demands of the lighting system [5] and typical values for a pumping system. Additionally a 20% reduction of the energy demand of the lighting was taken into account since it is proposed the use a more efficient system. By this it is shown that an efficient energy supply can be applied to the building to increase sustainability as well as to reduce the purchased energy provided by public service.

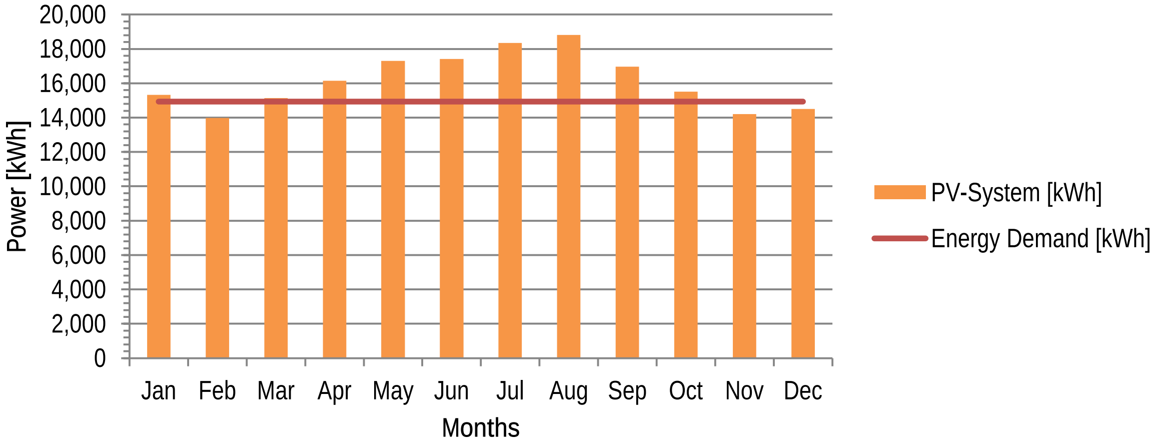


Figure 32: Monthly Net Generation of Energy by the PV-System

5. Conclusion

The investigated building is a good example to start retrofitting process for federal buildings in Brasilia. Their current performance is out of date since they are built in the 1960s and in need of thermal, energetic, environmental and economic improvements.

This case study is a unique example of a retrofit process for a heritage protected building designed by a world renowned architect. However, for the purpose of the workshop the design teams were free to design the building façade and to explore potential intervention to retrofit the building's overall performance without limiting themselves to the heritage protection issue. The already performed retrofit design helps gaining insight on the building condition without determining the design approach. The final design shows that these constraints didn't limit the designing process.

The intervention that are proposed to be applied in the design has managed to address some of the dominant issues of cooling, lighting and user comfort. The retrofit design is not only limited to the building scale, but also to the surrounding site in the urban planning context as well. There are some concerns that calls for furter research in the intervention, such as the appropriate use of light shelf, structural integrity of the building, and so on. However, the proposed retrofit is to show the magnitude of possible intervention on the building case subject.

5.1 Strong Points

- Respecting the heritage with clearly defined vertical and horizontal design elements
- Improving user comfort as shown in the calculations
- Social spaces is addressing the issue of strict zoning, isolation and the formality of the place
- Rainwater collection and PV-system satisfy the need for a sustainable design
- Added vegetation will be self-sufficient by rainwater collection and PV-system for the pumps
- Building will no longer be only a working space but also an inspiring and relaxing space due to the added rooftop, marketplace and loggias (work-life balance)
- The extensive use of passive measures such as use of thermal mass for cooling the building

5.2 Weak Points

- Moving façade in and adding concrete fins to both façades are a strong intervention that will affect the visual of the building and change the image of the former design
- Changing the ventilation and sun shading system will require more user engagement
- User must be convinced touse the daylight and HVAC can be turned off most of the times because of the shading fins, night cooling, thermal mass; educating the occupant and raising awareness is necessary
- Fins are not moveable or adaptive therefore at times direct sunlight might get into the building and heat it up; the permanent solutions was made because of reported problems with dust so motors would eventually break down
- Loggias are not part of the actual ventilation system although the used for chimney effect could be explored
- Light shelf might have a problem with heat transfer inside the building

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Design concept for retrofit of the ministerial building in Brasilia

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Abstract

In the analysis, the group identified two main problems in the existing building. The internal comfort is low, the energy efficiency is poor. At the same time one main design criteria was to keep the legacy of Oscar Niemeyer. Therefore at lot of small actions add up to a wholsome design, instead doing a big gesture, which would change the apperance of the building entirely.

One important aspect of the proposed design is the new ventilation system, which ensures a kind of cross ventilation through solar chimneys and hight differences. Another aspect is a new façade. The proposed elemental façade combines different features in different partitions (natural ventilation, protection from solar radiation, natural illumination) and also has shadings on the outside, which are adjusted to the sun angle. A new roofgarden is also part of the concept. Since this shows to have to little outcome, it was decided during the analysis to not follow up on this feature.

The analysis clearly showed, that some changes are of bigger importance then others, since they have a bigger effect on the comfort and the energy consumption as others. Therefore, following the analysis, it was tried to prioritize some aspects over others. For instance: reduction of radiation and natural illumination interfere with each other. Since the reduction of heat, and the new possibility (supported by the activation of thermal mass) to run the building without HVAC-systems is a huge gain, and justifies that natural illumination is not sufficient and support of LED is still needed.

As shown, a retrofitting concept makes it possible to run the building without an HVAC-system and mechanic ventilation. This results in huge gains of energy efficinecy and user comfort.

1. Analysis

1.1 Location analysis

Figure 1: Birds eye of the Esplanada dos Ministérios [1]

The Brazilian federal ministry buildings in Brasilia are placed on the “Esplanada dos Ministérios” on the “Eixo Monumental” in the very center of Brasilia, closed to the iconic building of the congress and the senate. The building the design team took a closer look at in the workshop is mainly housing the ministry of environmental affairs. Like many buildings from the 60´s it has a problematic east-west orientation. Being part of the national heritage, the building also has an emotional significance for the Brazilian people. All in all the buildings are in very bad conditions, partly there where broken glass and damaged façade elements visible when Brasilia was visited in June 2017 just before the workshop. Since that, there is an obvious need for refurbishment, not just for the sake of an energy efficient retrofit. Between the ministries there are green (shaded) areas that offer a potential for recreation, but are poorly used at the moment.

Figure 2: West façade with bris de soleil

Figure 3: East façade with added HVACs

1.2 Analysis of climate data

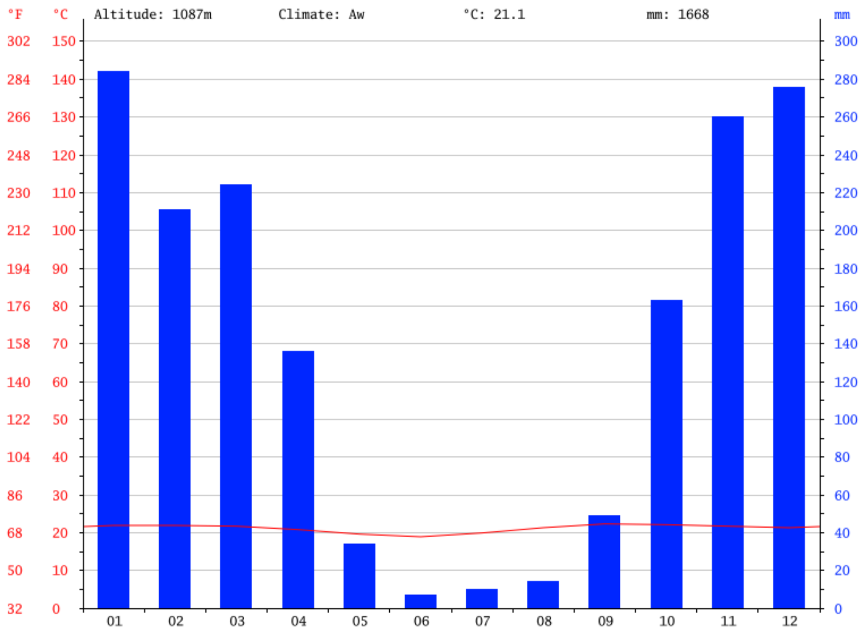


Figure 4: Climate chart of Brasilia

The analysis of the climate data showed, that all year through Brasilia faces a rather warm, but not super-hot climate with an average of about 21C° through the year with peaks up to 32C° and down to 12C°[1]. All in all the temperature does not vary to much over the year. Other than expected, Brasilia is not per se a dry city. The months from May to September are really dry, the other months have a lot of rain.

Since in reality, Brasilia is facing water shortages in these months, a sustainable water management should be considered. It could be a considerable option to collect water in the humid months and use it in the dry period.

In the beginning of the design process the team proposed a feature, that prevents dust (Brasilia has red, dusty dirt) to enter the building. This idea emerged from experiences different members of the team made themselves at the site. Since the cilmate analysis however showed, that this is a problem limited to very few months of the year, the team decided to waive of such a design feature. It would have meant a lot of investment with too little output. However, later in the process the team came back to this idea and decided to include open water bassins on top of the building to moisten the air, and by that increase the user comfort by making the air more breathable.

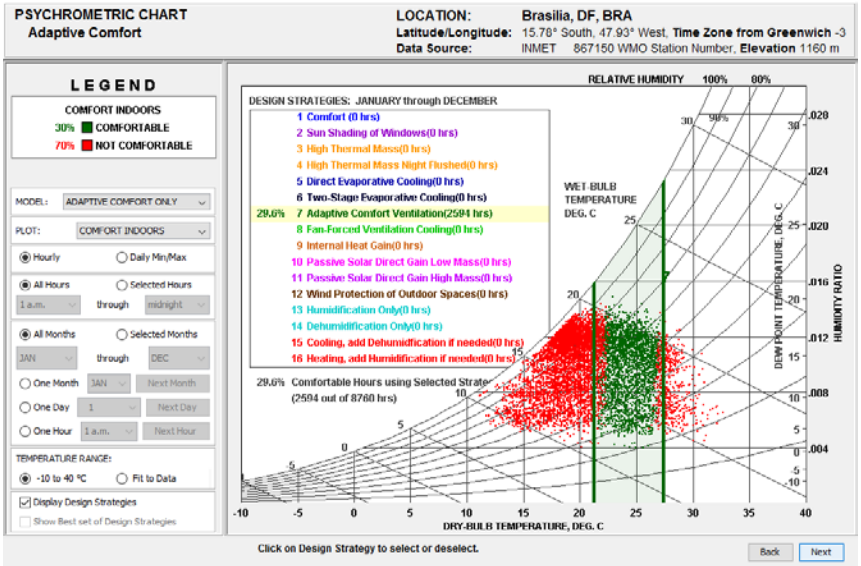


Figure 5: Comfort chart from the provided climate data

The wind velocity in Brasilia is standard, therefore no special protection needs to be considered, and also natural ventilation will work.

Not just the user experiences, but also the comfort chart for Brasilia showed, that there are a lot of days with uncomfortable climate. However, it´s surprising that there are also quite some days with comfortable temperatures and humidity.

1.3 Influential input during the workshop in Campinas

For the author, the most inspiring lecture was the one from Prof. Joana Soares.[2] Some really motivating best practice examples (like the Copan Building in Sao Paulo or the Commerzbank Tower in Frankfurt) showed, that climate responsibility, good design and user comfort can go together to create good architecture. It showed, that the activation of thermal mass can have a huge impact and also simple actions, like the rise of the temperature benchmark to 26° can increase the time where natural ventilation is possible up to 75%. This benchmark was also pointed out by Prof. Leticia Neves [3], who also referred to her studies. She found out, that 26° is the maximum benchmark for comfort where the average Brazilian user would intervene with turning on a cooling system. However a lower temperature is preferable. Therefore 22° were taken as operable temperature for the simulation in PrimeroComfort, but special attention was paid to the 26° benchmark. Prof. Neves also spoke on mixed mode ventilation, where she pointed out the importance of resilience in buildings. Maybe in Brazil even more than in Germany it is an important factor to ensure that buildings are still operable even without electricity. At the same time users just like to open windows, turn on the light, in general control their environment. Prof. Frank Wellershoff [4] added to this in his lecture, “that data knows more than the users”. Therefore the team decided on a combination (mixed mode) of natural ventilation run by a data driven system which can be overrun by the users. That way the users still have the control over their environment and at the same time night cooling is assured, and, if it´s appropriate, windows can be opened during the day. The system should be mechanical, to ensure the resilience of the building at all times. An alternative could be, that parts of the façade are operated manually, parts automatically. Since Prof. Wellershoff also mentioned a thumb rule about natural ventilation (2% (two sides open) or 3% (one side open) of the floorplan needed as operable window area), with with this rough calculation it was checked whether a system with both (manual and automatic openings) would ensure enough openings. However, this numbers are not reliable and some further simulation would be needed. Since this evaluation focused on the user comfort, it does not go into detail on this aspect.

Another lecture with a lot of useful input for the design process was held by Prof. Claudia Amorim. [5] According to her, 19% of worlds electric consumption is for lightning. This number is much higher than expected, so this also led the group to really consider natural illumination as a driving factor for a successful retrofitting concept. Since using less artificial lightning and switching to LED- technology can contribute a lot, the team also integrated these aspects into the concept. However, the use of natural sun light conflicts with the negative effects of glare and solar radiation. Therefore the design reduces glare and radiation by a vertical and a horizontal shading system and also the use opaque glazing (laminated & low-E coating) in the upper parts of the façade, where the view isn´t affected.

Another thumb rule, mentioned by Prof. Amorim, is that only about 2,5x the window height in depth can be illuminated. The group used this thumb rule for the design, and later validated the design with a simulation in DiaLux.

1.4 Analysis of the existing building performance

The quick analysis of the situation showed, that at the moment in many aspects the buildings have a very poor performance. These conclusions could already be made at a really early stage, without going into further performance data evaluations. Some assumptions were rather obvious, like the lack of cross ventilation (since the corridors have no openings for neither airflow nor light but the doors towards the façade). Another aspect is the very poor utilization of the positive effects an activation of thermal masses can have on night cooling. So far just the floor and the columns can contribute to the night cooling, since the ceiling is detached from the airflow by a false ceiling. All in all, the corridors are dead zones without any natural light or natural ventilation. Also an assumption was, that the high proportion of glass surface in the façade causes high solar radiation as well as glare near to the façade. This aspect will be further analyzed in the following chapters. Since the Brazilian people told the team, that it is very unlikely, for Brazilian users to open the windows for night cooling, it was assumed that also in this case study this is not carried out. Apparently security needs and the unawareness of the positive effects an open window by night can have cause these user habits. Therefore one should also consider that giving information to the users and taking them more into responsibility for the comfort inside of the building can also have a positive effect on the indoor climate and the performance of buildings. By analyzing the existing drawings further, it was tried to prove these assumptions. As shown in the graphics below the outcome of this analysis met the assumptions from the workshop in many places. Especially the evaluation of the actual façade-proportions led to valuable information for the further simulations. Further analysis of the existing situation can be found in the chapter about the simulations, which were carried out with PrimeroComfort.

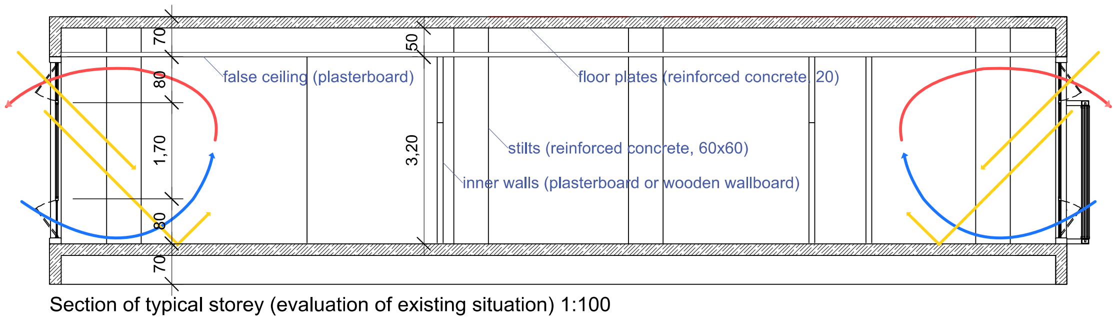


Figure 6: Graphic evaluation of a possible building performance in the existing state

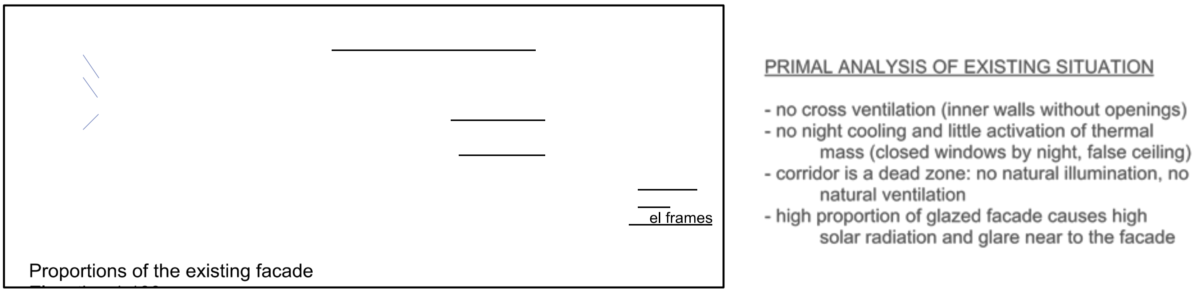


Figure 7: Analysis of the façade, used for simulations

Another example, which was also evaluated by Prof. Luciana Fernandes [6] is natural light. Since there is no natural light in the corridors, the usage of artificial light is high. Also it is known from her and Prof. Claudia Amorim`s [5] lectures, the typical light sources in Brazil are still ones with a rather high consumption, therefore the total consumption is even higher.

Many of the detected structural week points of the buildings are indicators for low user comfort and result in an extensive energy consumption. To make one example: high solar radiation results in high temperatures in the office spaces. The users react and use HVAC system to cool down the air temperature. This causes high energy consumption. The fact, that the buildings do not cool down by night, enforces this problem, because the HVAC systems come into use even earlier.

2. Design

2.1 Main design criteria

During the workshop in Campinas, the team developed three main design criteria. As it was found out in the analysis, the existing buildings have a high consumption of energy and very little user comfort. To improve these aspects was the main goal. At the same time, the buildings are representatives of the Brazilian heritage and were designed by Oscar Niemeyer during the early construction phase of the new capital Brasilia. Since they are under protection and there was also a lot of admiration for the existing architecture in the group, it was decided that therefore the third main goal will be the keeping of Niemeyer`s legacy.

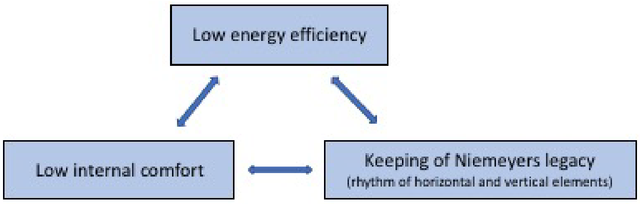


Figure 8: Three main design criteria

2.2 Design concept

The main design feature is a new curtain wall façade. This allows to combine different features – like operable windows, fixed parts and also a shading system in one element. The elements can be prefabricated and easily be mounted at the site. In addition to this, in the designing process the team defined different problems, which are tackled with several approaches, which can be found in the following graphic:

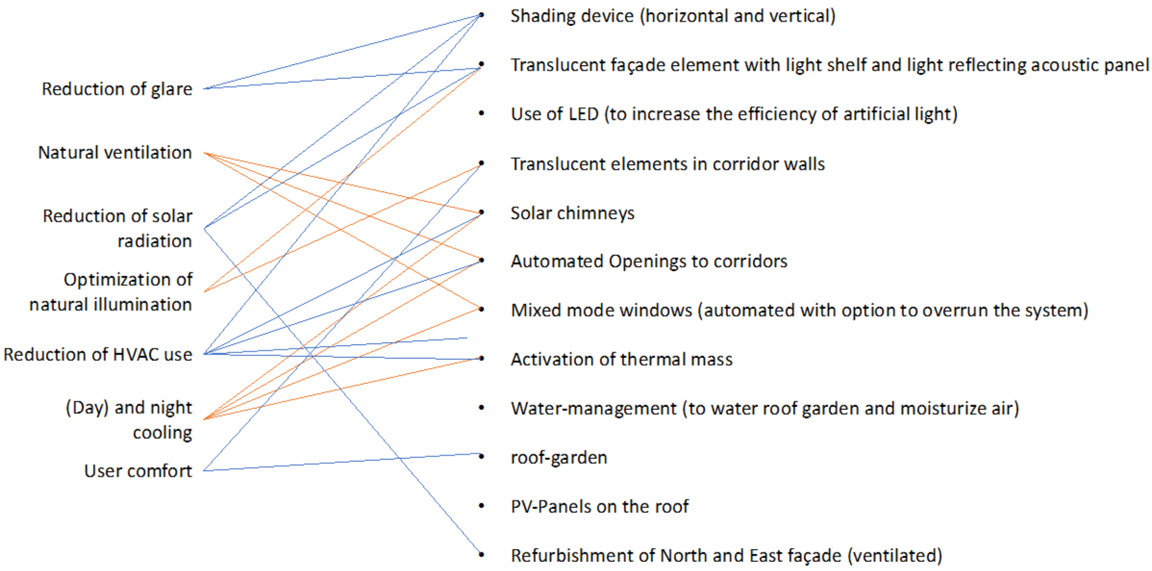


Figure 9: Concept of problems and approaches

From these first ideas the group developed different strategies to achieve the set aims. The next step was to design specific solutions for all these aspects. An overview of the whole concept gives the conceptual section below:

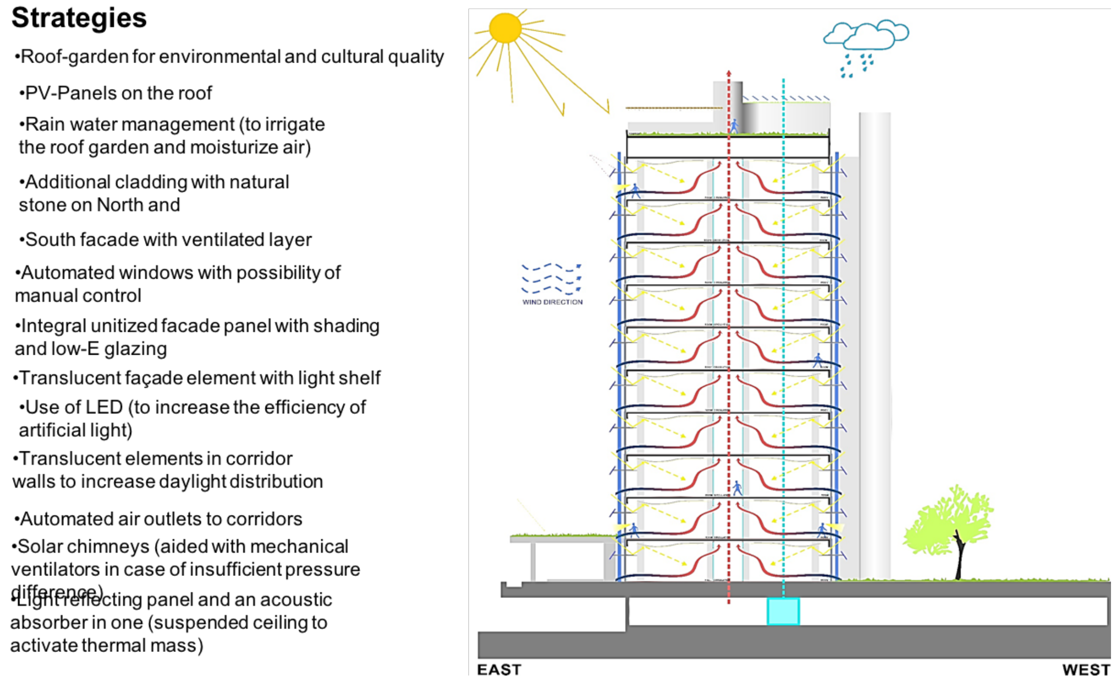


Figure 10: Conceptual section with retrofitting strategies

2.3 Curtain wall façade and shading

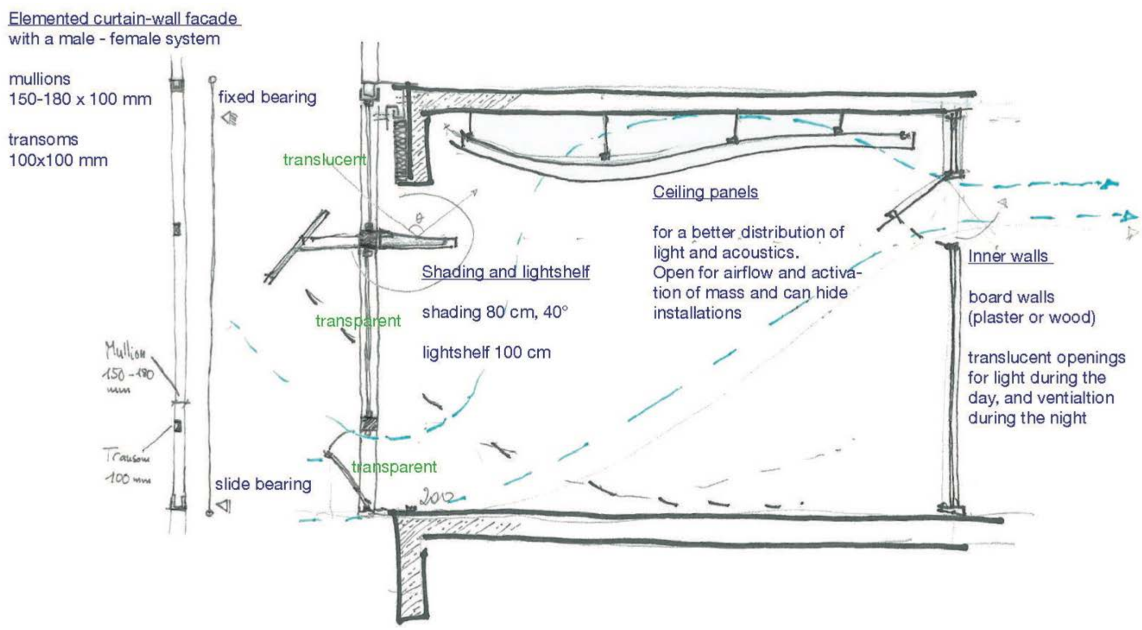


Figure 11: Sketch of the new curtain wall façade, the new cross ventilation concept and the ceiling panels

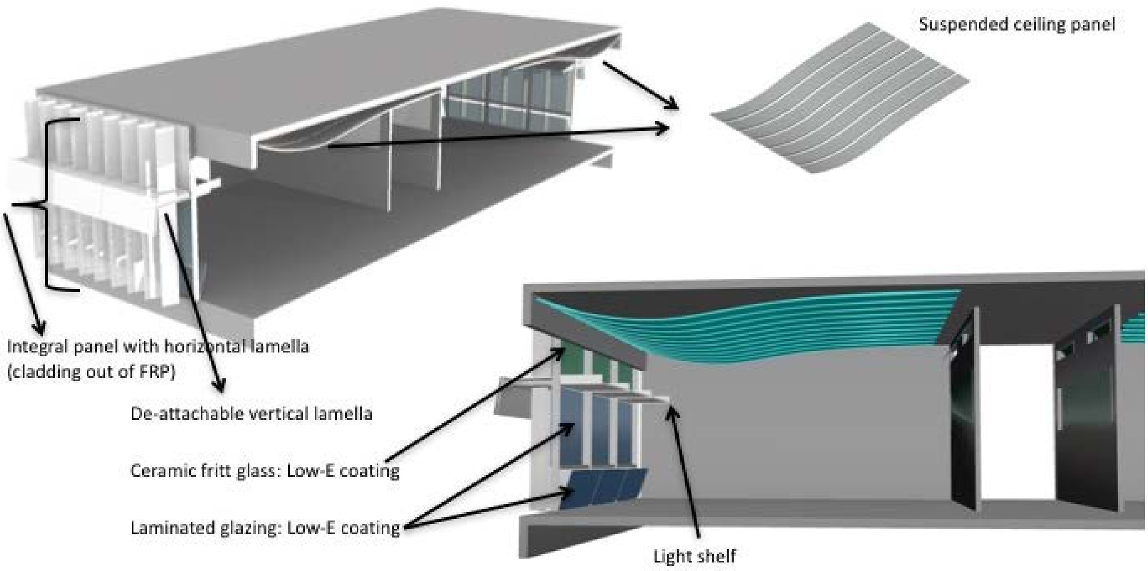
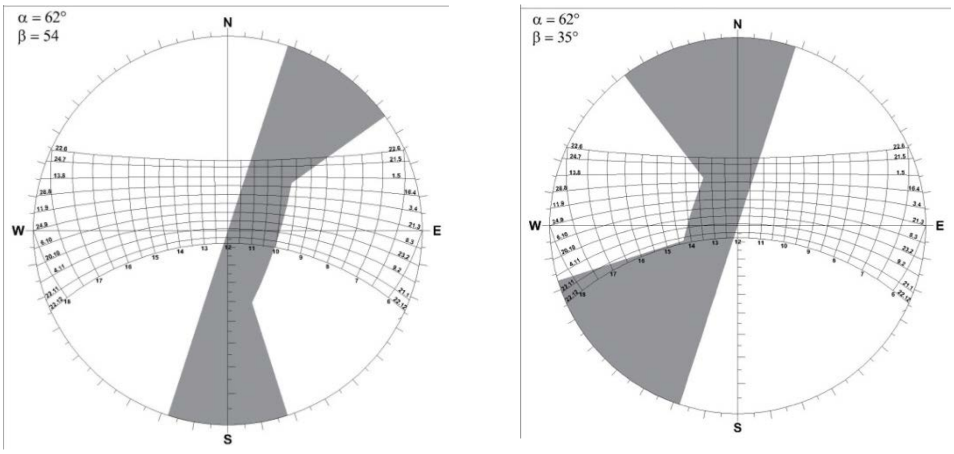


Figure 12: The new curtain wall façade, the new cross ventilation concept and the ceiling panels

For the new façade the design team proposes a curtain wall system which can be prefabricated and just needs to be mounted in place. The glass façade has three different partitions. The bottom one is transparent and operable for natural ventilation (run by a data driven system, which can be overrun by the user). Having the operable window at the bottom takes advantage of the natural airflow. Cold air comes from down below and when it heats up, it flows up to the openings in the corridor walls, which are at the top of the corridor walls. The middle partition is fixed transparent glass for light and view. The upper part is just translucent. That way there is still a gain of natural illumination, but also a chance to reduce the solar radiation. In the simulation a sun protection (Low-E) double glazing with a argon gas filling (U=1,2; g=0,35) is proposed. This, as foreseeable, already showed a huge effect on the solar radiation when the simulation was run with just new windows.



To increase the gain of sun light in terms of natural illumination the is a light shelf on the inside of the façade. Since this does not prevent the building to heat up by solar radiation, the upper partition is opaque.

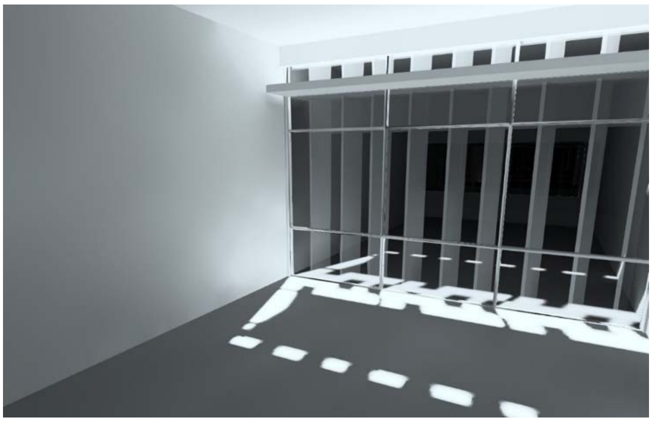
Figure 13: Sun diagrams of Brasilia for calculation of the needed blind angles

On the outside there is a system of both horizontal and vertical shadings to increase the effect of shading. The horizontal system cantilevers 1 meter, relying on a thumb rule from Prof. Soares [2], which states that cantilevers with more than a meter have just little more effect. The simulation later shows, that this works well and the expected effect is realistic. Already in the workshop some calculations with sun diagrams were carried out, giving information on angle and amount of needed blinds.

According to the 2% (3%) thumb rule mentioned before [4], natural ventilation is possible with the proposed façade. Since there are have solar chimneys, which provide a cross ventilation effect 2% of the floor plan as openable windows area should roughly be enough. On 1 meter façade there are 0,65m2 openable window partitions. At the same time there are 17,26m2 in the floorplan. Therefore there is an openable window area of 3,7% of the floorplan.

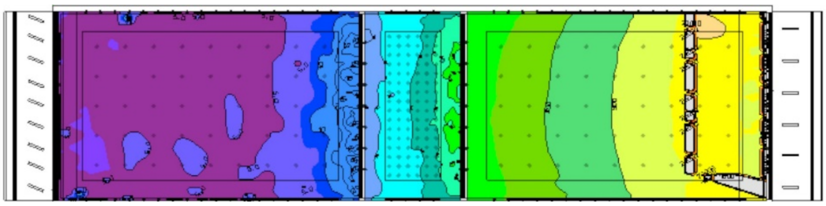
2.4 Natural illumination

A rough check with thumb rules [5] showed that in the best case up to 7,75m can be illuminated by natural light (with opaque area) or 6m (without opaque area. This numbers are questionable, since there are systems of shading, which keep out the radiation, but as a negative effect also the sun light. To therefore validate the design in terms of natural illumination a simulation in DIALux evo [7] was carried out. The simulation shows the distribution of direct light, because the team wanted to find out how big the glared areas will be. The design already takes into account the vertical and the horizontal shading, which angles and frequency already adapt to the radiation (number of blinds) and the azimuth and altitude (angle of blinds) of the sun.

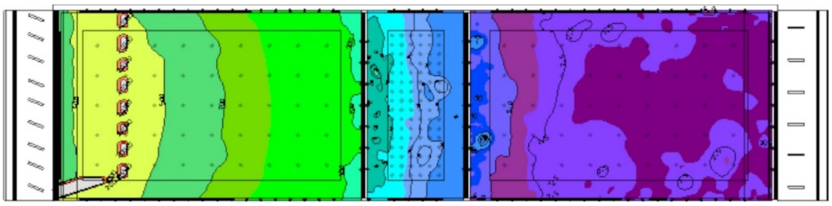


West façade at 4 pm

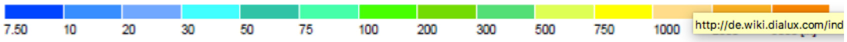
It is visible in the charts, that there is a good daylight distribution, but partial use of artificial lightning is necessary. More illumination than the thumb rule calculation suggested in the first point is needed. In the east there is a sufficient (500 lx) [8] sun light illumination up to 4,5m from the façade, in the west up to 3,5m. The differences come from the more dense shading blinds on the more exposed west façade. There is glare, but in small areas only, therefore it is tolerable, and extra blinding's against it are not proposed.



Summer solstice at 10am



Summer solstice at 4pm



lux key of DIALux evo

Figure 14: Simulations from DIALux

At this point a decision need to be taken. Either natural illumination but more radiation or the other way round. This concept proposes to rather protect the building in a sufficient way from radiation and use artificial light. There still is enough daylight to create a good user comfort (50 lux in the corridor). LED technologies are very energy efficient, therefore for the proposed way to go is, to use the natural light as far as possible, but to support it with artificial LED-lights.

2.5. Roof

2.5.1 Roof garden

In the analysis it was found out that the buildings are in lack of social spaces, where people can gather or have short breaks to improve the working quality. For this purpose a roof garden, inspired by the Brazilian landscape architect Roberto Burle Marx is proposed. It serves as a social and cultural space. There could be a cafeteria of something similar. In partly shaded areas, which are surrounded by open water basins and plants for cooling down and moisturizing the air, people can have a break outside.

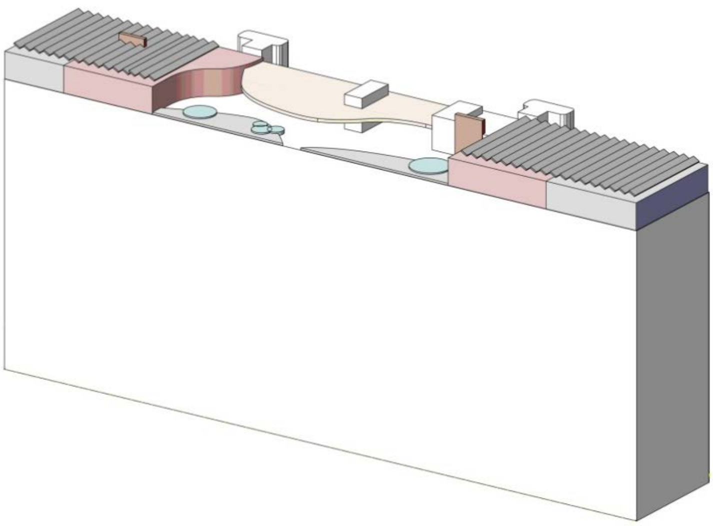


Figure 15: Design for a possible roof garden

But the new top floor is not just a social space. At the same time the roof collects the water from the humid months for later use. The roofs of the enclosed spaces (cafeteria, rooms for technical installations) are covered with PV panels that also gain energy for the operation of the building.

2.5.2 Implementation of water management

In lack of actual water consumption data of the buildings or comparable numbers from other office buildings in the area, the calculation was carried out with the general UN benchmarks [9] for water consumption in office buildings. Taken this number of 50l per person and day and an estimated number of ca. 900 people working in the building, there is a total of 11.925.000 l water consumption per year. Taking a look at the yearly rainfall over the last 30 years [10] shows that just on the roof of the building an amount of 2.758.942 l yearly can be collected. This corresponds to 23,1% of the consumption. Therefore, the idea to collect water in the humid months really makes sense, and could contribute to defuse Brasilia's water shortages. Since there are three existing shafts in the building, these could easily be used to carry the water to underground tanks, where the water is stored for later use.

2.5.3 PV panels

Since there is a lot of solar radiation in Brasilia, PV panels are an efficient option to create energy for the operation of the building and therefore reduce the use of nonrenewable energies. If the panels go on top of the technical installations, according to a thumb rule 72% of the roof can be covered with solar panels. Since there is 959 m2 of roof area, ca. 650,5 m2 of solar panels can produce energy. According to some research done by the Hochschule Bierberach [11], the gain of solar power is almost twice as high in Brasilia (194,4 kWh/m2 and year) as in Germany. Therefore one can expect an huge outcome of 134233 kWh/p.a. from the solar panels. However, further research would need to go into this aspect to find out whether 72% is actually a realistic number and how much this gain could contribute to energy needed to operate the building.

3. Simulation

3.1 Introduction

For a simulation of the user comfort in the building the simulation program PrimeroComfort was used. It mainly focuses on overheating through solar radiation by giving good information on the effects on users comfort. But PrimeroComfort also has some valid information on energy efficiency, which allow conclusions on how well natural ventilation or cooling systems work.

In the simulation a four meter wide partition of the building from one façade to the other was examined. This way also cross ventilation and the impact of the dead corridor zone could be taken into account. It was worked with different versions of the modeled space, which of course, were mainly the current state and an the other hand the retrofitting concept. From this variations of the retrofitting concept where done, e.g. trying out different modes of cooling (just cooling through ventilation, addition of mechanical cooling) or ventilation (just natural ventilation, addition of mechanical ventilation).

3.2 User comfort

This chart shows how many hours with temperatures above the operative temperature (the “aim” of the building) there are, both in the existing building (B) as in the retrofit concept (1). One can see, that there are still some hours above the operative temperature. But at a closer look it is visible, that just very hours are actually above 26° degrees, the benchmark mentioned before. Since the retrofit concept was simulated without any non-natural ventilation or cooling, the results are surprisingly good. During the simulation with PrimeroComfort it was found out that especially the ventilation through the solar chimney has a huge effect on the performance of the building. The Solar chimney were simulated in Primero as “Lüftung durch Höhendifferenz” (Ventilation through height difference).

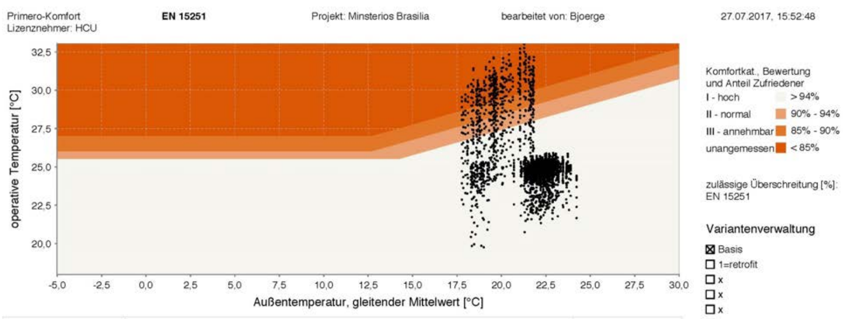
Figure 16: PrimeroComfort “hours above operative temperature” according to DIN 4108.

B=existingbuilding;

1=retrofitconcept

Stundenanzahl über operativer Temperatur

	24°C	25°C	26°C	27°C	28°C	29°C	30°C	31°C	32°C	33°C	34°C	35°C
B	2541	1350	603	521	433	344	212	86	18	0	0	0
1	1775	855	240	60	7	0	0	0	0	0	0	0

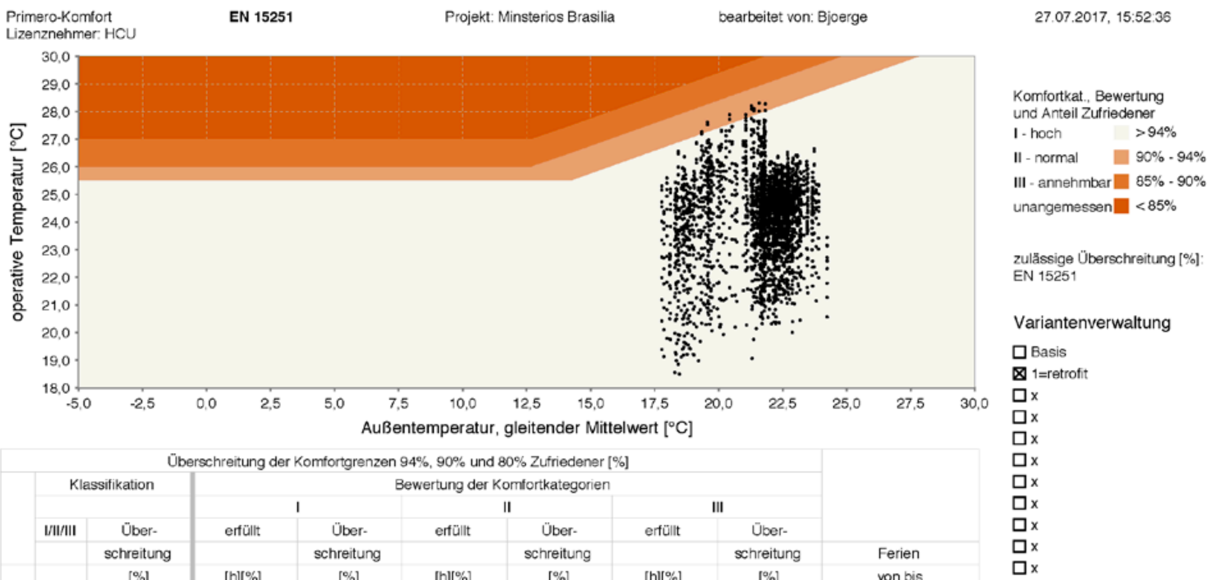


Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]

	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	2292 / 80%	20%	2382 / 83%	17%	2446 / 85%	15%	-
1	III	0%	2772 / 97%	3%	2864 / 100%	0%	2871 / 100%	0%	-

Figure 17: PrimeroComfort comfort diagram for the existing state according to EN15251

When looking at the comfort diagram for the existing state of the building the expectations from the analysis of the climate data were met. On the psychometric chart which was shown before it was visible, that Brasilia does have around 30% of comfortable days. Since the buildings do use HVAC systems for cooling this percentage is higher in the inside. However there is an amount of 15% of hours which are above (partly way above) the maximum which is considered “not acceptable” by EN15251. Therefore this chart clearly shows again what was already told by the users and known from former evaluations. The need for a comprehensive retrofit is real!



Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]	Klassifikation		Bewertung der Komfortkategorien: I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	2292 / 80%	20%	2382 / 83%	17%	2446 / 85%	15%	-
1	III	0%	2772 / 97%	3%	2864 / 100%	0%	2871 / 100%	0%	-

Figure 18: PrimeroComfort comfort diagram for the retrofit concept according to EN15251

In comparison to the existing state, the retrofitted concept performs very well. As mentioned before, in the version of the simulation shown here, cooling systems and non-natural ventilation where left out. This gives the chance to show the potentials of an integral façade, as well as a good ventilation concept and night cooling through thermal mass. On this comfort diagram there are only very few hours (3%) that are outside of the comfort zone. During the workshop it was still considered, that there might be a need for an additional cooling system. But since no hours are outside of the acceptable zone, it is feasible to completely leave out mechanical ventilation as well as a mechanical cooling system and by doing so to save a lot of money during the operation as well as acquisition costs.

3.3 Energy efficiency

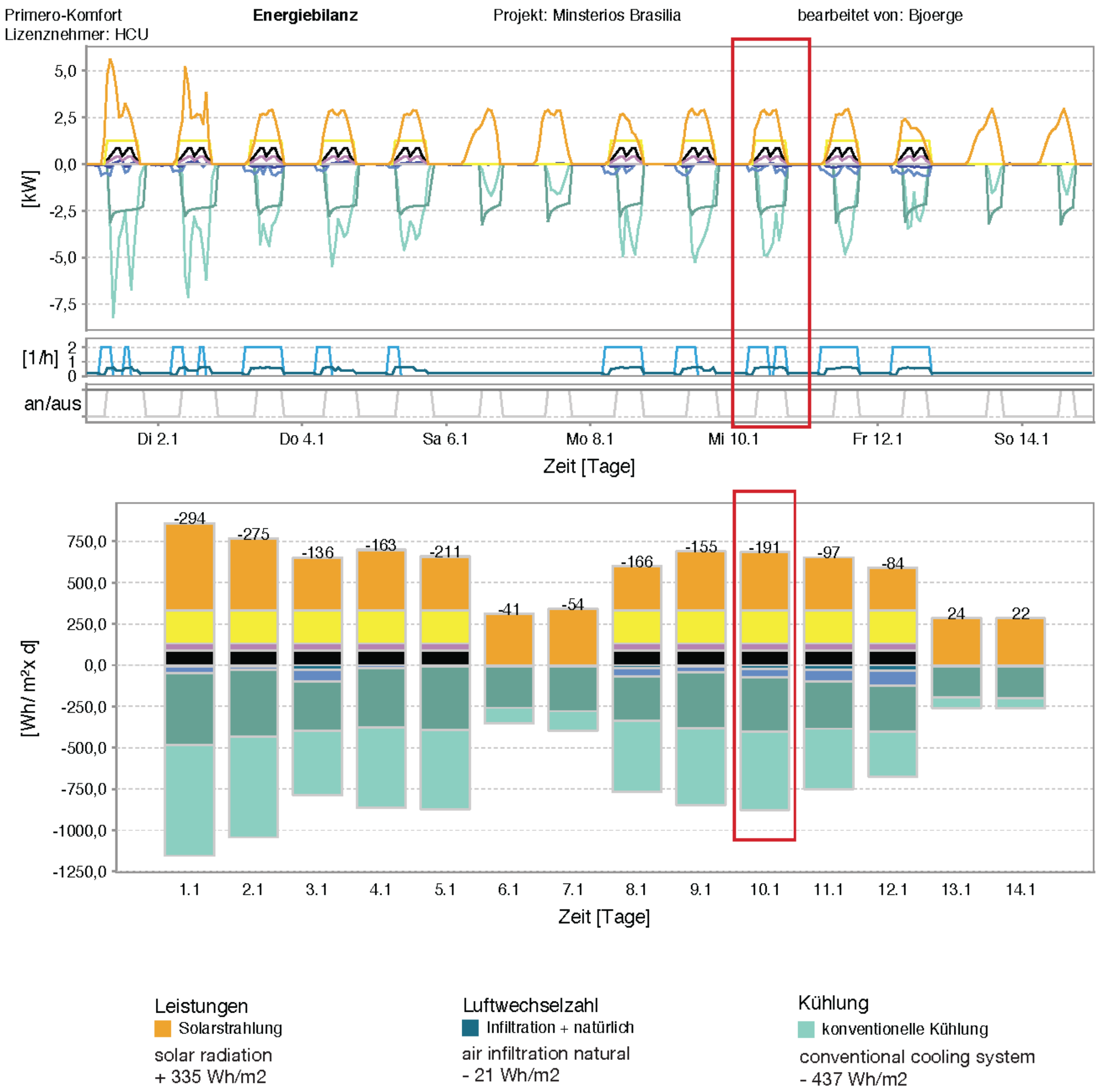


Figure 19: PrimeroComfort energy efficiency of the existing state

In another version the energy input was simulated (from the sun, people and machines) as well as the output which is needed to compensate the input (by Infiltration, cooling, etc.). For this simulation a version with a mechanical cooling system was used, both in the existing as in the retrofit, to provide comparable numbers. For this comparison a day (10.01.) with an average summer climate was taken. In the two charts presented it is clearly visible that the shading system and the glass with low-E lamination have a very good effect. The solar radiation is reduced from 335 Wh/m2 per day to just 64 Wh/m2 per day. Also a positive effect is visible with the natural infiltration. It raises from 21 Wh/m2 per day of heat it carries out of the building up to 115 Wh/m2 per day. This also means, that need for conventional cooling shows a solid reduction from 437 Wh/m2 per day down to just 133 Wh/m2 per day.

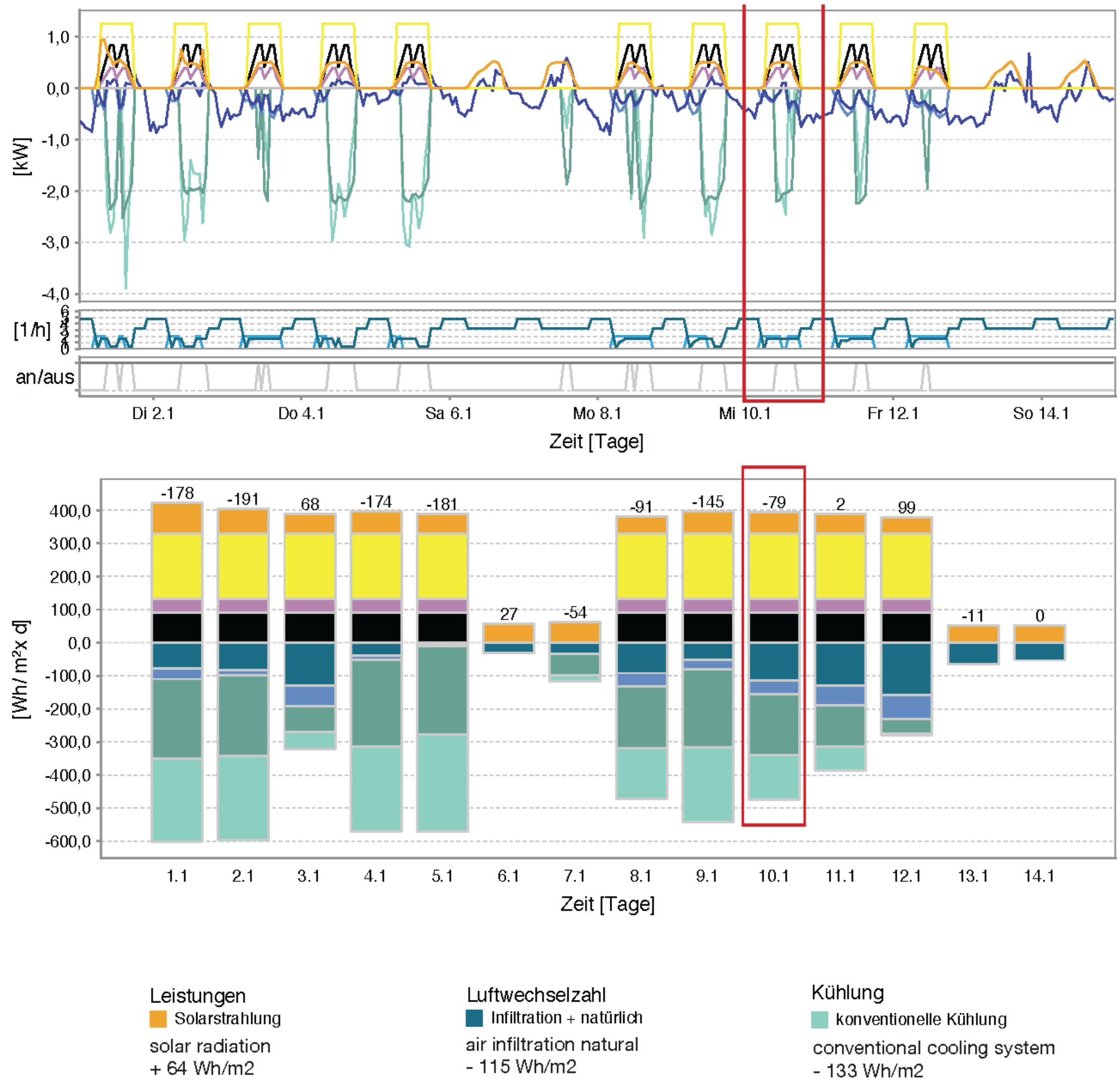


Figure 20: PrimeroComfort energy efficiency of the retrofitting concept

The same simulation also showed, that the activation of thermal mass in this case has a much smaller effect than expected. However, mass activation can contribute. Especially the covered up ceilings have a potential. In the concept the team introduced a panel which serves as an acoustic panel and a cover for installations at the same time. At the same time the panel is suspended from the ceiling and between the panels there are gaps every meter. This ensures, that the air can flow around the panels and reach the concrete ceiling for cooling. Even though the effect of cooling is not that high (which might also be caused by the little component heights) it could still contribute to the design as a whole.

4. Evaluation

To sum it up, the main factors in reducing heat in the building and energy use for cooling are the reduction of solar radiation (new glass façade & shading) and the increase of air infiltration (night ventilation & solar chimneys).

In the end, the proposed design tried to follow one simple rule, which Prof. Doris Kowaltkowski mentioned in her lecture. “Don´t overdo it”. Since some things (like the orientation of the building) are “wrong from the start” and can`t be changed, the team tried to take a lot of small actions instead big changes. The only big changes done by the design team are a new elemented façade and the roof garden. The designed façade picks up the original design by having the same proportions, just slightly shifted of the original axis, and therefore does not affect the appearance of the building very much. The roof garden showed to not have the whished outcome. Most the positive effects of it, like the recreational area with open water basins for cooling and moistening the micro climate and the PV-panels can also be implemented on the ground (garden and basin) or on the a classic roof (PV panels). Therefore in conclusion the roof garden, which did not fulfill its promises, was left away.

The conclusions from this evaluation in some bullet points are:

- Reduction of radiation over natural illumination
- Light shelfs can be left away, because they show too little effect (still extra lightning needed in the offices, building is simply too deep (>17m)) = therefore rather close the upper part of the façade and increase the reduction of radiation.
- Natural ventilation is possible
- Cross ventilation or ventilation trough height contribute a lot and should be considered under all circumstances
- Don’t overestimate the effect of thermal mass, especially when you have thin slabs
- No roof garden, because positive effects can be used without (recreation in a park next to the building, collection of water and PV panels on a classic roof

After all, the proposed concept contains of a lot of small actions. Therefore it was not possible to validate all of them in a short time with a group of just one person. However it was tried to give some valid numbers, especially on the users comfort in the offices. Summing up, the authors believes, that the proposed concept could be way to go to modernize the historic Niemeyer buildings in an efficient way, which respects the users comfort and is climate responsible at the same time.

5. References

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[11] Kulakow, Hannah (2012): Optionen zur technischen Realisierung von PV-Anlagen gemäß der neuen Regulierung in Brasilien

Design concept for retrofit of the ministerial building in Brasilia

Group 3
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Abstract

During the Brazil Summer School 2017 workgroups had to design a building retrofitting concept based on an existing ministry building in Brasília. Retrofit of existing buildings represent an opportunity to upgrade the energy perfomance of building assets for their ongoing lifetime. The Goals of the retrofit case study is to reduce the energy balance of the building and to increase the comfort of the occupants.

At the end of the process, the building changed in its form and its appearance to adapt better to the local circumstances. Parts are added or cutted out. In addition, the ventilation concept is strongly revised to avoid unnecessary heating of the building. A uniform ventilation system is installed which is automatically controlled. Ventilation outside the times of use has a great effect on the cooling of the building. A Solar Chimney is added to the north and south side of the building to improve the natural ventilation. A full-scale shading concept of the East and West façade contributes significantly to the reduction of solar radiation and thus also reduces the need for artificial cooling of the building.

Figure 1: Design concept for retrofit of the ministerial building in Brasilia

The evaluation clearly shows the advantages of the developed ideas. In addition to the evidence of the analysis to improve the energetic value of the design, great attention was paid to the appearance picture. The team has succeeded in developing a concept which optimally combines the energetic benefits and the architectural design.

1. Input

In June 2017 in cooperation with the HafenCity University the University of Campinas organised the international Training School “design process for building retirofit” which enabled the participants to get the experience in creating a retrofit case study for the Brazilian Ministry of the Environment. The basic knowledge for the designing façades were presented in the first half of the Training School. International Experts from Germany and Brazil gave the lectures and guided the workshops.

The first lecture was about the design process of retrofitting. Prof. Dr. Doris Kowaltowski held a very interessting lecture about the meaning of retrofit, when and why retrofit is useful and how to act in creating a process. It was very helpful to learn about the meaing of retrofitting and the acting in the process.

Another very useful contribution were the both lectures from Prof. Dr.-Ing. Frank Wellershoff. He started with the design aspects for adaptive façades. Adaptive building envelopes can provide improvements in the building energy efficiency and economics, through their capability to change their behaviour in real time according to indoor-outdoor parameters, by means of materials, components and systems. He showed which external factors effect on the interior and building. There are different kind of façade regulatory measures like heat/air flow, daylight management and noise penetration which can be effected through the vapour resistance, form, shape and color. Prof. Wellershoff stated that a virtual building can be used to simulate the impact on the room like comfort parameters, level of daylight or the amount of energy consumption. There are several iterative process, involving creation of model (incl. analysis of building), simulation with relevant boundary conditions and multi-variate analysis of simulation results and extraction of relevant design information.

After this he went to his second focused topic of natural ventilation of building. He explained a five step design program for double façades. On the beginning the specific terms of protection has to be picked out. Then the ventilation concept must be selected. Afterwards the local conditions are analyzed, the double façade type will be choosen and at the end the detail façade design has to be defined. This approach was very helpful when planning the retrofit design.

There were many other interesting topics during the workshop. Prof. Dr. Leticia Neves spoke about the mixed-mode ventilation which is combining natural ventilation with mechanical ventilation and/or cooling in the most effective manner. This strategy offers the possibility of using existing building features to enhance passive performance. Prof. Dr. Luciana Fernandes gave us an introduction to the existing ministry building on which the case study was initiated. At the end of the first day, Prof. Dr.-Ing. habil. Wolfgang Willkomm presented a lot of examples of retrofitted buildings. It was very interessting to see which different kind of retrofit potentials the existing builings and construction systems had.

On the third day there were two more lectures. Prof. Dr. Cláudia Amorim gave us more information about the daylighting and lighting systems. The lighting quality depends on many factors like human requirements, environmental and economical aspects and the architecture. The daylighting has ad- and disadvantages. Prof. Amorim gave us helpful information of how to use and to protect from sunlight with the room's depth, window size and shading systems (light shelves, prismatic panels). The advanced lighting solutions for retrofitting buildings were a good input for searching own solutions in the workshop. The last lecture was about the environmental performance of buildings from Prof. Dr. Joana Gonçalves. This lecture showed five key messages for environmental design. The "power" of environmental and space diversity, just rules of thumbs - no pre-determined architecural solutions, possibility of natural ventilation, energy efficient buildings instead of energy efficient façades and Qualitative + Quantitative Indicators for Urban Impact and Buildings' performance.

In the second half of the workshop the team used the great extent of knowledge in order to design a new concept regarding to the given boundary conditions. The german students worked together with bazilian students and experts to share their knowledge and to leran about typical Problems and solutions in Brazil.

2. Location Analysis

The Headquarters building of the Ministry of the Environment (MMA) and the Ministry of Culture (MinC) are located on the Monumental Axis in Brasília, Federal Dirstrict.

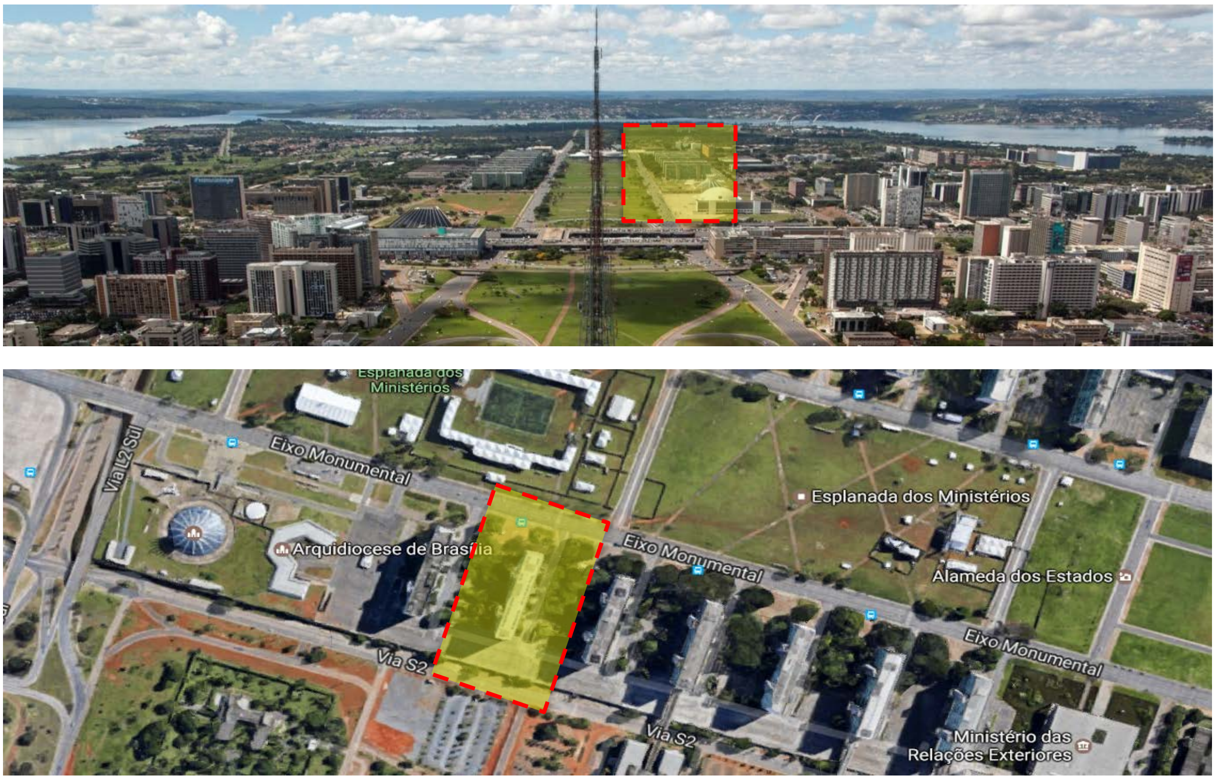


Figure 2: Location of the ministerial building in Brasilia

1.1 Building Description

The building is a 10-storey building with exterior walls of ceramic bricks and exterior ceramic tiles on the North and South façade. The west and east façades are fully glazed. Currently 4 mm thick glass with an external metal film is used. Over the glazing on the west façade, operable vertical metal overhangs are used for shading the façade.

Figure 3: East façade

Figure 4: West façade

1.2 Weatherdata

The weather data for the location of Brasília is taken from the "EnergyPlus weather data" database. Twelve typical meteorological months were selected, which reflect a year of weather data. The most important parameters for weatherdata analysis are given below.

1.2.1 Temperature & Humidity

Brasília has a tropical savanna climate with two distinct seasons: the rainy season, from October to April, and a dry season, from May to September. This is typical for a climate near the equator. The average temperature is 21.5 °C. February has the highest average maximum temperature, 22.8 °C. Average temperatures from September through March are almost consistent 22.4°C. The coldest month of the year is July with 19.0°C. The relative air humidity varies between 64 and 80 percent. Average annual humidity is about 72%.

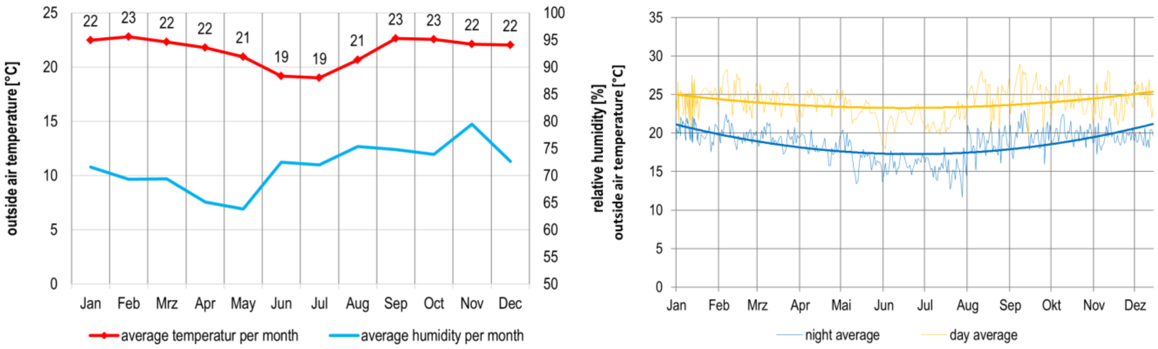


Figure 5: Outside air temperature of Brasilia

On average, the temperature drops by 5 degrees Celsius at night. During the usage time (office, for example, 8 -18 o'clock) the outside air temperatures range is between 18 and 29°C. Due to the high outside temperatures, during the times of use, the building is heated up. In principle it should not be possible to ventilate during the day to avoid unnecessary heating of the interior of the building. Instead, the colder air during the nighttime should be used to ventilate and cool down the building.

1.2.2 Precipitation

The average annual precipitation is 1552 millimeters. Most rain falls from October to April with an average of 124 to 249 millimeters, the minimum of rain is expected from May to September with an average of 52 millimeters. In total there are about 130 days of rain, mainly during the warmer months from October to April.

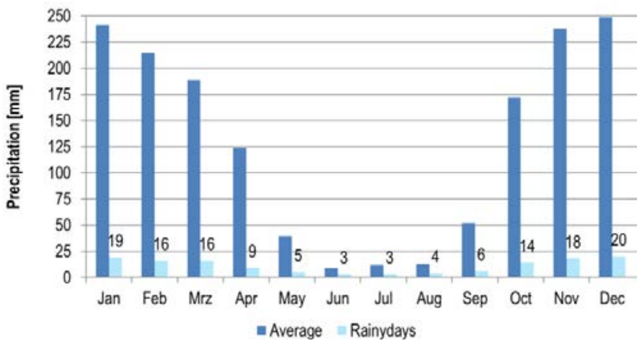


Figure 6: Precipitation of Brasilia

1.2.3 Wind

The wind speed with a wind force of 1 to 5 corresponds to a weak to moderate wind of 1.0 to 10.7 km/h. The dominant wind direction with the highest wind speed comes from the east. This is related to the pressure areas during the different periods of the year.

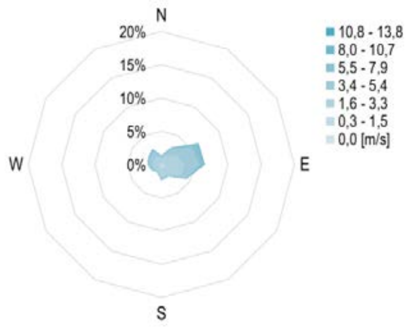


Figure 7: Wind rose of Brasilia

1.2.4 Solar Radiation

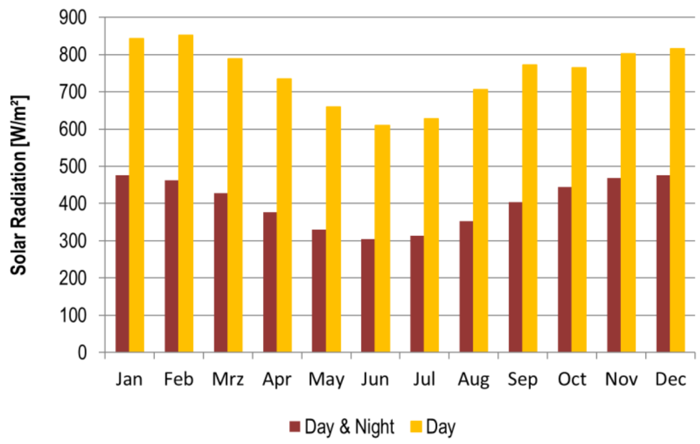


Figure 8: Solar Radiation of Brasilia

The following figure shows the average global horizontal solar radiation during sunshine (day) and the whole day (day & night). The yearly sum of Brasília is 1700 kWh / m².

1.2.5 Climate Classification & Psychrometic Chart

The climate clearance is carried out according to Köppen-Geiger. The climate is divided into climatic zones and climatic types. The criterion for the classification of the climatic zone is the temperature. The climatic type is determined by the precipitation quantity. The effective climatic classification according to Köppen-Geiger is Aw. An “A-Climate” stands for tropical rain climate, which means that the coldest month of a year is warmer than 18°C. The “w” says it is a tropical savannah climate; the average precipitation of the driest month is less than 60 mm and also less than 4% of the annual precipitation.

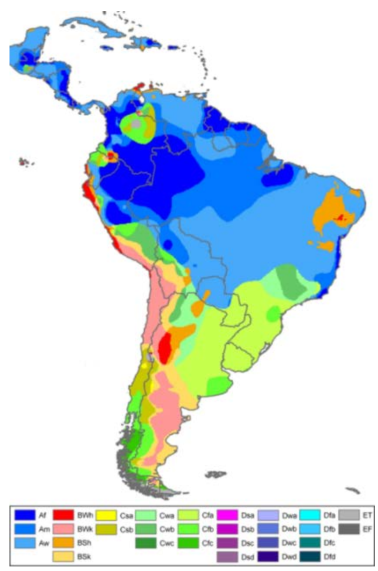


Figure 9: Climate Classification from Köppen-Geiger of South America [12]

With the criteria of the Brazilian standard ABNT NBR 15220-3 Brazil is divided into eight bioclimatic zones. The classification of the zones was carried out under the criteria of average air temperature, mean relative humidity, and considering their altitude above sea level. The program Zoneamento Bioclimático do Brasileiro (ZBBR) is a database for the cities of Brazil with its characteristics in the relevant climate zone.

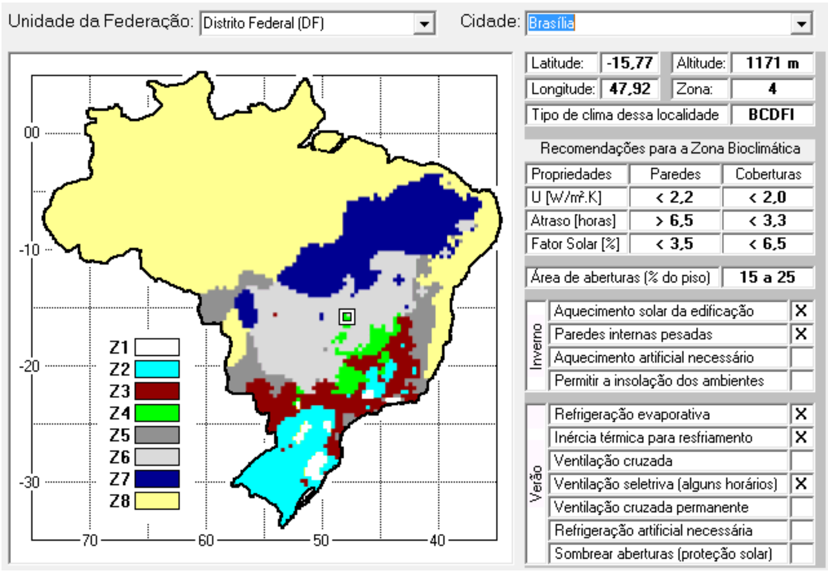


Figure 10: Bioclimatic zones of Brazil

The database provides recommendations for the bioclimatic zone of Brazil. For the winter, solar heating and massive interior walls are required, in the summer evaporative cooling, thermal inertia for cooling and selective, temporary ventilation.

The psychrometric chart shows graphically the parameters of Brazil relating to water moisture in air. The study of psychometrics and therefore the usefulness of the chart are important because people feel comfortable over a narrow range of temperature and humidity.

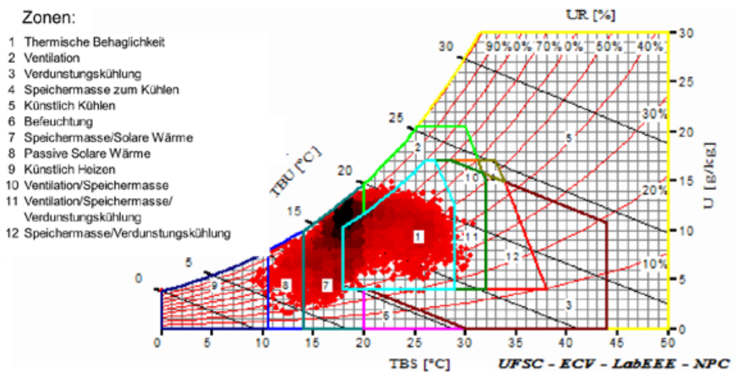
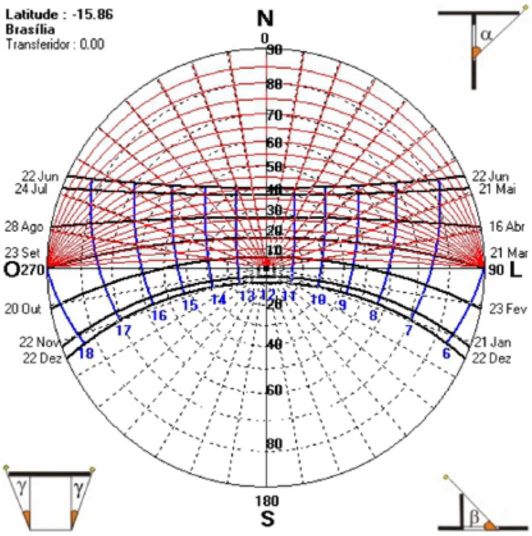


Figure 11: Psychrometric Chart of Brasilia [13]

The chart shows that 44.30% feel comfortable, while 55.70% feel uneasiness. At 53.13% it must be cooled and only at 2.66% a heating is necessary.

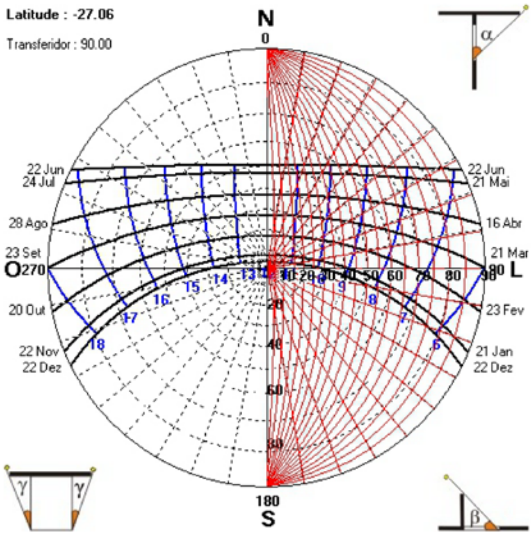
1.2.6 Sun Path

The following diagrams show the course of the sun based on the façades aligned in the respective direction of the sky. As you can see, on the northern façade there is almost all year round sunshine, in the east in the morning, in the west in the afternoon and in the south almost nothing.



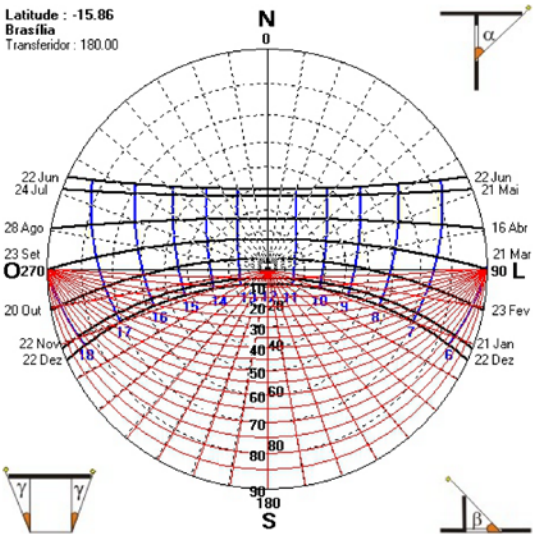
Fachada Norte	Início da insolação	Fim da insolação
Verão		
Inverno	6:30	17:30

Figure 12: North façade



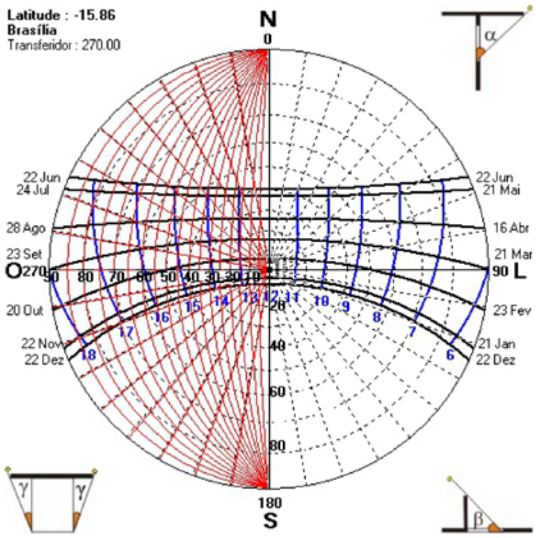
Fachada Leste	Início da insolação	Fim da insolação
Verão	5:30	12:00
Inverno	7:30	11:30

Figure 13: East façade



Fachada Sul	Início da insolação	Fim da insolação
Verão	5:30 (13:30 Tarde)	10:00 (18:30 Tarde)
Inverno		

Figure 14: South façade



Fachada Oeste	Início da insolação	Fim da insolação
Verão	12:00	18:30
Inverno	12:30	17:30

Figure 15: West façade

3. Guideline | Concept

The government district in Brasília impresses with its spacious squares and futuristic buildings. In collaboration with the city's and landscape architects, the entire district was designed by the architect Oscar Niemeyer. At the edges of the six-lane road, there are 18 uniform disk-houses, Brazil's federal ministries. Niemeyer began to rely almost exclusively on reinforced concrete as a building material. On the basis of his futuristic and plastic form, he was regarded as one of the most important representatives and innovators of architectural modernism. He almost renounced the orthogonality. With his curving, soft contours he always maintained a balanced relationship between free space and volume.

The state buildings erected along the long axis represent a strong contrast to Niemeyer's modern form. To take advantage of its unconventional design, the team decided to loosen up the eastern and western façade of the selected Ministry building by proposing curved balconies. On the other hand the north and south façade should not be altered optically, except for minor renovation measures (insulation). This means that the building continues to fit into the clearly structured surrounding of the entire district and nevertheless there is the option that each one of the state buildings receives an individual eastern and western façade without losing the uniform concept.

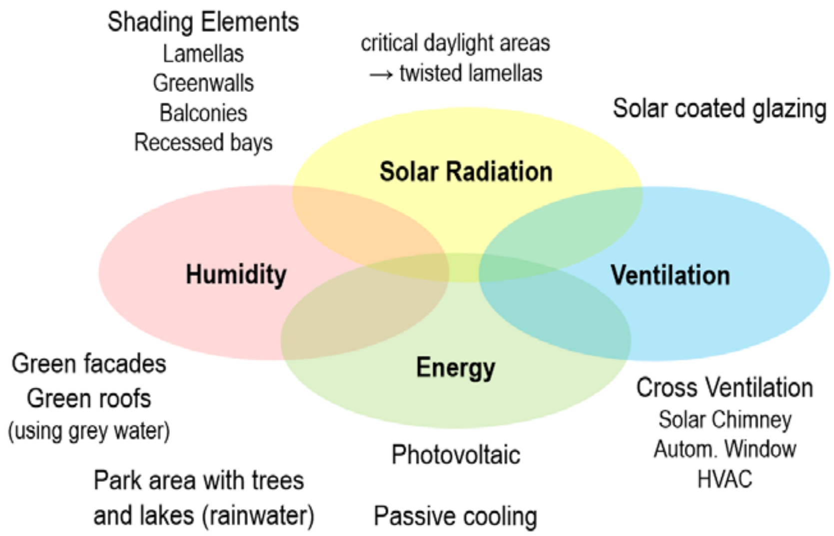


Figure 16: Concept of the design

The aim of retrofitting was to improve the performance of the building, to increase its useful life and to meet current performance requirements. Therefore the team analyzed thermal, energetic, environmental and economic factors. Four topic areas have emerged that contribute to the optimization of the building's performance: solar, humidity, ventilation and energy. By shading elements like Lamellas, green walls, Balconies and recessed bays the solar radiation is to be reduced. To counteract the critical daylight zones, the team has developed twisted lamellas, which enable the heat to stay outside and at the same time to keep the shading as low as possible. The dry climate is positively influenced by green façades and roofs as well as park areas with trees and lakes between the buildings. In order not to increase the water consumption unnecessarily, greywater and caught rainwater from the lakes are used for irrigation of the plants. Another optimization is the use of cross ventilation. A natural ventilation process can be enhanced by a solar chimney. It will be used to decrease the energy used by mechanical systems. The natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside. At the same time cooler air can be drawn in through vents at the lower level. The trees which are planted on the side of the building provide shade for cooler outside air. Photovoltaic systems are installed on the rooftop for additional energy production. These are particularly productive due to direct exposure to the sun.

Overall the concept improves many factors for optimizing the building performance. At the same time the focus is also on the architectural appearance. The close co-operation between Brazilian architects and German civil engineers has resulted in a diverse concept, which focuses on the optimization as well as the architectural design.

4. Progress

With a first glance at the existing building the first ideas came immediately. At the beginning, the first step was to loosen up the striking façade of the building and make it more open. The team started to create a cubic structure in the façade. The idea was partly to add balconies outside the building and cut into other sections of the building and insert recessed bays.

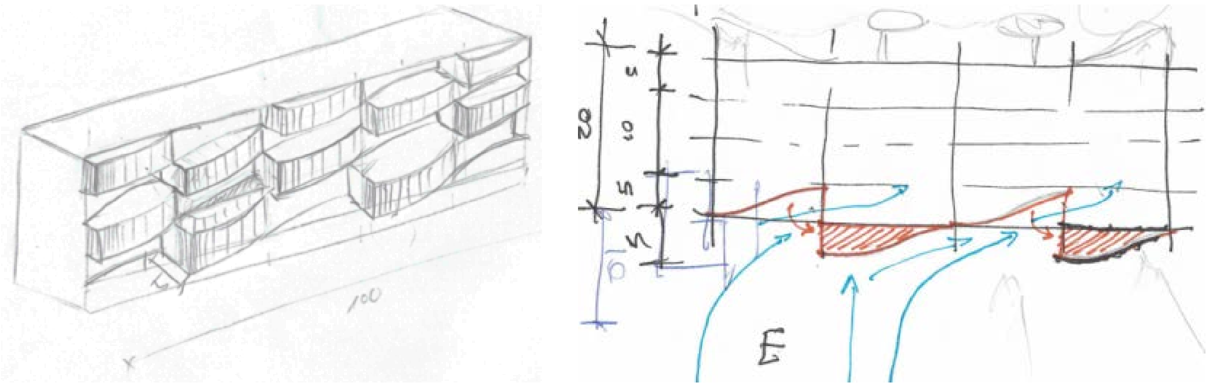


Figure 17: Ideas development and progress of the design

At the beginning, the team was still working with an ever-recurring structure, which then developed into a seemingly random structure during the design process. In the end the cubic forms were replaced with a wave-like surface. This has been better integrated into the overall picture. The cuttings, in combination with the balconies, ensure that the wind can be absorbed by the building and thus contribute to cooling. The first idea of cooling the building with a cross-ventilation did not prove to be a good idea, as the air that had already been heated in the first office is still directed into the second office. So the idea came to use a solar chimney to remove the heated air from the building and supply the building with cool air from the outside. The team planned an automated System with automatically opened Windows, which can be overruled by the occupants for some time. The added balconies should be designed very open so that the wind can circulate undisturbed between the building and the balconies. It is important to avoid the accumulation of air. In addition, the balconies are also used as shading elements. The parapet, which is spread over entire floors, is provided with lamellas.

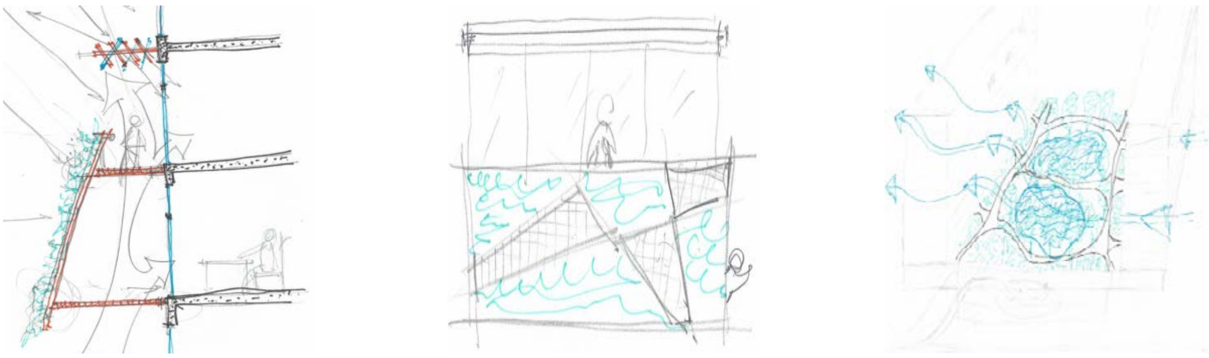


Figure 18: Ideas development and progress of the design

Another idea was to provide a greenery to the façade. This is said to provide a pleasant climate and contribute to the cooling by the irrigation system and the evaporation of the water at the same time. At first, the consideration was to provide photovoltaic cells to the vertical façade. This idea proved to be unfavorable due to the sun's course. In order to produce their own electricity, photovoltaic cells have found a place on the roof of the building. Another important point during the design process was the surroundings of the building. The space between the buildings is to be used as a park with large water surfaces which provide a cool, pleasant air due to the evaporation of the water.

5. Design

With the design it is possible to access the various types of use of the rooms and to react to the needs of the occupants. The following façade designs are possible for the optimization of the room climate:

- Balconies, with Lamellas/Greening
- Vertical shading, by Lamellas/Greening
- Recessed bays

There are also critical areas where sufficient daylight must be provided. Special Lamellas have been designed for this variant, which reduce the solar radiation and at the same time allow daylight to pass through. More information about this design of lamellas can be found in the chapter on Shading.

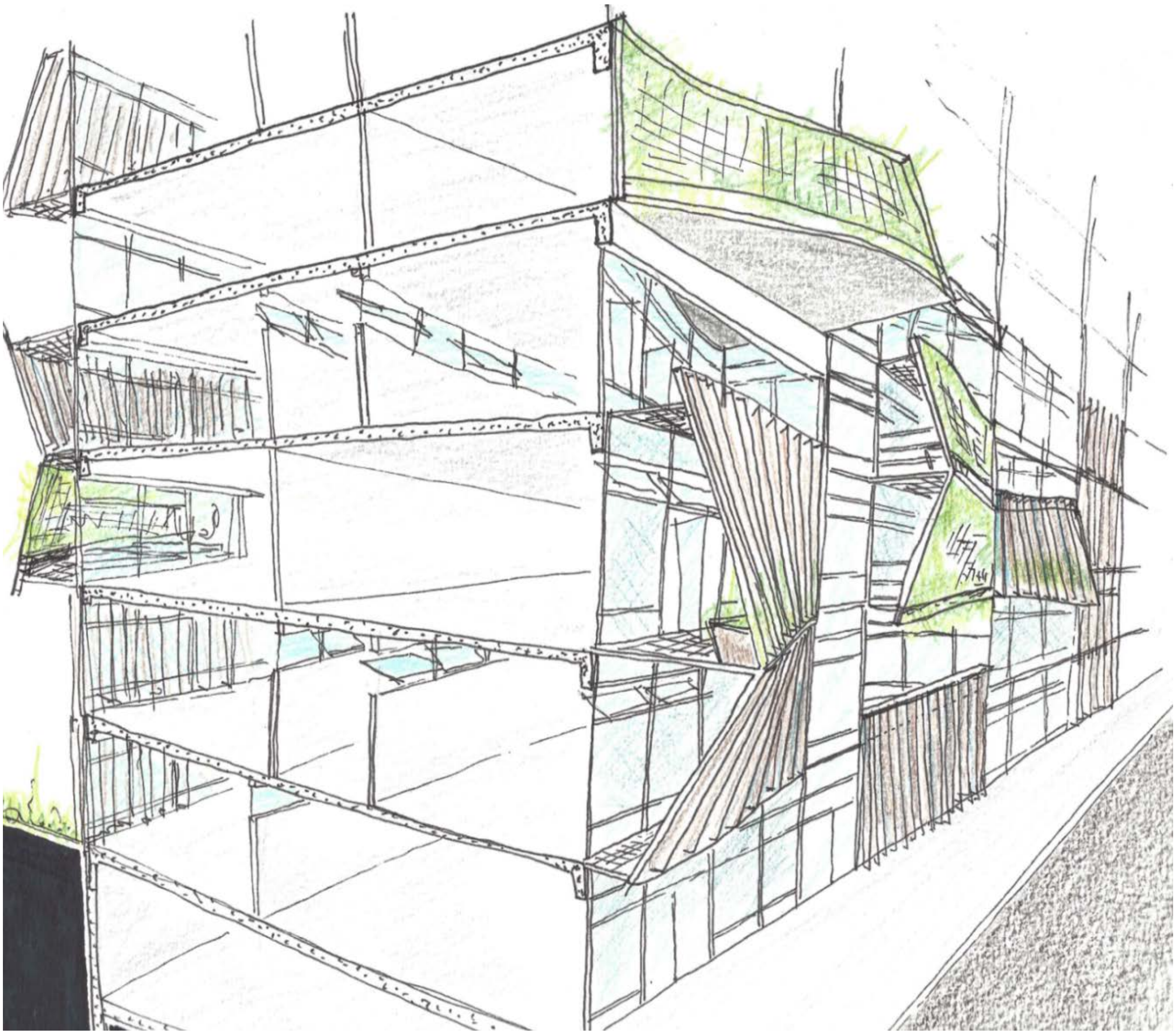


Figure 19: Design concept for retrofit of the ministerial building in Brasilia

Balconies are used in areas where it is beneficial for users to spend time outside. This applies to the sitting rooms (offices, meeting rooms, and kitchen) as well as to traffic areas which lead along the façade. In the areas where it is necessary to completely shade them, vertical shading elements are placed directly on the façade. The lamellas serve as variable systems, which allow the solar radiation and daylight to be controlled automatically and manually. Green sections are only used if the room behind is not or only partially dependent on a daylight supply. Another option of shading is to cut out of bays by moving the façade backwards. Due to the high depth of the room, this is a further variant for meeting rooms. The recessed bays have a railing, so it is possible to use this area as an additional place to stay outside.

The following table shows in which areas of space use which façade structure is useful:

Table 1: Legend of the façade structure

Use of space	Balconies with lamellas	Balconies with greening	vertical lamellas	vertical greening	recessed bays	critical area for daylight
Office	x		x			x
Meeting room	x	x			x	
Kitchen		x				
Sanitary facilities				x		
Storage room				x		
Corridors		x	x	x	x	
Stairwell			x	x		

The view of the East façade shows a possible division of the façade structure. The sections of the critical areas for daylight are not shown. A final version is to be defined in collaboration with the architects.

Figure 20: View of the façade structure

6. Environment

The wide streets in the government quarter are made for cars. No one wants to spend time and space here. The district offers a lot of space, but no places that invite the users of the buildings to spend their time. The many cars and the asphalt support the heating up of the environment. To create a more comfortable climate, one part of the concept is to transform the area between the individual government buildings into a parkland. Trees and bushes provide shade and lakes serve as cooling by the evaporation of the water. The higher water vapor content of the air reduces the solar radiation and the lakes can be used as a catch basin for rainwater.

For the cars of the employees underground garages are designed. By the fact that the cars are parked under the ground, they no longer radiate heat and do not heat up by themselves during the day. This has advantages for humans as well as for the environment.

The goal for the users of the buildings is to spend their lunch breaks outside. The time should serve as a recreation and lead to new energy for the remaining working hours. A balanced range of living space and areas to rest and relax help the user to work productively.

Figure 21: Overview of the environment

7. Shading

The shading of the two façades probably has the greatest influence on the optimization of the building. A shading of the glass surfaces is achieved in the design by different measures. On the one hand, balconies are attached to the façade, which provides shadow by their distance to the façade, on the other hand areas of the façade are recessed and the shadow of the building parts lying over is used. The façade is additionally protected by Lamellas from solar radiation. Parts of the building that do not require daylight are completely shaded by greenings.

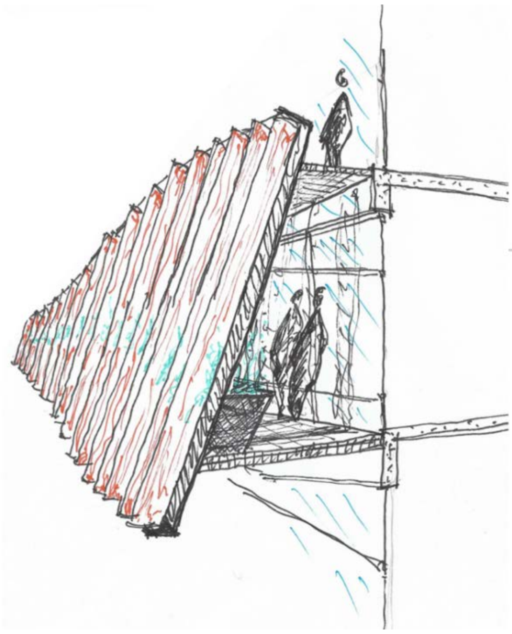


Figure 22: Section of a balcony with vertical lamellas

In addition to the visual effect of the lamellas, which loosen the façade and contribute decisively to the new appearance, they also have an energetic effect. The biggest problem of the building is the heating up of the workspaces by the direct sunlight and the complete glazing of the building. The lamellas are to reach the maximum of sunlight with a simultaneous minimum of solar radiation. Due to the automatic control of the lamellas, they always align themselves at the optimum angle to the sun. However, the automation can be overruled at any time by the user, for example if more sunlight is desired. The system takes over automatically again after some time to avoid an overheating of the building. Two different types of lamellas are used in the design.

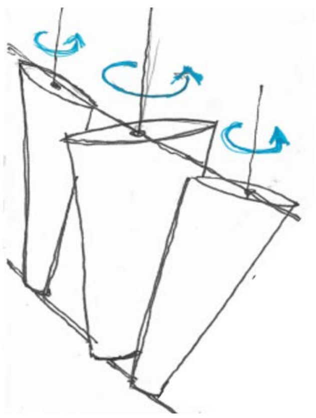


Figure 23: Rotated Lamellas

The normal Lamellas are used for public areas such as meeting rooms, kitchens or sanitary facilities. These are all manufactured in the same way and permit almost complete shading of the glass surfaces when it´s exposed to direct sunlight. They are linear, monochrome and always equidistant. They are installed everywhere in the building where the natural light input does not have to be as great as the people there are only briefly there.

For the offices and working places, the critical areas, special Lamellas are used. Two things are of great importance for the workspaces. On the one hand, overheating of the room must be prevented and, on the other hand, it should not be completely shaded. A certain amount of natural light contributes to well-being. The lamellas must therefore fulfill two opposing functions in these areas. They need to spend enough shadow and provide enough daylight at the same time. For this reason, the lamellas are twisted 90° in themselves. Thus, the lower part of the window surface can be completely shadowed, while the rotation of the lamella in the upper part causes enough light incidence. The Lamellas are twisted in such a way that over the working height a complete shading can be present, which protects the occupant from direct sunlight. To further enhance this effect, the lamellas are provided with a color gradient. The lower part of the slats is painted in a light absorbing color like natural wood, while a reflective white is used in the upper part.

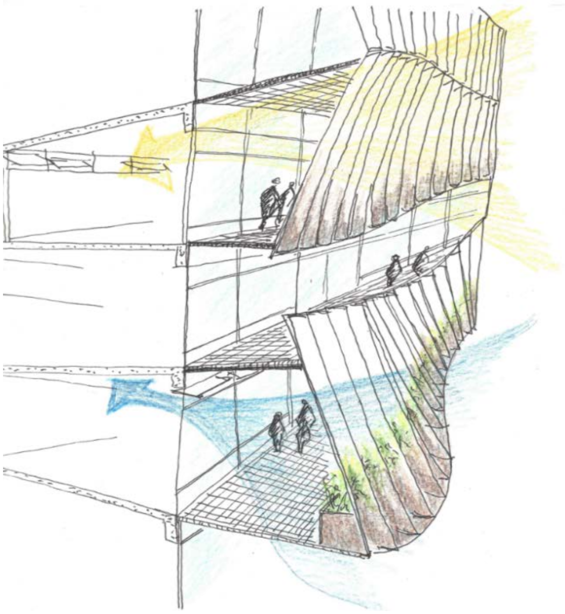


Figure 24: Permeability of the Balconies

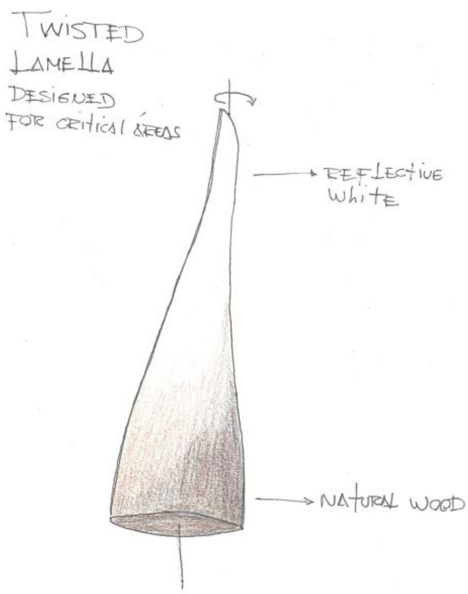


Figure 25: Twisted Lamellas

Not only the lamellas spend shadow to the building but also the balconies as such. The expansive shape of the balconies shades the windows below. The balconies have a minimum distance of 2 meters and a maximum of 5 meters to the façade. This creates attractive areas for the user. The same effect is achieved by the recessed areas. Areas of the building which do not require any natural sunlight, such as server rooms, storage areas or similar, are completely shaded. The shading is made possible by a complete greening of these areas.

8. Energy | Ventilation

In addition to the shading of the glass surfaces, ventilation also plays an important role in the energetic optimization of the building. Until now, ventilation of the building was only possible during the period of use from 8 am to 6 pm. During this time, the outside temperature is already so high that cooling of the building cannot be achieved by the ventilation. A cross-ventilation of the building was also not possible so far, since the two building halves were separated from each other by the corridor in the middle. In the design, these points are improved to contribute to the cooling of the building and to a pleasant room climate.

To ensure that there is still enough air to reach the façade, the façade elements and balconies are designed very open. For example, the flooring of the balconies consists of a grating grate, which is not a resistance to the air. Due to the large distance between the shading elements and the façade, a jam of warm air between façade and the lamellas is avoided. The air can circulate freely in the areas in front of the façade.

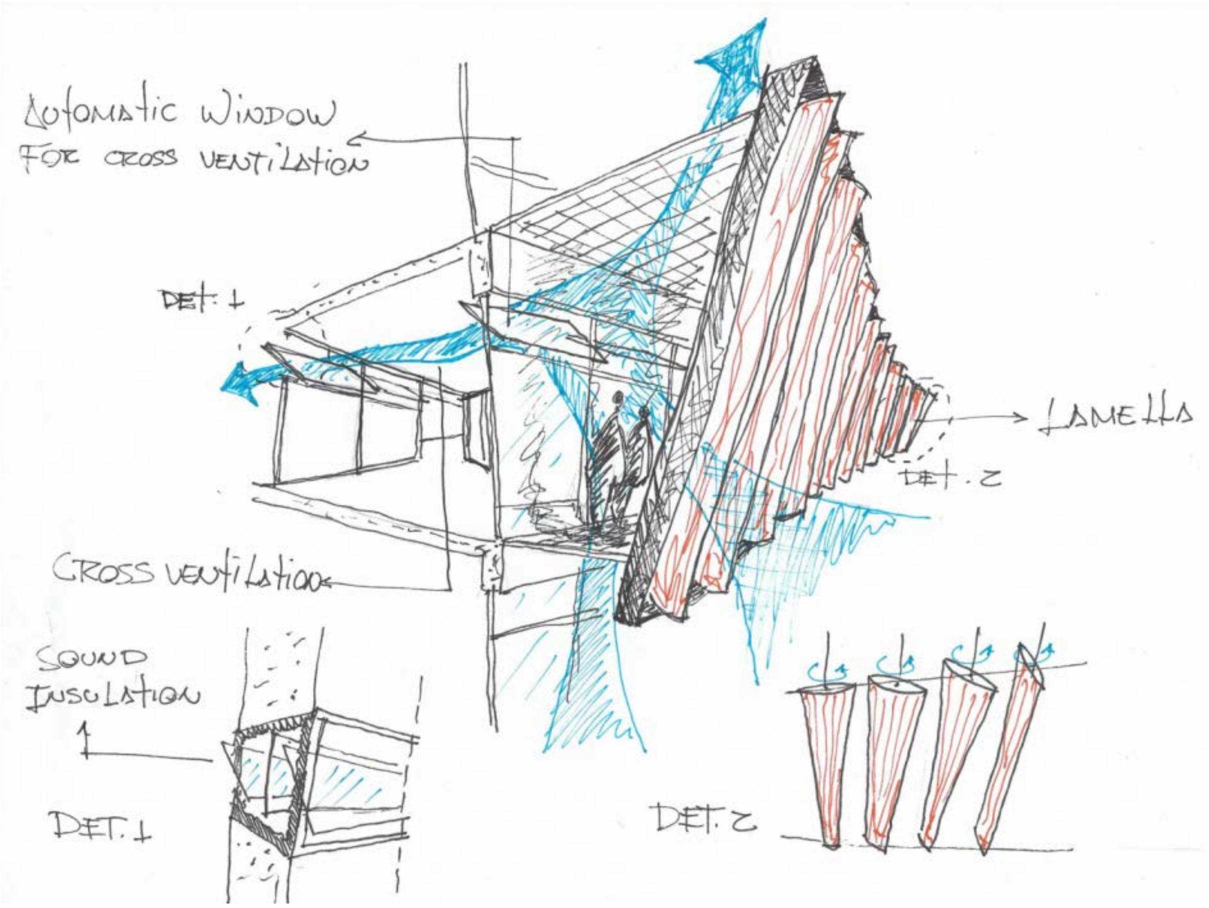


Figure 26: Ventilation System of the building

For a sufficient ventilation of the building, as well as a daylight supply of the corridors, small windows are inserted into the corridor walls. Per office two windows are openable to provide an air flow while the other Windows are fixed. The air can flow in the one side of the building and exit again across the hallway and the opposite offices on the other side. In order to avoid noise transmission from the vaults to the corridor through the windows in the corridor walls, special noise reduction devices are used. This is a system similar to a silencer, which allows the air to flow through the window via detours. Thus the air can cross the opening, but the sound is reflected in the interior of the system and loses in intensity. The opening and closing of the windows is automatically controlled with a mixed mode system. The windows are mostly open at night to cool the building with the cooler air from the outside. The cross-ventilation during the day is kept to a minimum as the outside temperature is too high and would heat up the building. However, ventilation during the day is still important to maintain the minimum air exchange rates of 1 / h and to supply the rooms with sufficient fresh air. A cross-ventilation of the building takes place mainly outside of the times of use, in order to reach a maximum of cooling performance. The automatic opening of the windows is always overruleable by the user, but the system also takes over the control again after a certain time.

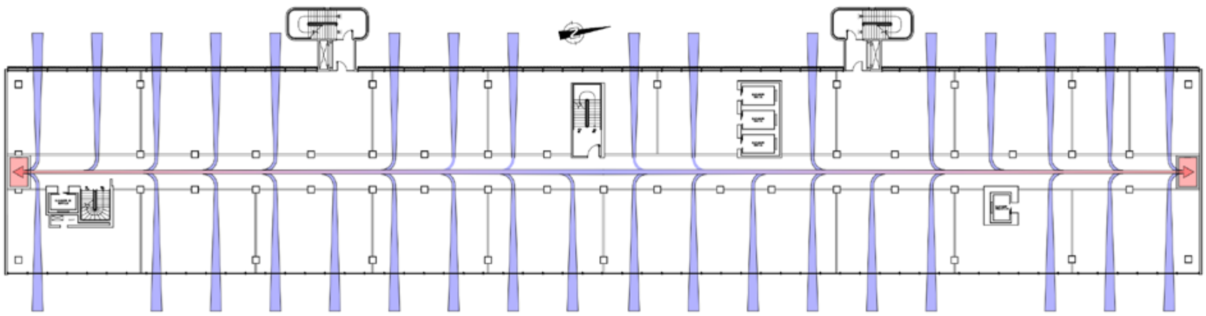


Figure 27: Solar Chimney - Ventilation - Ground Plan

Two solar chimneys are installed in the building to enhance the ventilation effect. These provide increased ventilation of the building by using simple physical effects of warm, ascending air. The chimneys are arranged on the north and south side of the building, in the axis of the corridor and run within the building up to the roof. On the top of the roof, the chimney is constructed with massive walls. These are coated with a special black, sun-absorbing color. This results in an extreme heating of the upper part of the chimney during the day. The massive construction allows to store the heat and use the energy at night. Outside the time of use, the automatically controlled windows are opened and the cold air can enter the building. Through the stored heat in the upper part of the chimney, the cold air is channeled into the building and rises above the chimneys and finally reaches outside the building. Sufficient air exchange takes place outside the times of use and the building cools down. During use, the air supply to the chimney is closed on each floor so that no warm air is channeled in from outside and no vacuum effect can occur.

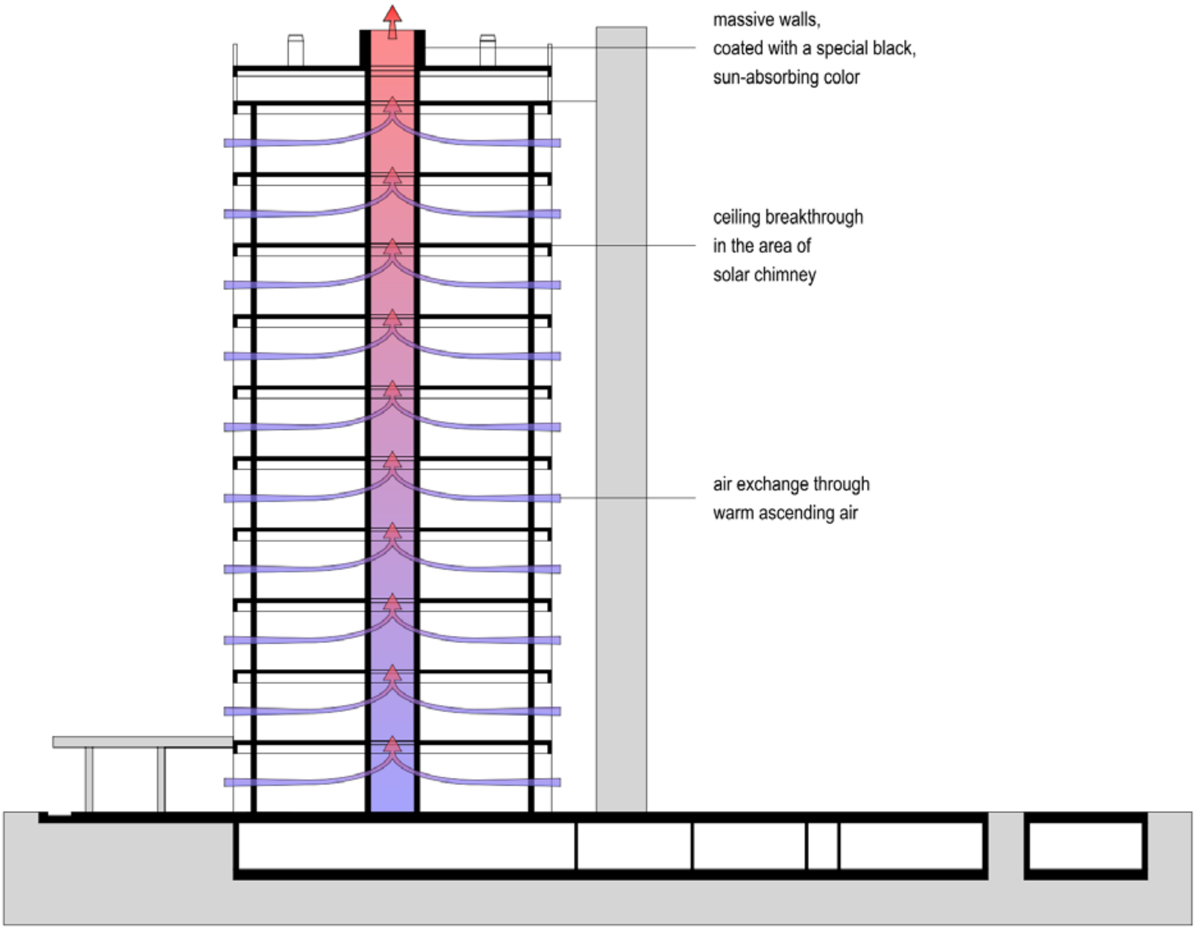


Figure 28: Solar Chimney - Ventilation - Cross Section

On very hot days, overheating can occur despite the nightly cooling and almost complete shading of the building. Compared to the original building, these days could be kept to a minimum, so that cooling the building with air conditioning is only necessary at peak hours. The energy to operate the systems is generated by the PV-System on the roof.

9. Green Areas

Multiple positive effects can be achieved with building greenings. For example it can serve as a protection for the building itself and simultaneously improve the air quality and regulate the humidity.

A green façade has a positive influence on many things:

- Improving the climate
- Protection against UV radiation in summer and prevention of building heating
- Insulating effect in winter
- Absorption of sound and carbon dioxide
- Discharge of the sewer system in case of heavy rain due to water retention
- Creating natural liveliness, without negatively affecting the appearance of the building

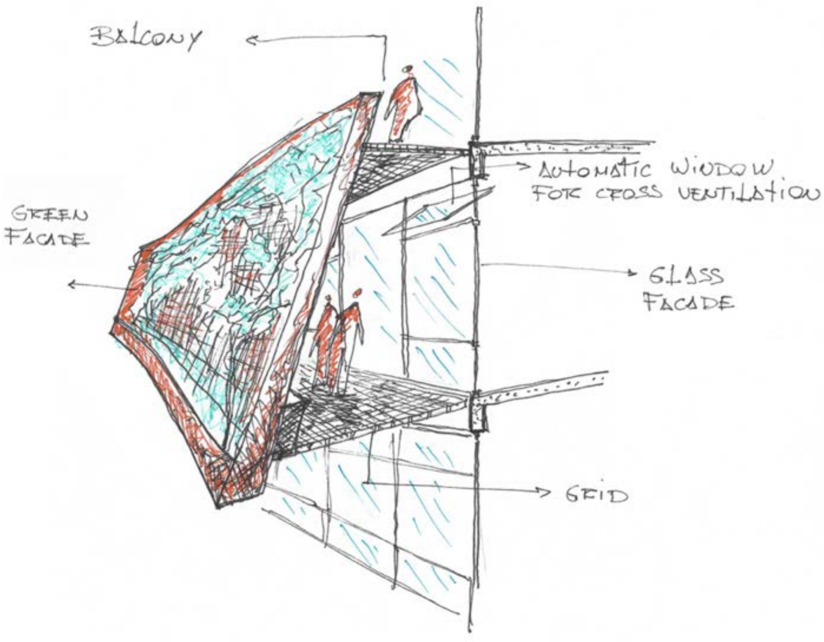


Figure 29: Green elements on the balcony

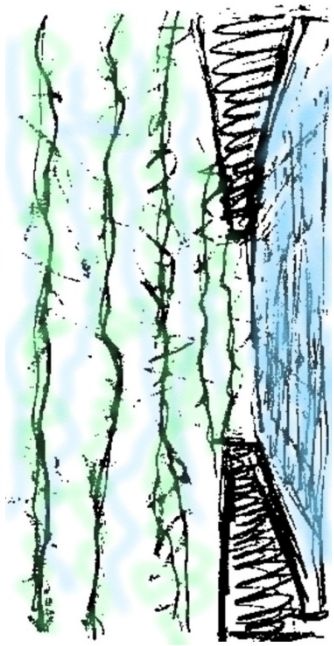


Figure 30: Green façade

The façade greening is not ground-based; it is planted in suspended vessels. In areas of the building, which do not require much sunlight, such as laundries and storerooms, the façade greening is applied all over the closed walls. In areas where partial shading is possible (e.g. meeting rooms, kitchen), the greening is to be installed as a transparent hanging structure in front of the windows or on the balconies. The plants filter the daylight, serve as visual protection, actively contribute to the air-conditioning of the rooms and ensure a clear improved quality of the air. Also the content of dust and dirt in the air is reduced and in contrast to large trees they do not obscure the environment and take no place on the road or the walkway. The plants are selected in such a way that a changing image of color and density is produced over the course of the seasons.

Through a walkable roof greening, an additional resort is created for the occupants. Unlike conventional roof terraces, roof greening contributes to thermal insulation and supports the roof drainage. Not greening roofs are exposed to extreme weather influences without protection. Greening can almost double the lifetime of a flat roof by reducing climate and environmental influences. A green roof has a sound-proofing effect, protects against the heat in the summer and improves the thermal insulation in the winter. The roof greening offers numerous advantages. It is not only nice to look at, but also practical. The roof greening is an optimal enrichment and expansion of the office building.

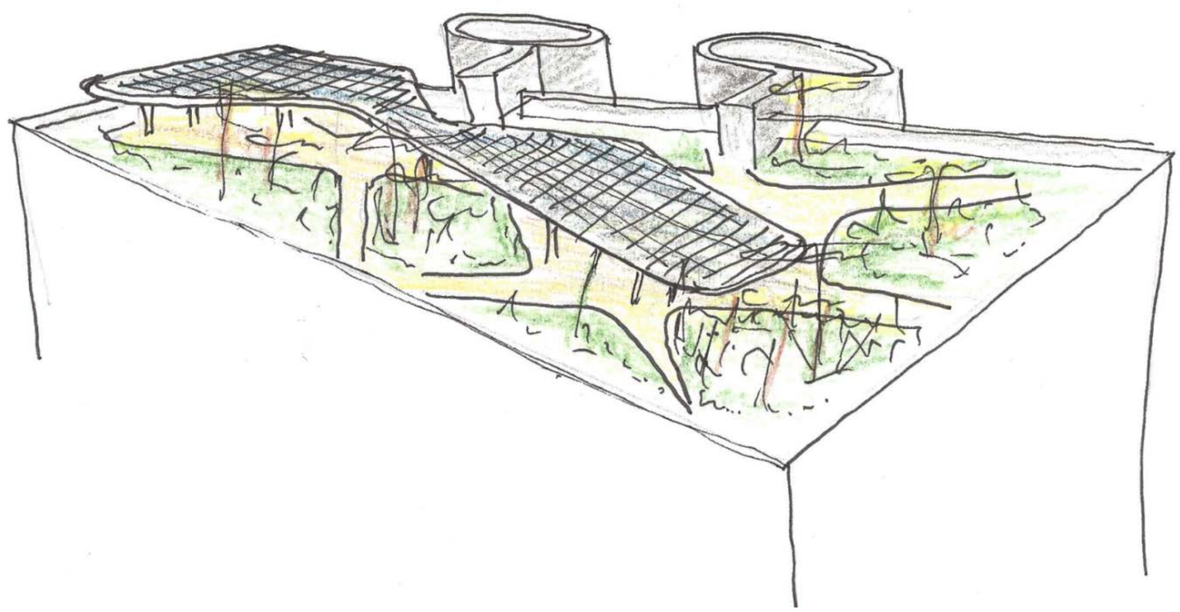


Figure 31: Design of a green rooftop

To protect the occupants from direct sunlight, a solar roof is installed on the roof. The terraced roof creates a cool and shady place to stay and on the top the solar cells converts the incident sunlight into electric energy which can be used. These solar modules offer excellent sun protection and at the same time they are so transparent that they do not shadow too much.

10. Pre-Dimensioning

10.1 Room Comfort

With the help of the evaluated weather data of the location analysis, the critical area with regard to the overheating and/or the summer heat protection could be determined. The relevant room for the further analysis depends on the solar radiation and the hours the room is exposed to the sun. Brasília is located on the southern hemisphere, for this reason the sun rises in the east, runs across the north and goes down in the west. The strongest solar radiation is in the afternoon and comes from the North West. This means the room must be located in the northern part of the building. In addition, the room is on the upper floor, this area will heat up faster than the ground floor. Furthermore, the afternoon sun is worse than the morning sun. In the afternoon, the building has already warmed up and is now heated further by the afternoon sun. For this reason, a room is selected on the 9th floor, on the western side of the building for further analysis. The chosen room has two external façades. The northern exterior façade consists of Ceramic Bricks with mortar on both sides and external ceramic tiles. The western façade consists of a full glass façade.

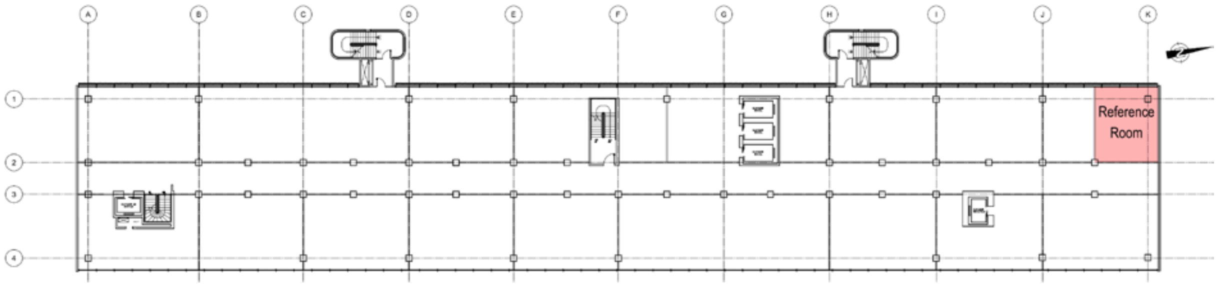


Figure 32: Selected reference room

According to the documents about the use of the building, the following internal charges result. The office space is occupied on average with 6 people per office. The energy input from the occupants is about 80.00 W, which is an average value and is taken from the literature. The energy input in relation to the office area is determined below:

Table 2: Energy input in relaton to the office area

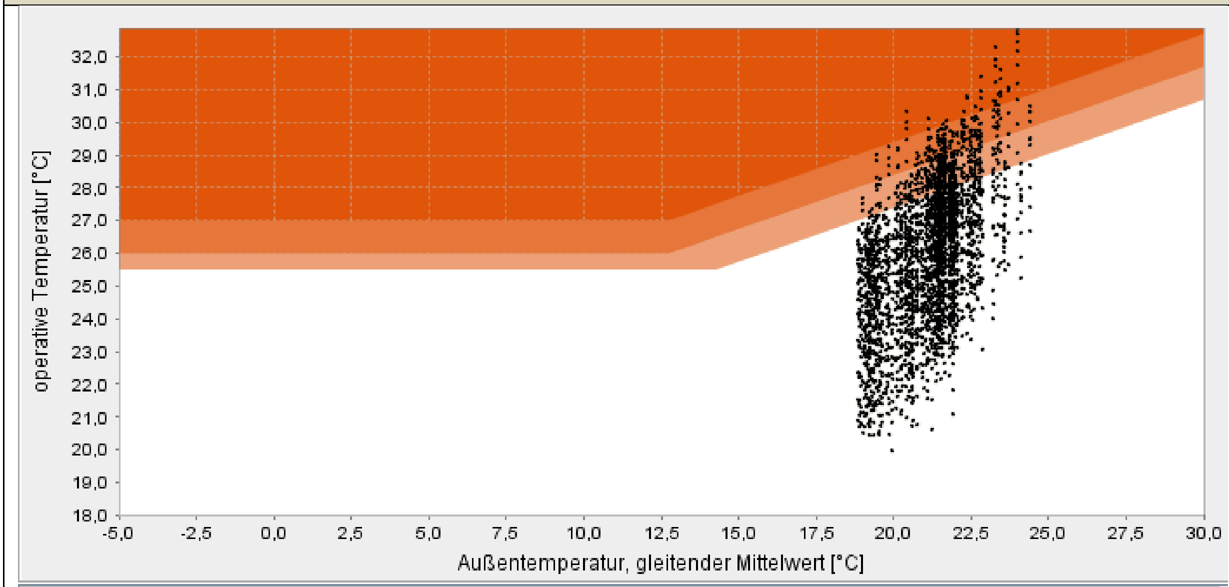
Group Office				
Internal Energy inputs	Pcs.	Energy input [W]	Area [m²]	Energy input [W/m²]
occupants	6	80,00	38,25	12,54
Lighting				7,90
equipment				19,40
			Total input	39,84

Below is a comparison of the initial situation with the optimized version in the workshop. The table shows the optimized parameters. The calculations were carried out with the program "Primero-Komfort". In essence, the ventilation strategy of the building was optimized as well as the insulation of the external walls and the glass used in the façade. In addition, the building allows the possibility of cross ventilation, which leads to a cooling down of the building just outside the times of use. Furthermore an external shading system was added to both sides of the building.

Table 3: Comparison of the initial situation with the optimized version

1. utilization		
	old	optimized
main use	Group usage (group office)	
acreage	38,25 m²	
Occupancy	High (7 W/m²)	
Equipment	High (18 W/m²)	
Lighting Density Power	High (15 W/m²)	
Energy input	39,38 W/m² (calculations with 40,00 W/m²)	
2. ventilation		
Natural ventilation		
Within period of use	Yes	
Outside period of use	No	Yes (22 to 06)
Cross ventilation		
Within period of use	No	Yes
Outside period of use	No	Yes (22 to 06)
Mechanical ventilation		
Within period of use	Yes	Yes (peak hours)
Outside period of use	No	
3. shading systems		
Inside/outside the building	Outside Directly in front of the window	Outside With distance to the window
Closed when	When sun is shining	When sun is on the façade
4. Insulation		
Windows	U-value 5,90 W/m²K	U-value 1,20 W/m²K
External walls	U-value 1,80 W/m²K	U-value 0,20 W/m²K

5. Results with Primero Komfort



Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]									
	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	1891 / 66%	34%	2433 / 85%	15%	2682 / 93%	7%	-
1	-	-	2083 / 73%	27%	2643 / 92%	8%	2818 / 98%	2%	-

As the graph shows, the situation within the building has improved. The ventilation strategy has the greatest influence on these improvements. Ventilation is now also taken into account outside the usage times. This allows the colder air to cool down the building during the night. It is controlled automatically, so that none of the occupants has to worry about it. With the help of the climate analysis, a time window from 22 o'clock in the evening to 6 o'clock in the morning is provided for ventilation. During this period the air temperature is the lowest. In addition, shading was taken into account in the calculation, which also has a great influence. Finally, the existing windows were replaced by new windows with a better U-value just like the exterior walls get insulation. This helps the building not to heat up so quickly and keep the cool air of the night in the building. With the changed parameters, the transgression within the second comfort category could be reduced from 15% to only 8%. Due to the fact that some ideas of the concept (e.g. chimney function, evaporation cooling of the green façade) could not be considered in Primero, it can be expected that the optimization will be even better.

10.2 PV-System

As already described in the concept, the roof of the building is to be partly equipped with a photovoltaic system (PV-System). The above-described optimization of the building is expected to result in a significant reduction in the energy consumed. The air conditioning systems used by the occupants are replaced by a general ventilation system for the entire building. In addition, a cooling of the building is only necessary at peak hours. The goal is to cover the electricity consumption caused by the cooling of the building by the photovoltaic system.

From the existing analysis of the building, an average consumption of the building of about 223 297.4 kWh per month emerges. This electricity consumption includes all the power sources of the building. An average office building without air conditioning needs about 65 kWh/m² per year. For a building with 10 floors and a floor space of about 1800 m², the following energy consumption results:

$$65\ \frac{kWh}{m^2} \cdot 1800\ m^2 \cdot 10\ Storey = 1\ 170\ \ 000\ \frac{kWh}{a}$$

For each month: $$\frac{1\ 170\ 000\ \frac{kWh}{a}}{12} = 97\ 500\ \frac{kWh}{month}$$

If this value is deducted from the current electricity consumption of the building, the electricity consumption which is generated by the air-conditioning system remains about:

$$223\ 297{,}4\ kWh - 97\ 500\ kWh = 125\ 797{,}4\ \frac{kWh}{month}$$

Through the optimization of the façade and shading elements it is assumed that the consumption, caused by the conditioning systems will be reduced by about 80%. The energy required is:

$$125797{,}4\ \frac{kWh}{month} \cdot 0{,}2 = 25\ 159{,}48\ \frac{kWh}{month}$$

The goal is to generate the amount of Energy, which is needed by cooling the building, with the PV-System installed on the roof. Since the cooling is only needed at peak hours on some days in the month, and the PV-System constantly produces Energy, the excess energy is fed into the Brazilian power supply system. In Brazil, the surplus energy can be fed into the public power supply system and reused at a later stage. So you don't need to save the produced energy. In the following, the energy produced by the PV-System is calculated.

Two-thirds of the roof area is available for the PV-System. With an area of 1800 m², this gives an area of:

$$1800\ m^2 \cdot \frac{2}{3} = 1200\ m^2$$

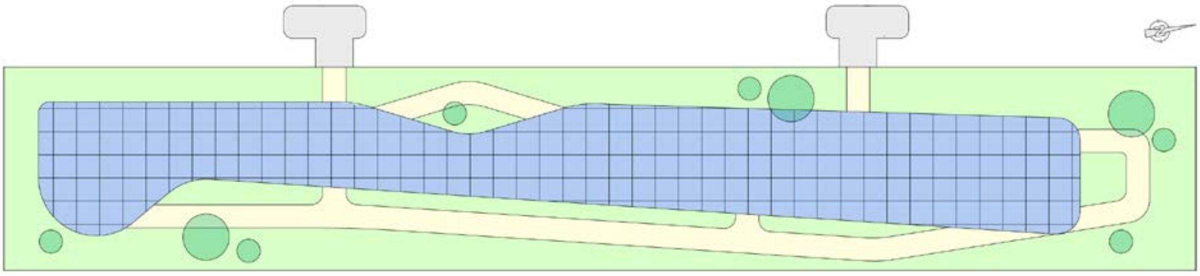


Figure 33: PV-System on roof

The sun is very steep throughout the year. The angle of the solar radiation is almost vertical on the panels. In the figure it can be seen that the sun, especially in the Brazilian winter, is slightly inclined towards the north. For this reason, the photovoltaic panels are tilted 10 ° to the north. Since the sun rises in the east and sinks in the west, the panels are not tilted towards the east or west. This ensures that the maximum solar radiation can be captured by the panels and thus the output of electricity is maximized.

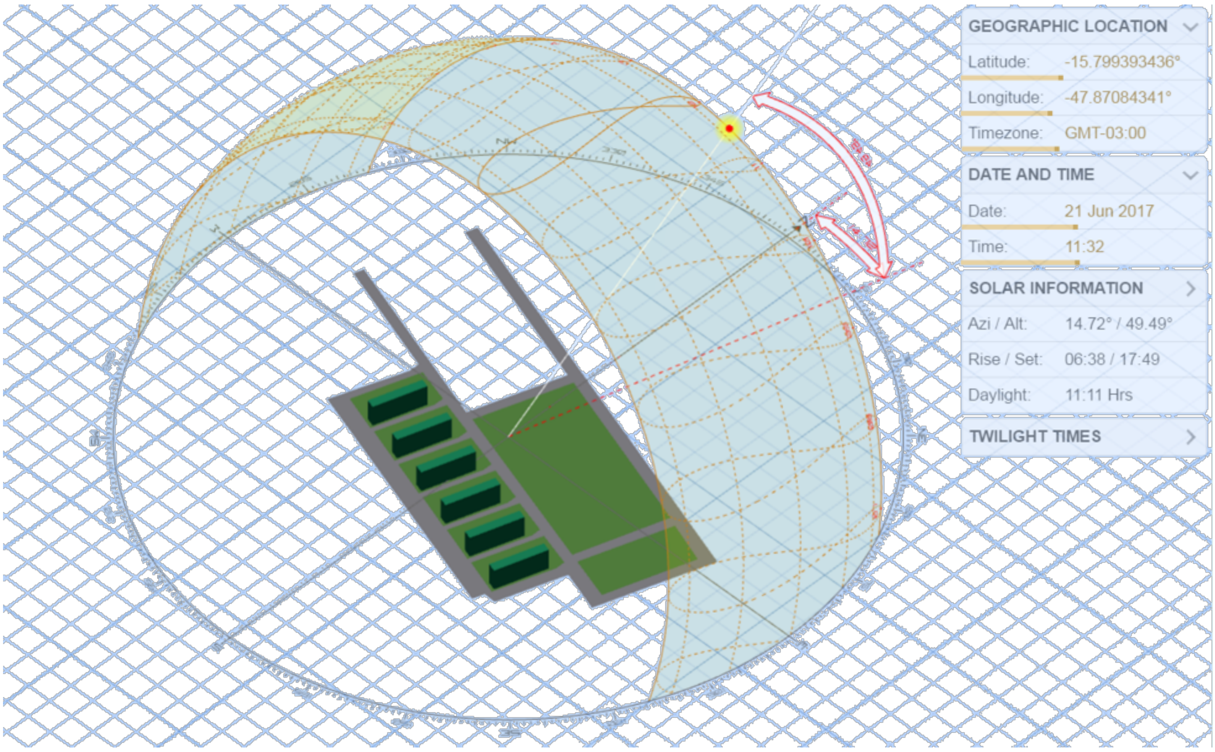


Figure 34: Sun-Path of Brasília [14]

The installation shall be carried out as follows:

- Installation on the roof
- Mounted slightly inclined towards the north about 10°
- Panels with monocrystalline silicon cells

The calculation results in a coverage ratio of 80%. The exact calculation can be found in the appendix. The following graph shows the utility of the system.

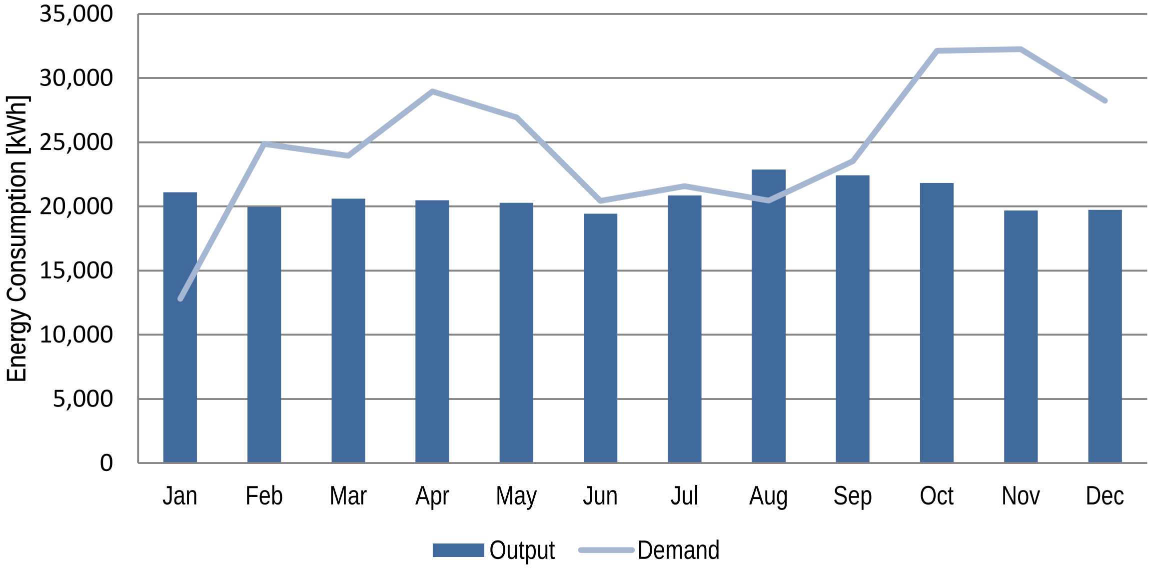


Figure 35: Energy Performance of the PV-System

The degree of coverage could be further improved by increasing the area of the elements. This is a design decision and must be well thought-out. With a full scale design of the photovoltaic cells, coverage of 99% could be achieved.

Due to the high solar radiation and the large existing roof area, it is almost possible to cover the energy requirement for cooling the building with the PV-System. It remains ultimately a concept question whether the roof terrace should be completely roofed or not.

11. Conclusion

With the design, the team has managed to optimize the building not only energetically but also to make it even more interesting in its appearance. The design elements such as the lamellas, green areas within the façade as well as the balconies and recessed bays contribute to the shading of the window surfaces and thus reduce the amount of solar radiation entering the building. Due to the solar chimneys and the automated control of the window openings, it is possible to cool down the building significantly. The building can now be supplied with sufficient fresh air.

Through the roof terrace as well as the large balcony areas, places are created where you can stay and enjoy the time. A park between the buildings invites people to spend their lunch break outdoors. The work-life balance is significantly improved with the design. To achieve these improvements, however, some effort has to be spent. The technical installations for controlling the shading and ventilation systems must be maintained at regular intervals. Users of the building must be trained to avoid unnecessary ventilation or a too late shading of the windows. The users of the building themselves have a great influence on the functionality of the concept.

The result of the energetic evaluation of the idea shows that the effort is worthwhile. Many problems can be improved or even eliminated altogether. A much better working environment will be created, which will also lead to increased employee productivity. The investment and the effort that has to be taken to achieve the improvements is low compared to the gained benefits.

The workshop was a very interesting exchange between the Brazilian and German participants. The different approaches and perspectives have contributed to the development of new ideas and concepts. Not only the professional cooperation also the get-to-know with the new people from other countries are an enrichment.

Figure 36: Team of Brazilian and German students

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Design concept for retrofit of the ministerial building in Brasilia

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Prof. Dr.-Ing. Frank Wellershoff

Abstract

Retrofitting – Modernize a building for today's standard. This is the keyword for the whole project of the Brazilian Summer School 2017. The task was to design a retrofitting concept for an existing ministry office building in Brasilia (capital of Brazil) which is currently no longer up to the requirements of the occupants regarding the comfort. The special orientation of the building, especially the facades with many windows, leads to a high exposure to solar radiation and heat input. The occupants defy this circumstance with air condition and shading the windows, so there is almost no daylight in the rooms. Out of these circumstances there is a high usage of energy and low level of comfort for the occupants.

Focused on these problems a sustainable retrofitting concept was designed (by two Brazilian architecture students and three German civil engineer students) and is presented in this work. The sustainability of the retrofitting is one of the main emphases, but on the other hand to keep the shape and character of the existing building is part of the design. Out of these two points the idea of the **"green niemeyer"** was born. A combined system for the long facades of the building out of green elements (for cooling) and moveable lamella systems (for view and shadow at the same time) is the solution. To keep the sustainability a combined façade system with utilization of rainwater to irrigate the green façade elements is the solution. For cooling the building a natural night cross ventilation is designed, but due to climatic conditions it is not possible to avoid the air condition at all.

To make the whole concept complete a rooftop with a photovoltaic system for the lack of energy and added green roof elements is part of the design. The analysis shows up how much energy and water could be saved by adding these sustainable parts.

1. Location

1.1. Brazil

The state Brazil is situated in southern hemisphere and is the biggest country of Southern America and the fifth-largest country of the world. It borders on ten different countries and is separated in 26 federal state plus the district of the government. Because of the dimensions of Brazil there are two different time zones and seven different climate areas.

1.2. Brasilia – The capital of Brazil

Before Brasilia became the capital of Brazil in 1960, Rio de Janeiro had been the most important city of the country. Ten years before due to a change of the capital the government wanted to set a new point of view for every inhabitant to look forward and leave the historical association of Rio de Janeiro - time of colonialism - behind. The new capital should stand for neutrality, federalism and the economic strength and progress of the country. To get the best result the government gave Lucio Costa (urban planner) and Oscar Niemeyer (Architect) the task to work on a concept for the new city, which appears in the nineteen-sixties out of nowhere. The urban design was centered on the building of the National congress as the most important edifice of the government district so that the central axis of the city is orientated to this building (Figure 1).

The idea of a new capital which should be the face of the "new" Brazil and a symbol of equality is not implemented as well as envisioned. The combination of futuristic buildings for offices as well as working

Figure 1: Urban design of Brasilia from Lucio Costa

space and the building made with precast concrete slabs for flats as place to live, did not fit together because after the opening ceremony the capitalistic way of thinking dominated the rental prices so that Brasilia got the face of a typical Brazilian city with a lifeless, rich city center and an over populated poor periphery called favela. [7]

1.3. Climate Analysis

To identify the climate regarding the method of Köppen-Geiger it is necessary to analyse the relevant climate data from the EnergyPlus weather data file. The relevant data for this are temperature and the precipitation. Furthermore, there has to be an analysis of the humidity, the relevant wind speed and directions and the solar radiation to be able to evaluate the favorite concept from the workshop.

1.3.1 Temperature

The following diagram (Figure 2) shows the run of the outdoor temperature during the year. There are two different sum of data which belong to each other. The light grey graph shows the outdoor temperature of each day from the whole year, whereas the red one sums up the data from one month to get a more harmonic series of data. The maximum of the outdoor temperature per month is in February (22.79°C) and the minimum is in July (19°C). The yearly average is about 21.53°C. The hottest day of the year is 25th September (25.53°C) whereas the coldest is 17th June (16.54°C). The data shows a monthly run which is a little bit influenced by two seasons. This is typical for a climate near the equator where the dry and wet period dominates. Even though the average from the year is below 25°C which is rule of thumb to classify climate data for tropic conditions Brasilia belongs to the tropic climate because you have to consider that the capital of Brazil is 1158 m above the sea level. [8]

The next sum of data is the comparison from day to night temperature. This is needed to evaluate the cooling concept which is explained in Chapter 3.3. Figure 3 shows the run of this data separated per day (light grey) and per month (blue). To get a feeling for this kind of diagram you have to define how

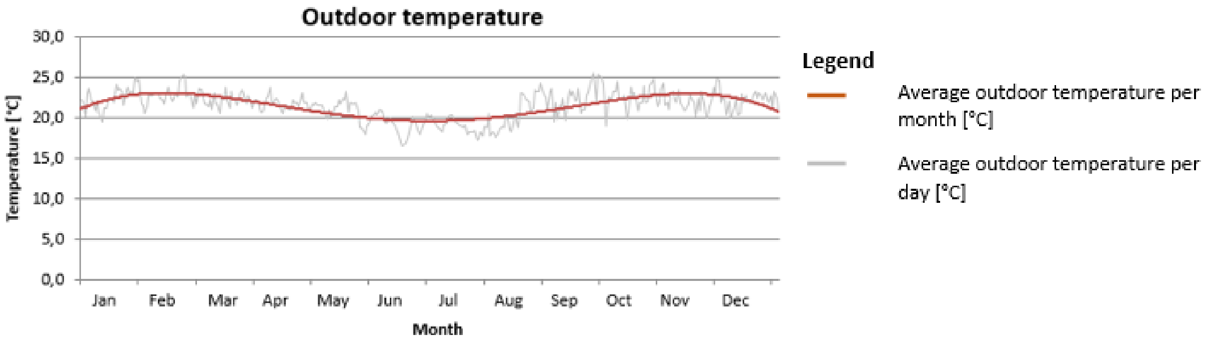


Figure 2: Outdoor temperature

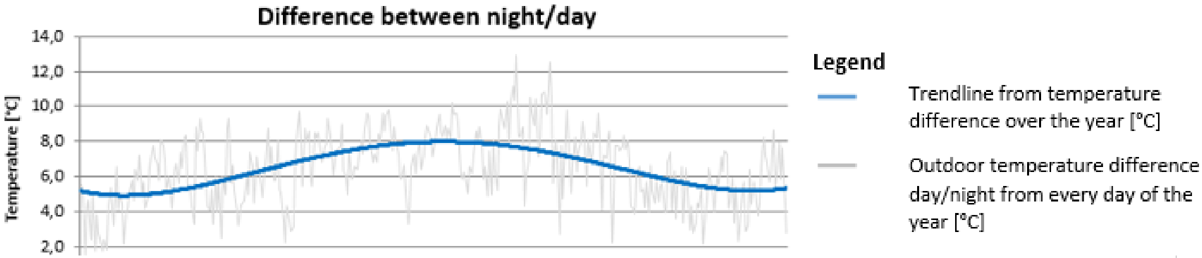
long is the day and the night. For this diagram the following periods were defined

Night: 9 p.m. to 7 a.m.

Day: 8 a.m. to 8 p.m.

While regarding the data you can see that the differences of temperature between day and night during the Brazilian winter are much higher than during the summer. The maximum is on 13th August (12.89 °C). The smallest difference between day and night temperatures is on 3rd January (1.49 °C). [8]

1.3.2 Precipitation



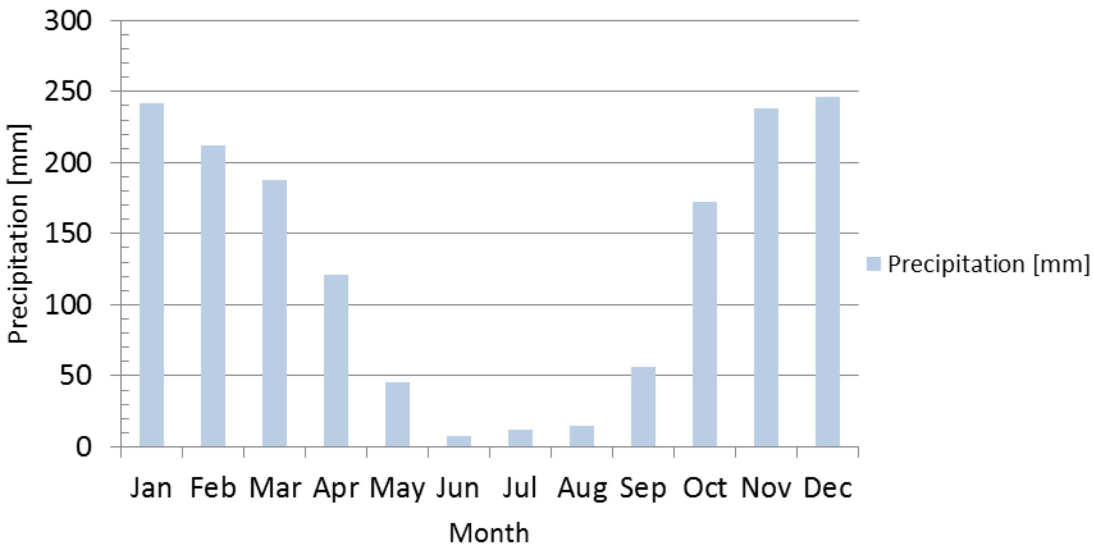


Figure 4: Precipitation over the year in Brasilia

The run of precipitation over the year is shown in Figure 4. Here you can see that there is a very wet period during the Brazilian summer with the highest value in December (246 mm) and a very dry period from April to September (Brazilian winter). This confirms the consumption that Brasilia is a part of the tropic climate from 1.3.1. In June the data shows us the smallest value of precipitation which is about 8 mm. The sum over year is 1555 mm. [8]

1.3.3 Humidity

On top the mentioned climate data it is necessary to analyse the humidity to get some information about conditions of the air during the whole year separated value per day (light grey) or per month (green). While looking at the run in Figure 5 it can be seen, that the lowest point during the Brazilian winter is a value of 42.83 % (18th August). The maximum of humidity is 94.63 %. This value is from 16th April. The yearly average is about 69.73 %. [8]

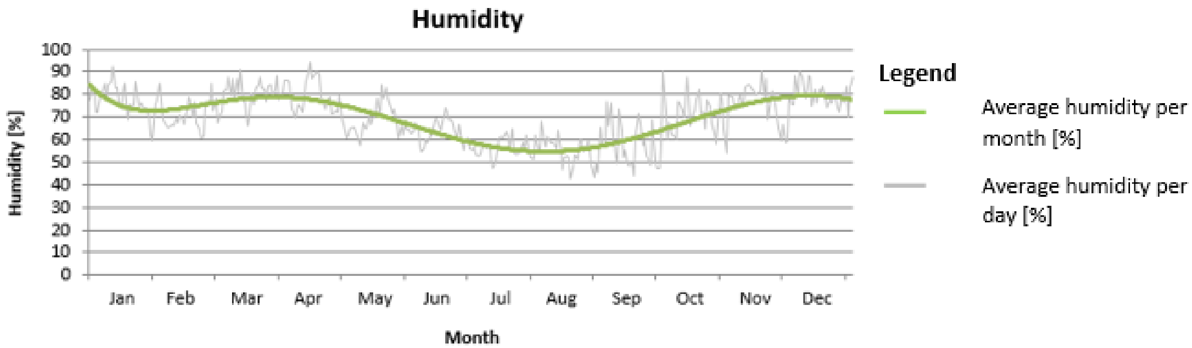


Figure 5: Humidity

1.3.4 Wind

The last data to analyze is the wind. Here you have to focus on the wind speeds and the respective direction without paying attention at the exact date. While looking at Figure 6 you will recognize that the dominant wind direction with the highest wind speeds is from the east. This is related to the dominated pressure areas during the different periods of the year. When you want to fit the shown data to the exactly date it will not be very easy to identify so that you can simplify the data and say that the highest speeds will occur in July but you cannot explain this to the Brazilian winter or summer because there are high wind speeds in February or November, too. [8]

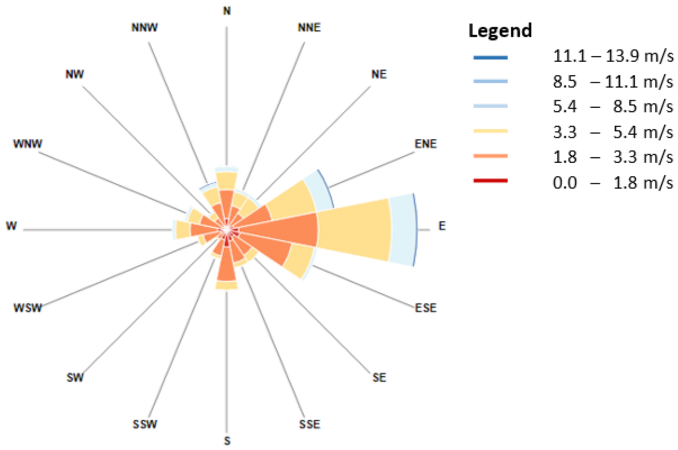


Figure 6: Windrose

1.3.5 Classification (Köppen-Geiger)

At first it is important to identify how to classify Brasilia in the meaning of Köppen – Geiger. For this it is necessary to check if Brasilia is part of a tropic area. The condition to check is if the mean annual temperature is above 18°C. Comparing this to the climate graph, Brasilia is part of the tropic area. So it is necessary to look for the right equatorial climate. The different opportunities are

- equatorial rainforest, fully humid (Af)
- equatorial monsoon (Am)
- equatorial savannah with dry summer (As)
- equatorial savannah with dry winter (Aw)

To identify the right it is needed to check different conditions

1.)	Af:	$P_{min} \geq 60$ mm	$P_{min}=7$ mm (Jun)	wrong
2.)	Am	$P_{ann} \geq 25 \cdot (100-P_{min})$	$P_{ann}=1668$ mm	wrong
3.)	As	$P_{min,summer}<60$ mm	$P_{min,summer}=163$ mm (Oct)	wrong
4.)	Aw	$P_{min,winter}<60$ mm	$P_{min,winter}=7$mm (Jun)	<u>right</u>

After this short analysis it can be stated that the local climate in Brasilia is an equatorial savannah climate with dry winter and a wet summer. During this classification it figured out that the summer in Brazil is from October to March and the winter consequently from April to September.

While looking at the climate graph it can be seen that there is a lot of precipitation during the summer. This is the result of a chain from ground-level low-pressure areas nearby the equator (near-equatorial trough or Intertropical Convergence Zone) which oscillate between the northern (21st June) and the southern (21st December) tropic. These troughs appear because of a lot of ascending air-current which lead to huge cumulonimbus. The result is a lot of precipitation and the opportunity of thunderstorms. During the Brazilian winter the near-equatorial troughs go to the northern hemisphere the subtropical high-pressure areas which dominated the climate of Paraguay and Argentina during the summer go to the north, too. For this reason the climate during the winter is dryer than the rest of the year. Furthermore, some ridges of high pressure generate some east winds, called southeast trade (high-pressure areas circulate effect in the southern Hemisphere the other way around than on the Northern Hemisphere) so that the climate is dominated by these trade winds. [10]

2. Building – MMA & MinC

The concerned object is one of 16 similar buildings which belongs to the district of the government of Brazil (Figure 7). In the inside of this edifice is the Ministry of Enviroment (MMA) and the Ministry of Culture. Oscar Niemeyer gave the building a shape of a building block. The dimensions are about 102 m long, 17 m wide and 42 m high.

Figure 7: View over the ministry district [5]

2.1 Orientation

Like mentioned in point 1.2 the whole city is orientated to the district of government. The ministry buildings are placed orthogonally to the central axis, so that the building is turned about 20° clockwise from the north. The result is that the two long facades orientated to the southeast and to the northwest. Consequently the shorter sides look to the northeast and southwest.

2.2 Construction

2.2.1 Structure

The object was built in a skeleton construction with slabs and beams out of concrete. The stiffing is guaranteed through internal staircases out of concrete. Additionally they installed two more external staircases on the northwest façade. All in all the building has ten floors and one basement.

2.2.2 Façade

The northeast and southwest façade are made out of bricks (thickness: 20 cm) over the whole high of the building, without any windows. On the outside there is a layer out of 1.0 cm ceramic tiles which are fixed due to 2.0 cm cement filler (Figure 8). On the inside of the brick walls they put 3.0 cm of mortar. On the other sides of the building you can find façade elements out of glass. These windows are made out of one 4.0 mm glass pane with one external metal film. Regarding the heat gains over the year they

Figure 8: left: east facade; right west facade of the ministry building [5]

installed some vertical shading devices on the northwest façade. An overview about the construction elements is shown in Table 1.

2.2.3 Overview – Construction elements

Component	Description	U-Value [W/(m²K)]
External walls	Ceramic brick with mortar on both sides and external beige ceramic tiles (0.26m)	1.80
Internal walls	MDF board / 6mm) + rock wool insulation (40 kg/m³) + MDF board (6mm)	-
Internal floors	Concrete slab (0.15m) with beige vinyl tiles	-
Internal ceiling	Thermal-acoustic mineral fiber lining (15mm), acoustic coefficient of 35 dB	-
External roof	Concrete slab (0.15m) with a metallic sandwich roof painted in white (air gap of 1.35m)	0.61
Glazing	West: 4mm glass with external metal film + operable overhangs East: 4 mm glass with external metal film	-

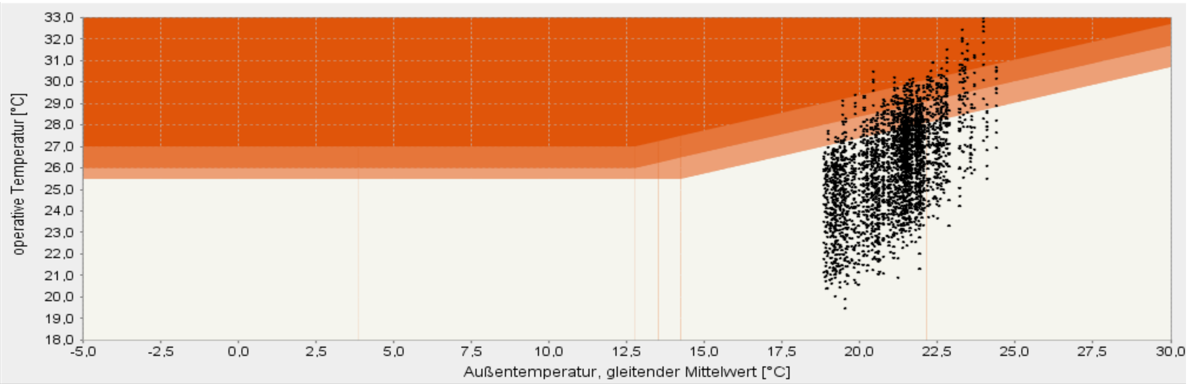
Table 1: Overview about the construction elements [5]

2.3 Problems

2.2.1 Overheating

Especially the room comfort is an important point in the building. To get a feeling for this an evaluation program called "Primero Komfort" was used, to analyze and to show the actual overheating hours. Unfortunately the program used norm standards from Germany but only to get a feeling it is applicable. The program evaluates the comfort in one room (group office). Therefore it was necessary to choose the worst room regarding the longest sun insolation and orientation. As the worst room a room in the 10th floor on the west side of the building with a shading system which adjoins the north façade as well was defined. After the input of the thermal loads from occupants, lighting and equipment (classification: high) and each constructional element (ceiling, walls, floor as well as windows with insulation glass and a frame ratio of 15 %) you have to add the technical systems (mechanical air condition over the day, the possibility of natural air flow by opening the window and the shading system which is closed when the sun shines on the facade). The actual standard in the building is an automatic air conditioning system with a set point of 21°C and the possibility of window opening. The result of this evaluation is displayed in Figure 9.

When you look at the results you can see that there not a huge problem with the room comfort. Actually 82 % of the occupants feel comfortable in the room (category II from DIN EN 15251). While analyzing the result regarding the DIN 4108 you get 927 hours during the temperature in the room is above 27°C,



	Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]								
	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	1799 / 63%	37%	2364 / 82%	18%	2634 / 92%	8%	-

Figure 9: Result of "Primero Komfort" (DIN EN 15251) for the actual standard

which is not a very good result because the norm standard set 500 overheating hours as an upper limit of comfort.

2.2.2 View

The view is an actual problem, too because the installed moveable shading devices can be closed by the occupants during the day and because of the actual level of comfort they are closed every time, so that there is no opportunity to enjoy the view. Another reason for the closed shading device is the problem with glare for the occupants so they have to close it when they want to work effectively.

2.2.3 Daylight

There is a strong relation to the problem with the view, there is a problem with less daylight in the rooms because of the shading devices which are almost closed (Figure 10), so that the occupants has to use artificial light which is very uncomfortable to work.

Figure 10: Actual situation in the MMA [1]

2.2.4 Humidity

In chapter 1.3.3 you can see the run of the humidity over the entire year. Here you can see that there is a minimum during the Brazilian winter which led to very dry air. For the occupants of the ministry building dry air is not good for the comfort in the room. On top of that a very low humidity will led to dry soil. In the following the wind will take the soil through an open window in the offices so that the offices become dirty (problem on the southeast façade because there are no shading devices).

2.2.5 Energy efficiency

Because energy efficiency is a very important thing in the entire world, it has to be part of the retrofitting process too. Even though Brazil uses a lot of regenerative energy sources (especially hydrodynamic power) there is a huge waste of energy all over the country. You can see this problem while looking at the interior building equipment. You will find in every office electronic devices with huge energy consumption. [14]

3. Retrofitting process

3.1 Influences by the lectures of the Summer School

Based on the lecture “day lighting and lighting Systems” by Amorim there is a strongly connection between daylight and heat gaining. It can be briefly summarized in on sentence: “more light – more heat”. This contradiction must be observed during the whole design process. Systems like light shelf and lamella system were introduced in the lecture. In design process these ideas have been further developed. [1]

Leticia Neves introduced in here presentation green technologies like ventilation. To achieve all the positive aspects of different cooling systems a combination of natural and mechanical is necessary. To keep the occupants thermal and mental comfort manual natural ventilation by openable windows during the day is required. The thermal mass of the building should be also used for cooling the building. Therefore a natural night cooling which causes a cross ventilation is an effective manner. However the advantages of HVAC should not be forgotten during the process. [2]

“Why retrofit?” asked Doris Kowaltowski in her presentation “retrofitting the process”. Different reasons like comfort, function, technology, cost, regulation and commissioning are causes for retrofitting. All of them influence each other particularly. For the retrofitting of the MMA the comfort is the main reason to focus on, but also the efficiency (technology) which is related to the cost are considered. [3]

Green façades are part of the summary of “sustainable architecture” by professor Willkomm. Based on the presented criteria to check the functionality of retrofitting the potential of the roof is another point to pay attention during the design process. [4]

3.2 Façade

The retrofit concept only plan some changes at the long facades of the building. Since that is established to keep the shape and the design of the building the northeast and southwest facades will not be changed to keep the characteristic frame. Even though the brick construction will not heat up over the day like concrete constructions will do, but there are some heat gains due to this facades, especially from the north east façade. There is the opportunity to adapt a few ideas from the concept to this façade but the design process concentrates on the longer facades because these have the main impact of the current lack of comfort. So we create the idea of a green façade with a combined shading system (Figure 12) for the northwest and the southeast facades.

3.2.1 Shading

While talking about an adequate shading system it was recognized that there is no opportunity to minimize the heat gain and parallel maximize the impact of the daylight. In the progress of finding the best solution for the shading two ideas was evolved, which were compared all the time.

The discussion about the “right” shading system only refers to the upper part of the system, which should guarantee the maximum of potential daylight for the offices. On the one hand the solution was about a light shelf which is moveable depending on the sun path. Contrariwise the other opportunity was a lamella shading system which can be opened or closed to manage the optimal impact of daylight. The only thing which was against the lamella system was the maintenance regarding the cleaning process, whereas the light-shelf-system will be a high-tech element which could be very sensitive and expansive. Besides, the light-shelf is not able to light up rooms with a huge room depth. Especially because of the cost and the simplicity the decision was taken to install a moveable lamella system in the upper and in the lower parts of the window to get on the one hand shadow for the occupants and on the other hand more daylight for a better illumination. The adjustable slats allow the view while shielding the occupant from direct solar radiation (Figure 12).

In the end a divided lamella system should be installed, which in the upper part of the window works automatically, without any possibility to move by the occupant and another lamella system in the lower part which is moveable by the occupant manually. Both systems are installed at the outside of the building directly in front of the window to avoid that the heat enters the room and to minimize the potential heat accumulations between the shading layer and the window layer.

3.2.2 Green façade elements

The windows are installed with a normal parapet high (depending at the national common standard). Below this glass-layer you will find the green-façade-elements. The actual state of technology for green façade system describes three different system.

There are self-clinging climbers, the modular system and the support system. After a short evaluation of the actual state of technology the modular system was selected because it neither damages the façade with the roots of the plants (clinging climbers) nor influence the view out of the building (support system). Another advantage of the modular system is that you can replace every module easily when there are sere.

The modular system works with pre-vegetated modules which consist out of light substrate as a media for the plants growth, a rigid substrate for embedding the light substrate, the metallic support structure, an impermeable layer for anti-root protection and an irrigation system. The used materials for the light and the rigid substrate are totally organic. A potential system is shown in figure 11. Additionally to this structure you have to arrange a drip molding below the green elements to avoid disturbing dripping for the lower offices.

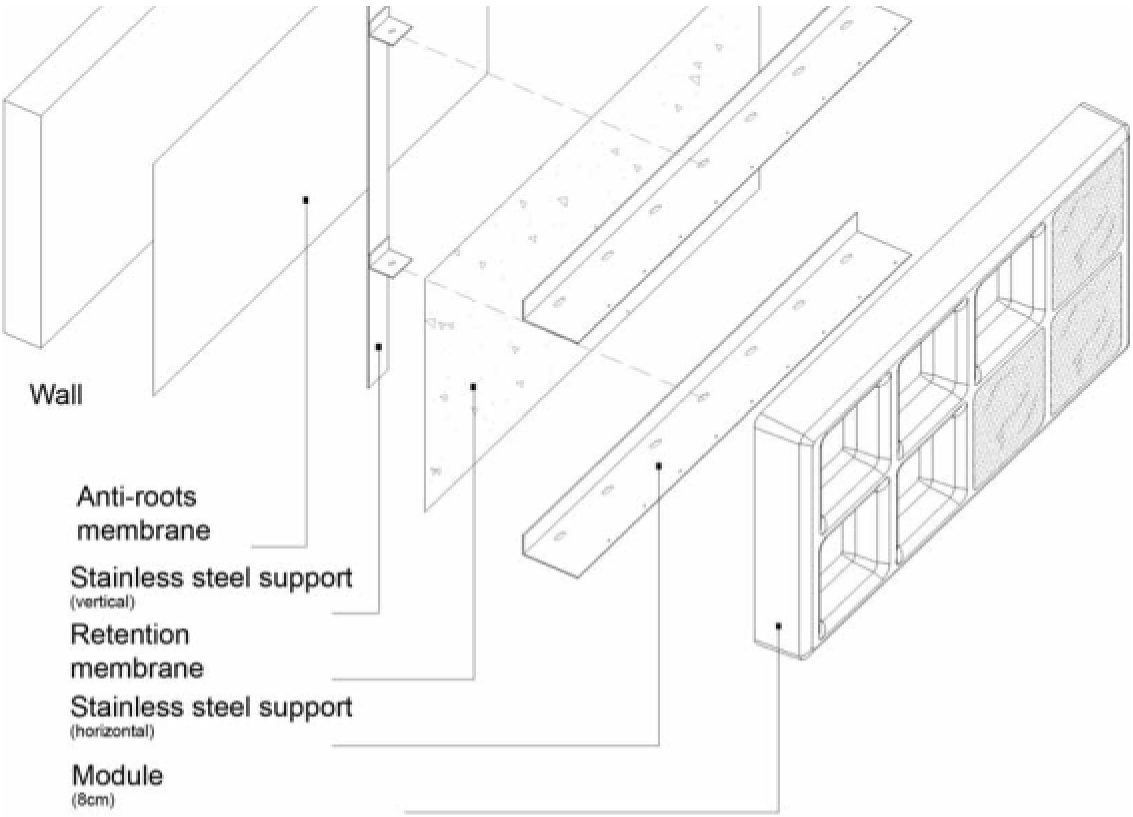
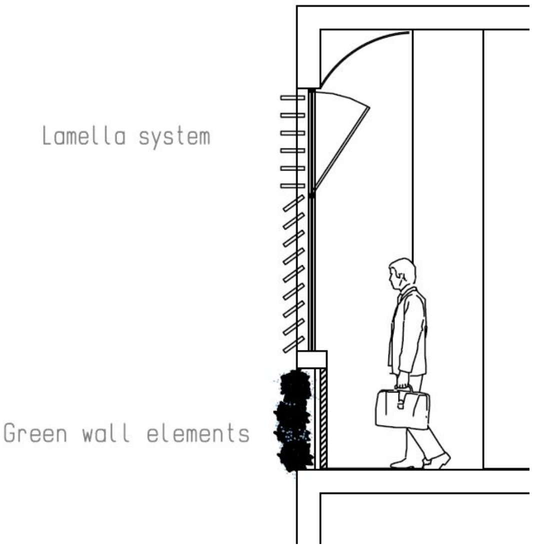


Figure 11: Potential system for the green façade elements [13]

The types of plants in the modules should support direct and intense sunlight as well as high temperatures. Regarding the dry period in the Brazilian winter (Figure 4) the plants should tolerate dry conditions as well. To satisfy all these points you have to choose a local sort of plants because these plants are weatherproof with the local climate. Another important point for the selection of the right plants is to use the advantages from the façade elements over the whole year so that the plants have to be evergreen.

The irrigation system will be out of small flexible tubes which are perforated so that the water will drop out of the tubes. There are two different kinds of irrigation systems. On the one hand there is the dropping system which works with a constant irrigation level over the whole day and without waste a lot of energy. Otherwise you can spray the water to irrigate the green elements but then there has to be a huge pressure inside the tubes and on top of that this kind of irrigation has not the same effect regarding the energy efficiency as the water-drop-system, because you will lose a lot of water and energy. The preferred system should solve the problem of humidity during the Brazilian winter.

Because the additional façade layer will stress the water economy it is necessary to irrigate the plants with stored rain water so that the water shortage during the winter does not affect the ministry building (3.6.1). An advantage of the green elements is the pollutant and the surrounding sound will be absorbed and reduced by the plants of the green façade elements. This is a benefit for the surrounding area and for the working space in the building. All in all the green elements cause also an improvement of attractiveness. Therefore there are many advantages besides the modern green look of the green façade elements. [12][13]



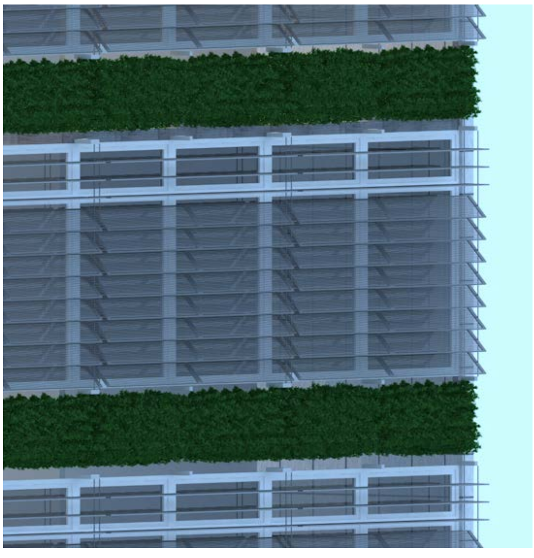


Figure 12: Facade construction with green elements and shading system (left: section; right: rendering)

3.3 Cooling concept

According the problem of overheating the decision is to use two separate systems to lose the heat gains which exist inside the building. The combination of night-cooling and cross ventilation will lead to a more comfortable climate for those days of the year the temperature differences are huge enough to make night cooling possible. During the other days of the year an air conditioning system will be necessary.

3.3.1 Night cooling

Regarding the heat gains during the day a solution to avoid overheating of the rooms during the day is required, so that the occupants feel comfortable. For this reason about a night cooling concept is part of the design. This way the windows will open automatically during the night, so that the cool air enters the building and will be saved by the massive construction elements. Due to their huge thermal mass the whole construction will cool down over the night and save this energy to cool the building during the day as well. But this kind of concept is not possible over the whole year because especially in the Brazilian summer the differences between the day and the night are not huge enough to cool down the building (Figure 3). For this reason you cannot avoid to install an air-conditioning system. To maximize the impact of night cooling and solve the problem of humidity in the building an evaporative cooling system in the façade layer is installed. This system is based on the irrigation system of the green façade elements (3.2.2). Due to the evaporation the air temperature increases because the air enhanced with humidity. This lead to a higher humidity for the surrounding area. Green façade elements have a natural cooling effect, which take place in front of the construction layer, so that these elements are cooled and the long-wave solar radiation is reduced. This effect maximize the impact of the night cooling because due to the reduction of the long wave solar radiation the massive elements behind the green façade will not heat up like sun exposed concrete elements so that the fresh air do not heated up due to radiation of heat from the façade (Figure 13). This way the humidity in the building will raise and working conditions will be better.

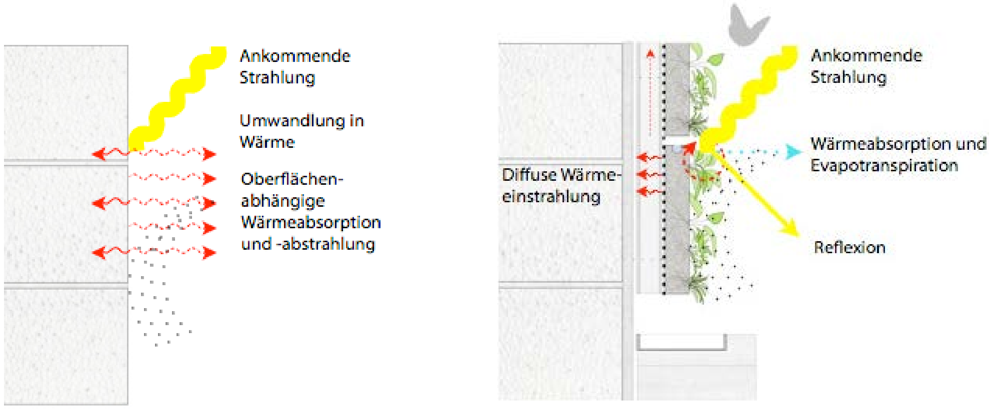


Figure 13: Comparison standard facade to green façade [12]

3.3.2 Cross ventilation

To support the process of night cooling you can combine it with the possibility of cross ventilation. Regarding the wind rose (Figure 6) and the main impact of the east winds you have to install some elements in the façade layer so that the wind is able to enter the building. After the wind crossed the southeast façade, it can leave the office rooms through some special lamella above the doors. These elements open automatically at a specific time of the day (10 p.m.) when the occupants left their offices.

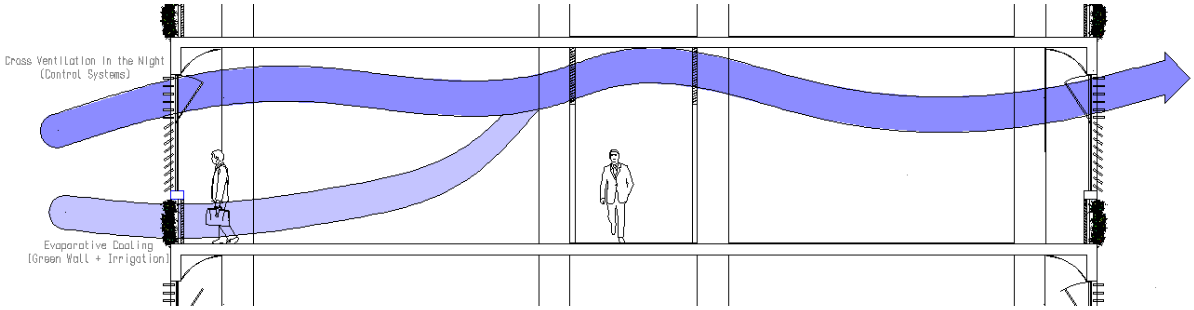


Figure 14: Possible cross ventilation and evaporative cooling in the Ministry Building

After the used air reaches the corridors the wind get the used air either to the staircases or the offices on the northwest façade (Figure 14).

At the staircases another lamella system above the doors which opens and closes automatically is installed to let the used air into the staircases. It is needful to install this kind of elements because of the fire protection, so that in case of fire the staircases as closed areas give the opportunity to evacuate the whole building. The staircases as well as the ceiling are massive elements, so that they can save a lot of energy during the day. Because of this heat-gaining process it is meaningful to use the chimney effect to blow the used, bad air out of the whole building. For this it is required to install an openable element at the top of the stair case (Figure 15). Regarding the huge air volume from every floor huge wind speeds in the stair cases are possible, but this is not a big problem because during the night the building is usually empty, so that nobody will be affected. To raise the effect of the chimney effect you can add some elements at the outside of the staircases which absorbs more solar radiation.

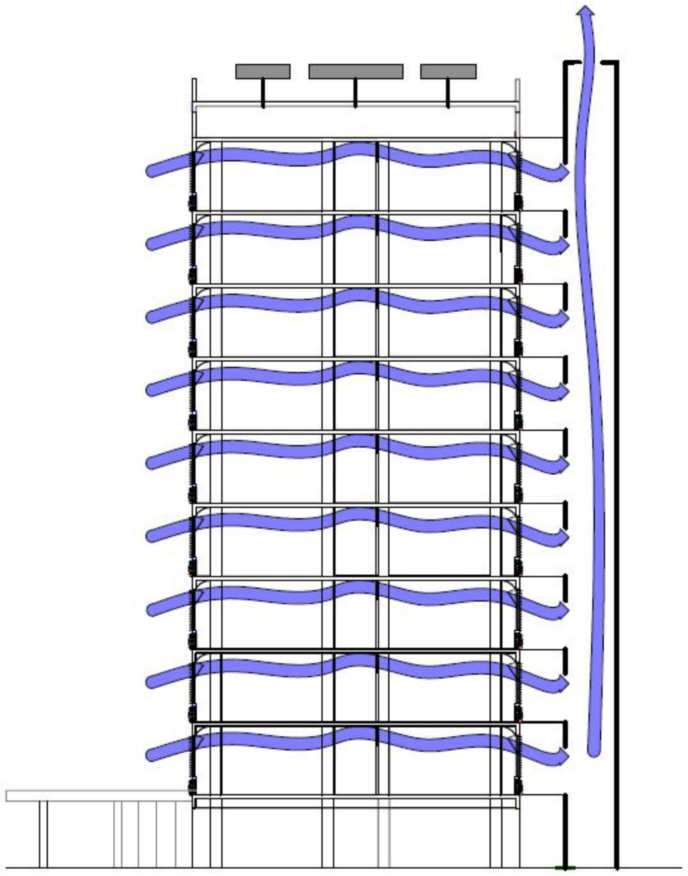


Figure 15: Night cooling effect maximized due to the chimney effect

3.3.3 Result of the cooling concept

Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]									
	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung	erfüllt	Über-schreitung	erfüllt	Über-schreitung	erfüllt	Über-schreitung	Ferien
		[%]	[h][%]	[%]	[h][%]	[%]	[h][%]	[%]	von bis
B	-	-	1784 / 62%	38%	2364 / 82%	18%	2633 / 92%	8%	-
2	-	-	2130 / 74%	26%	2582 / 90%	10%	2757 / 96%	4%	-

Figure 16: Comparison of the actual status and the “new” cooling system

The result of “Primero Komfort” shows the impact of the new cooling concept on the room comfort. In Figure 16 you can see the impact of the new cooling concept compared to the actual situation (DIN EN 15251). To get this result the cross ventilation and the chimney effect from 10 p.m. to 6 a.m. is included. Regarding the time the temperature in the building is above the comfort line you can say that only the cooling concept reduced the value about 378 hours to 549 hours in total. Unfortunately it’s impossible to integrate the impact of the green façade’s cooling effect, so that there will be a better result from “Primero Komfort” as shown in Figure 16.

3.4 Comfort

The currently comfort inside the ministry building is not the best one so that something has to be changed. The focus is on the following working conditions

- Daylight everywhere in the building
- Privacy
- Freedom of decision
- Less artificial light
- Less noise disturbance
- Comfortable working atmosphere

After studying the actual situation in the building, it was recognized that there is insufficient daylight in the offices and in the corridors. Since the occupants close the shading system all the day presently, there is no daylight in the rooms and every place in the room is influenced by artificial light. This problem could be solved with the preferred separated partly automatic partly manual, moveable lamella system (3.2.1). With this system the user is protected from glare by the sun and at the desk, while the daylight can enter the room. To manage the problem with the daylight into the corridors it is useful to install some fanlights above each door which is surrounded by a row of windows. Thus installing that system the impact of artificial light will decrease, so that there will be a better working atmosphere. Another advantage of these elements is that the occupants can decide, if they want to leave it opened or closed. This way the opportunity if more privacy is needed to encapsulate from the outside is given to the user.

In Figure 17 you can see the impact of the new system. The impact of the cooling concept is shown in Figure 16 so that you can recognize that there is not a huge impact from the changed shading system and the new sun protection glass, because due the automatic shading device on the top of the windows

Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]									
	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	1784 / 62%	38%	2364 / 82%	18%	2633 / 92%	8%	-
1	-	-	2205 / 77%	23%	2615 / 91%	9%	2778 / 97%	3%	-

Figure 17: Comparison of the whole retrofitting concept with the actual situation

with the possibility of cut off the daylight enters the room but simultaneously there will be a heat gain for the entire room.

Regarding the DIN 4108 you will get only 525 hours above the comfort line which is set at 27°C. Even though the norm standard classify that only below 500 hours the room comfort is "good" the concept will comply this limit because the calculation with "Primero Komfort" does not factor the impact of the green façade.

3.5 Green rooftop

To make the breaks for the occupants more comfortable a new area at the rooftop which invites everyone to spend some time (Figure 18) is part of the design. Apart from that a place to install the technique for the air-conditioning system is needed. So the rooftop is divided into two parts. On the one side the green roof and on the other side the place for the technical equipment (figure 19). The green roof will help to cool down the building because there will be a continuous cooling process of the last concrete ceiling of the building. Furthermore, on top of the last floor there is floor with half of the height compared to the other floors. This additional “entresol” protect the top floor from high heat-gains through the rooftop.

Figure 18: Impression how the rooftop could look like

Figure 19: Overview from the rooftop; left: “green area”; right: “technical area”

some time during the coffee breaks or the lunch. To protect the occupants from the sun there will be installed some shading elements with a special feature. The top of these steal components will be added with photovoltaic elements, so that there is the next step to an energy efficient building (look at 3.6.2).

3.6 Energy efficiency/Sustainability

Regarding the energy efficiency Brazil is not at the status of a development country. Today the main source of energy is hydropower. The impact of photovoltaic and wind energy is not that big that is can be in a country with a long coast where the sun shines nearly the whole year, so it is useful to implement some devices to make the concerned building more autarkic. [14]

3.6.1 Utilization of rain water

Regarding the continuous water shortage in the especially in the north of Brazil there has to be think about another opportunity to make buildings more autarkic in general so that the impact of MMA and MinC on the water economy decreases and set a good example how to fight against the water shortage. A cistern should be installed to save the rain water from the roof and the surrounding area, to use the surplus water during the dry period. You can use the saved water to irrigate the green elements from the facade layer and the entire green area around the building. For a small comparison of the precipitation and the consumption a balance sheet should show when it is necessary to get some additional water and when it is possible to us stored rainwater.

To get the rain water which has to be stored, the following assumptions have to be focused:

- store the rain water from 1734 m² (roof) and the same area from surroundings
- consider the material from the roof (50% green and 50% gravel= 0.75) and the area (green 50% and compacted area 50%= 0.75) due to the run-off coefficient (DIN 1986-100:2016)

The assumptions for the consumptions are:

- The irrigation level of the green façade is shown in Table 2. The water consumption of the green façade depends on the time of the year because as you can see in figure 4 the precipitation during the Brazilian winter is very low and the solar insulation is high so that you have to irrigate the elements to avoid withering of plants. The area of the green façade (northwest and southeast) is about 2244 m²

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation [l/m²]	1,0	1,0	1,0	2,5	2,5	5,0	5,0	5,0	2,5	1,0	1,0	1,0

Table 2: Irrigation for the green facade depending on the month

- For the irrigation of the surrounding area and the green elements of the roof structure you have to calculate with a water consumption up to 70 [l/(m²*a)]

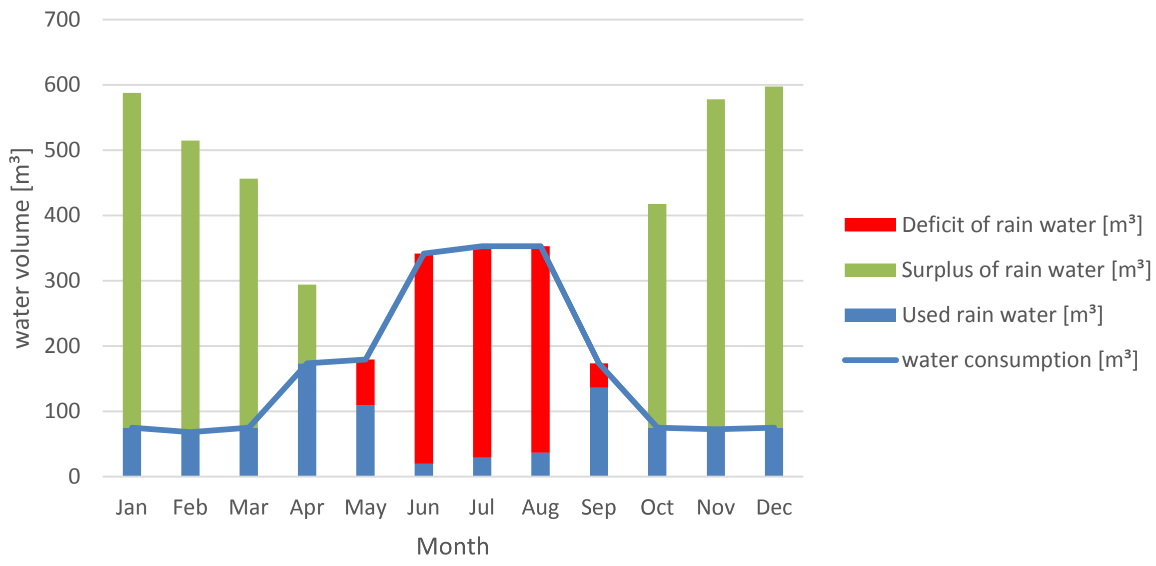


Figure 20: Diagram to show the water input and consumption

With this mentioned values and the mentioned precipitation (1.3.2) you can compare the input and the consumption to show what is the water deficit during the dry period in the winter about. This is shown in Figure 20.

In the time from October until April there is a surplus of rain water which can be stored in a cistern near the building. Only from May to September you have to use the stored rain water to get over the dry period. The sum of deficits during this period is about 1070 m³. This water volume has to be stored in the cistern until the dry period starts, so that after the cistern is full the remaining surplus of 1800 m³ can be used for something else.

3.6.2 Photovoltaic

For a better energetic household of the building a photovoltaic-system will be added on top of the shading devices on the green roof top (3.5). These elements were orientated to the northeast where the solar radiation is much better than in the southwest. A very important fact for the potential energy outcome is the inclination. The most effective way will be when the sun angle on the PV-system is about 90° as long as possible. But unfortunately you only can manage this with an adjustable system which are very expansive regarding the maintenance. For this reason a photovoltaic elements without the adjustability is implemented. This means you have to find the most effective angle for the system. Regarding this, [10] gives some information about the solar insolation with different sun angles in Brasilia for the selected orientation. After evaluation every possibility the best angle for the PV-system over the whole year is 74° to the vertical.

To have a value to compare the demand for the energy consumption of the lighting system can be used. The actual state of technique is that the lighting needs 7.9 W/m². With this value, the area of the whole building, a daily working time of 8 hours (unfavorable assumption) and an average time of absence about 9.83 days per month you get a value for consumption about 237 MWh per year. In fact the PV-system should cover the demand totally, but because of shortage of space a cover ratio of 75 % is satisfying. According to this an area about 692 m² out of 425 PV-modules which are fixed on 25 different steel frames is figured out. The impact of this system is displayed in Figure 21 as a part of the value of energy consumption from the lighting system.

On the one hand the elevated photovoltaic systems abet the stay on the root top because of their shading effect. Otherwise the green elements on the roof increase the efficiency and the long-life cycle

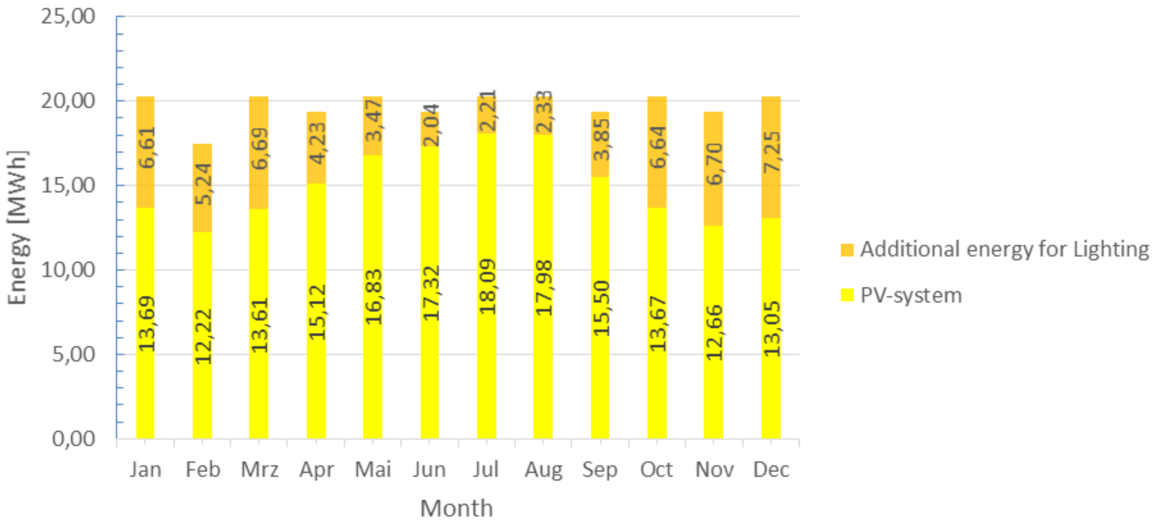


Figure 21: Impact from the PV-system on the consumption of lighting

of the photovoltaic system because through the irrigation of the plants on the roof and the evaporation of the water, the photovoltaic elements are safe from overheating. [13]

3.6.3 Sustainability concept

The following picture (Figure 22) should summarize the energetic aspects and why this project is called "green Niemeyer". Apart from the exterior view this project should use more green energy to be more efficient regarding the energy consumption.

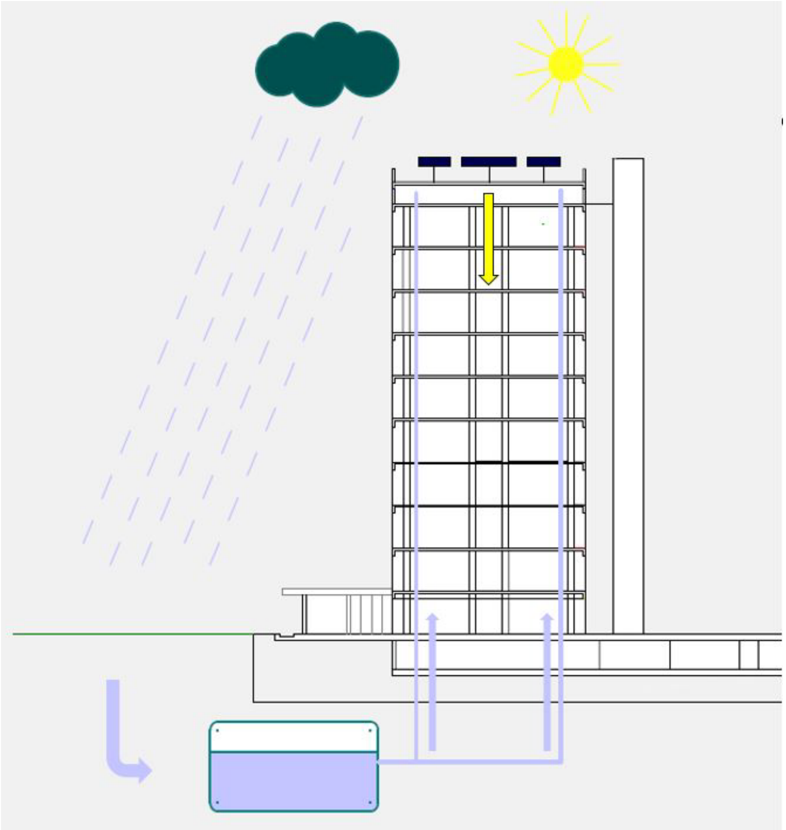


Figure 22: Overview about the sustainability concept

3.6.4 Renew the interior

On top of the additional system of PV and the use of rain water you can put the energetic standard inside the building to the actual standard. So you can exchange the old lighting system with a new system based on LED or daylight lamps and renew the old electronic devices (computer, printer, HVAC) which do not fit to the aimed energy level. Furthermore, you can regulate the usage of water to stop the waist of water.

4. Conclusion

The whole “green Niemeyer”- concept is focused on the comfort of the occupants, because the most important point of a (retrofitting) concept is to be accepted. Sustainability is the second most important factor, which is closely connected with a high acceptance, too.

The **“green niemeyer”** concept provides the preservation of the current building shape to honor the architect Oscar Niemeyer and keep the historical concept of Brasilia. Therefore there would be a high acceptance of the retrofitting by the citizens.

To retrofit the existing building a new concept for the façade is necessary. The new façade is equipped with a **modular green façade** system combined with a **lamella system**. A green façade would lead to much more comfort for the occupants, is sustainable and will modernize the building. The green façade elements optimize the façade in many points like adiabatic cooling, humidity, absorbing pollution, improving the micro climate and absorbing the surrounding sound.

The lamella system is divided in two parts. The upper part ensures the use of daylight and is integrated in the night cooling system. The bottom part provides the personal mental comfort of the occupants, with the possibility to move the lamellas and also to open the windows, so the occupants have the choice.

The rooftop with two functional areas combined the possible greening and the necessary technical equipment. **Green gardening** on the top improves the comfort of the occupants if they want to take a break.

To make the whole concept convincing, sustainability must be guaranteed. The **utilization of rainwater** for irrigating the green façade elements is one point for completing the sustainability part of the concept. Another aspect is the use of solar power. So the building produces energy with **photovoltaic elements** on the rooftop to cover a part of the energy consumption.

Another point for saving energy is an effective way of **natural ventilation**. The night cooling concept included a cooling for the whole building by using a natural chimney effect through the emergency staircases. The thermal mass cools down and avoid huge heat gains during the day. This natural cross ventilation reduces also the consumption of energy for HVAC.

Another important point is that all occupants have to be introduced to the new concept. They should be taught to the system for understanding and for accepting it. This point is important because **buildings cannot waste energy only their occupants can do this.**

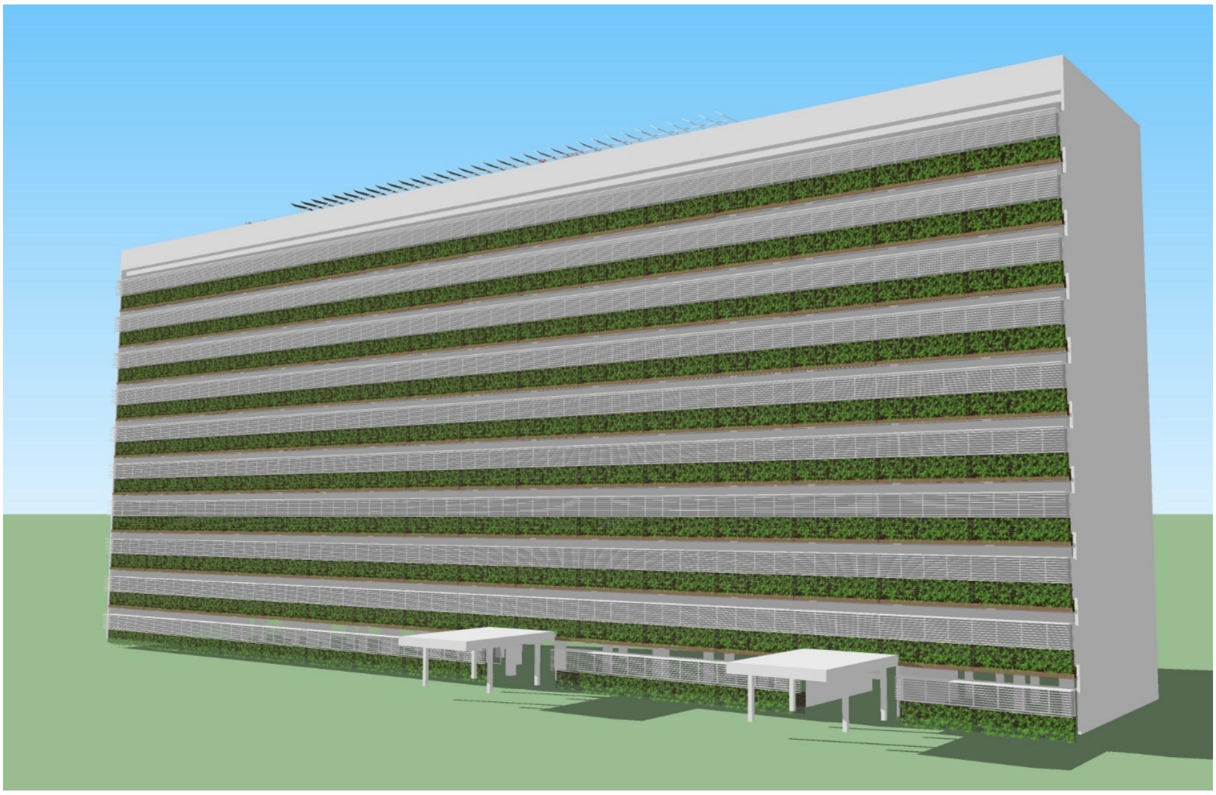


Figure 23: Impression for the northeast facade with the described retrofitting concept

In the end this will be the final outcome (Figure 23) of the retrofitting concept. Even though not changing the entire building, keeping the shape and the architecture of these heritage building and no possibility to avoid the use of HVAC at all, a new building is created which is more comfortable for the user, upgrade the entire area because of the external presentation and set a landmark for the whole city of Brasilia.

Ordem e progresso – this is the text of the Brazilian flag, which means order and progress. These were the aims of the foundation of Brasilia as the new capital of Brazil. But like in chapter 1.2 mentioned these aims more and more sank into oblivion. For this reason it is necessary to keep these aims back in mind due to keep the ordered and clear structure and adapt the green façade and the sustainability concept as point of progress, so that the ministry building could be a trailblazer for the city of Brasilia and the entire country.

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Design concept for retrofit of the ministerial building in Brasilia

Group 5
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1. Abstract

The following sketchbook gives an overview of the development and the results of the Summer School in Campinas, Brazil.

The Training School was an interdisciplinary project, conducted by German and Brazilian students. The main aim of the workshop was the development of refurbishment strategies for a building retrofit of the ministry buildings in Brasilia. Retrofit is an important strategy for energy conversation of existing buildings. By retrofitting buildings you can improve the whole building performance and increase its useful life. A whole energy-efficient retrofitting concept was established.

The buildings of the ministry of Brasilia were designed by the Brazilian architect Oscar Niemeyer dating back to the 1960's. The design represents an architectural and cultural heritage to the Brazilian. But energy consumption and the energetic building technology no longer reflect the current performance requirements (thermal, energetic, environmental and economic). It causes high costs and should be modernized.

Figure 1: Ministry of the Environment and Ministry of Culture Headquarter in Brasilia

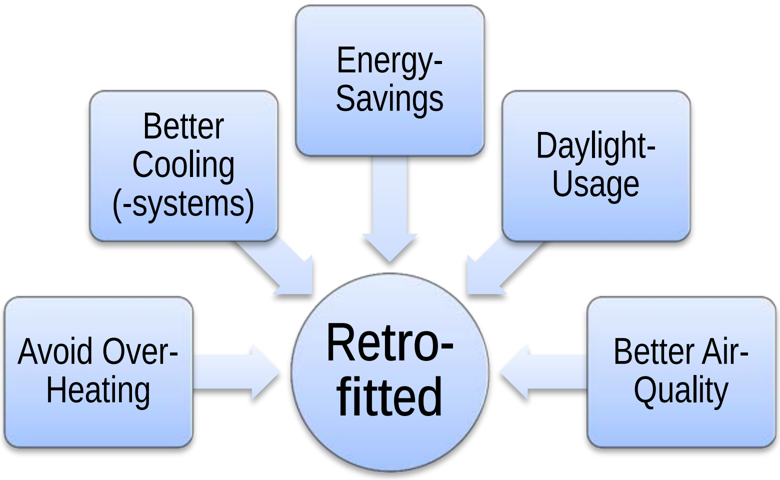
To meet the task, the entire process was initially divided into three processing steps:

Phase A	Pre-Preparation
	Analysis of local climate in Brasilia
	Analysis of energetic and comfort performance of a ministry building
Phase B	Project week at University of Campinas
	Impulse lectures: Adaptive facades and energy-efficient retrofitting
	Workshop: Conceptual design of retrofitting a ministry building in Brasilia
Phase C	Final Preparation
	Design development based on the workshop results
	Energy and comfort analysis (design evaluation)

First the preliminary analysis was carried out. Therefore the planned city Brasilia, the local climate data, the sun path in summer and winter time, the building location/ direction and the existing building's condition were analyzed. With the aid of this analysis and the preparatory (impulse) lectures at the university, first design concepts were developed and various possibilities were discussed within the group of the workshop. The results of the workshop and the discussions were then worked up in more detail.

The energy-efficient retrofitting concept tries to preserve the cultural heritage of Oscar Niemeyer on the one hand, on the other hand it improves the building performance and it simultaneously increases its useful life with the help of specific measures which are explained subsequently. The concept has two main characteristic points: The *energetic* part and the *social* part. Both parts are very important and should also interact together.

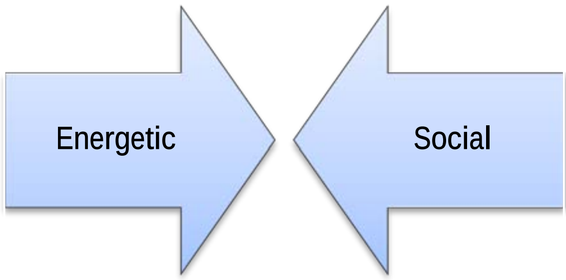
The concept has been designed to meet the following goals:



2. Concept

"Go with future, preserve legacy"

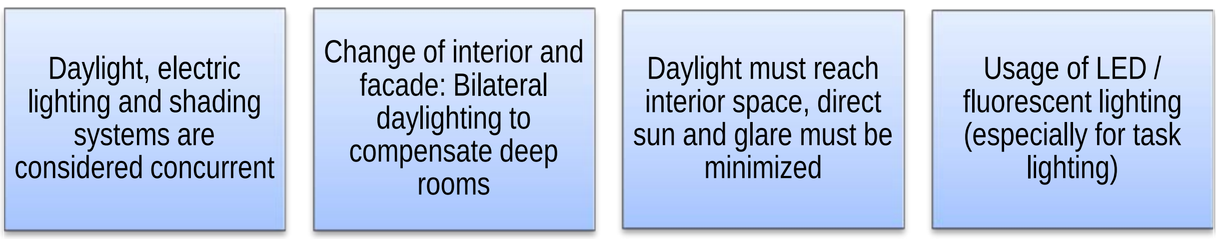
As already mentioned, the concept consists of two main pillars - the energetic part and the social part. Ideas have been developed for both of them, which will improve the performance of the building in a sustainable and energy-efficient way. It was necessary to keep both pillars in balance. On the one hand the users of the building felt more comfortable plus human requirements were respected and on the other hand the energy consumption was minimized. Various measures were taken for both points.



Before the overall concept is introduced, a brief overview of the introductory courses and the input lectures in Campinas are given [1]. The lectures included many different topics, which prepared the participants for the workshop. A rough overview was given of the expected difficulties, the boundary conditions and about various arrangements with regard to building technology, lighting (-systems), facade design or architecture. Retrofitting as a process and the environmental performance of buildings have also been explained in more detail.

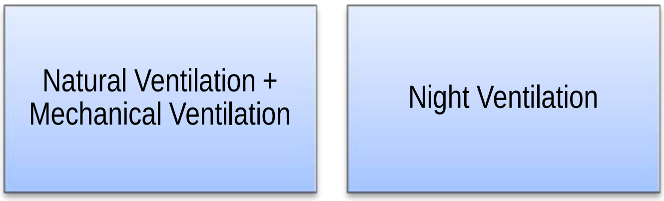
2.1 Input

Some of the above mentioned topics were very informative and helpful in the implementation of the concept. One main aspect of the concept is the right usage of daylight. In order to save energy on the one hand and on the other to create a natural and pleasant environment for the users of the building. The lecture “Daylighting and lighting systems” gave information about the global electric energy consumption and different measures to reduce the amount of electric lighting. The following arrangements are important and were incorporated into the concept:



By using increased daylight and modernizing the artificial lighting by LEDs, energy consumption has been drastically reduced. Besides, mood, atmosphere and also the health of the working people there is increased.

The lecture “Green technologies” includes topics of natural and mechanical ventilation. Both ventilation systems are explained and presented. Combining natural ventilation with mechanical ventilation (Mixed-mode ventilation) is really efficient and definitely important for the overall concept. The combination can work either concurrent, alternating or zoned. Another important feature is night ventilation, which is also included in the concept. The use of thermal mass and night cooling has indeed positive effects.



2.2 Location Analysis

The present ministry building, which was built in the 1960’s, has no more today's energetic standards. Therefore it is necessary to create refurbishment strategies, because the current situation is no longer sustainable and should be changed.

The building has in total 10 floors, with ceramic tiles on north and south facades (no windows at all). The west and east facades are glazed with an external metal film. Operable vertical metal overhangs are installed over the glazing on the west facade. The east facade has no extra sun protection device.

Figure 2: East facade (left) and West facade (right)

The windows are divided into three sections and extend from one ceiling to another ceiling. The room height is 3.74 m. The upper and bottom part of the window are smaller openable glass panels. The middle part is one large fixed glass panel. Upper and bottom part have two tilted openings. The entire facade consists almost exclusively of glass surface, which is extremely bad in energetic terms. It should also be mentioned that the glass panes do not have any good energetic properties.

The building causes an extremely high energy consumption. In addition, the building has no properties to save energy, much less produce. The high energy consumption is achieved by the countless air-conditioning units, which can be found in almost every single room. These devices run all day on high speed to cool down the building to 21° Celsius. The main problem is the heat that develops inside the building over the whole day. The sun shines directly on the east facade in the morning (no sun protection) and at noon on the west facade. As a result, the building heats up extremely. Although the sun protection on the west facade can minimize direct sunlight, it darkens the rooms behind extremely. As a consequence, the rooms have to be illuminated artificially, which in turn increases the energy consumption. Especially the current electric lighting devices are not optimal and consume a lot of energy.

But not only the energy consumption also the user comfort is important. The user of the building should go to work with a good feeling. The current situation is rather depressing and does not encourage a motivated working day. The entire building is dark and only a small amount of daylight comes into the office spaces because of the metal overhangs on the west facade which are darkening the rooms significantly. The hallways are empty and only dimly lit as well. Nobody will stay there, let alone work in such an environment effectively.

The following figure shows a brief summary of the current situation:

High energy consumption (AC-Units + electric lighting)

Large windows / glass surfaces (poor-quality panes)

"Wrong" sun protection devices (most of the time closed)

Less daylight, dark and only dimly lit

Bad atmosphere and mood; depressing

2.3 Climate Analysis

The available weather data of Brasilia is analyzed below [2]. When viewing the data, the following features are of concern:

2.3.1 Temperature

The diagram shows the average temperature during the year in Brasilia. The temperature is nearly constant warm/hot during the whole year (average value: 21,12°C). You can see that the temperature amplitude is only around 4° Celsius (Summer to Winter and viceversa). This kind of diagram of a temperature curve implies that tropical climate might be present. The fact that Brasilia is over 1000 m above sea level must be taken into account when classifying the climate. In this case it can be seen, however, that Brasilia belongs to the tropical climate.

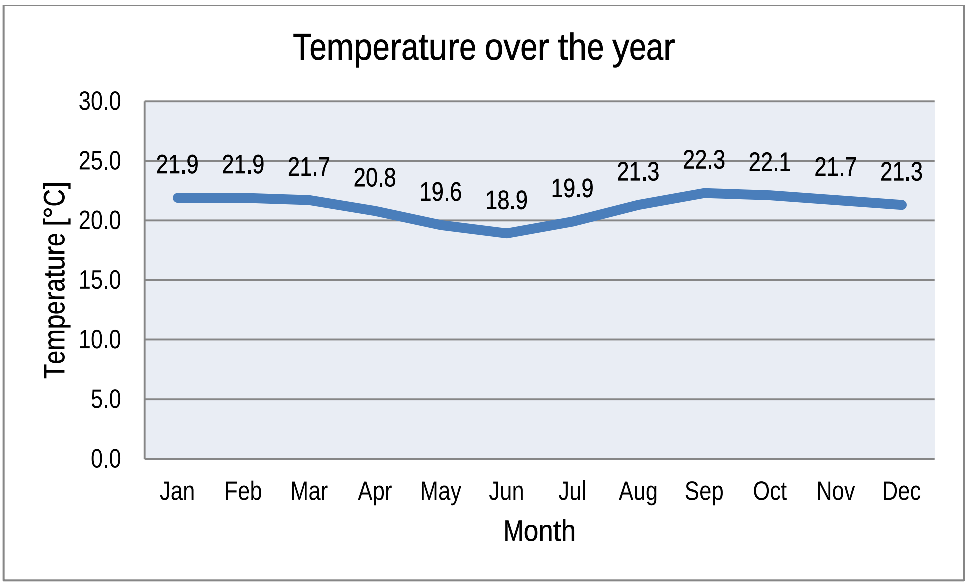


Figure 3: Graph of temperature over the year

The second graph concerning temperature is showing the difference between day and night. As already mentioned before one of the main topics from the lectures was night ventilation and the use of thermal mass and night cooling which is really important for the overall concept. The graph shows that there is a quite high amplitude of temperature during the days (from day to night). This cooling effect can be used to an advantage.

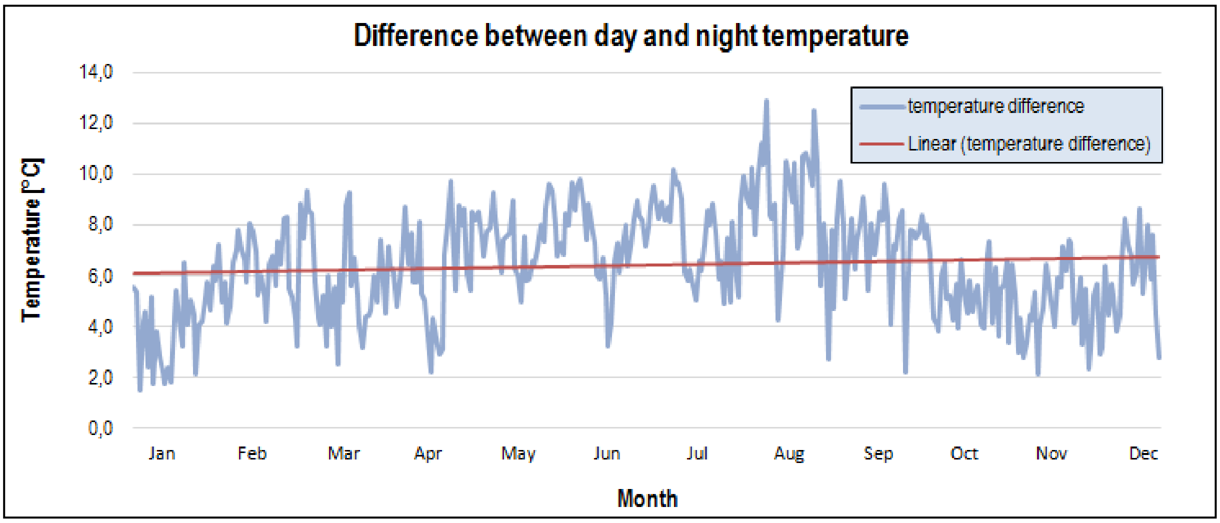


Figure 4: Graph of temperature concerning the difference between day and night

2.3.2 Precipitation

The next figure shows the precipitation of Brasilia during the year. It is easy to see that the summer months are extremely humid and the winter months very arid. Thus there are two seasons (wet and dry). In addition to the temperature diagram this chart confirms the assumption that Brasilia belongs to the tropical climate. The total rainfall is very high over the year (in total: 1668 l/m²/a). This fact is used in the concept later.

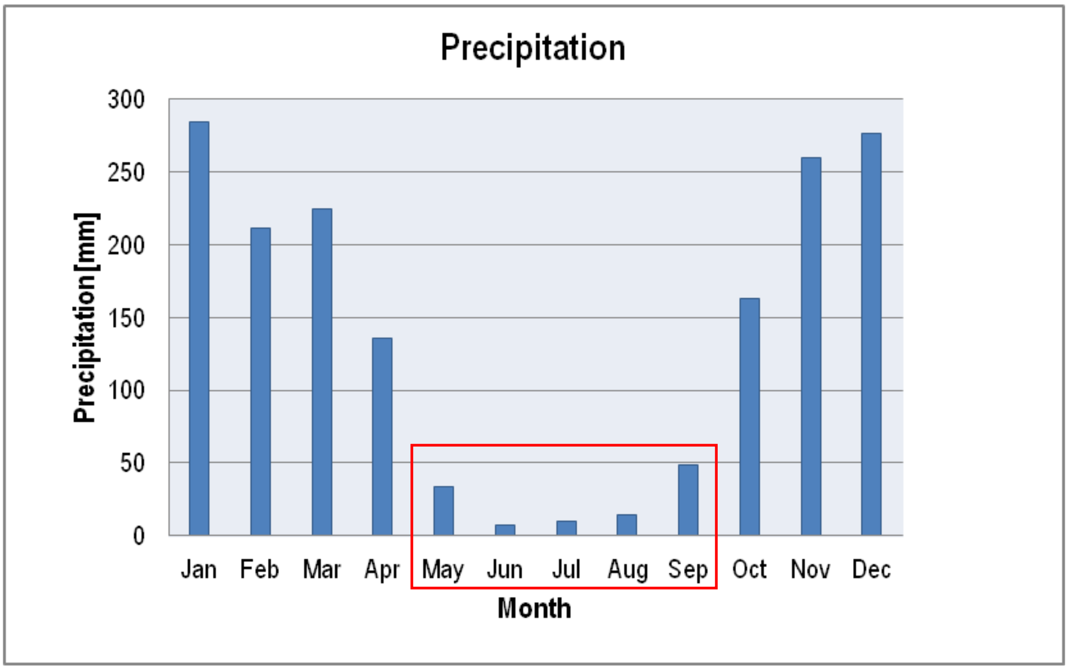


Figure 5: Graph of precipitation over the year

2.3.3 Humidity

The figure below shows the humidity during the year. It can clearly be seen, that the climate is mostly dry during the winter. Of course there are also some slightly humid months during the year, but most of the time it is quite dry or arid. This is why the concept has a certain specialty, which generally makes the entire climate more humid. The next chapter will be devoted to this subject.

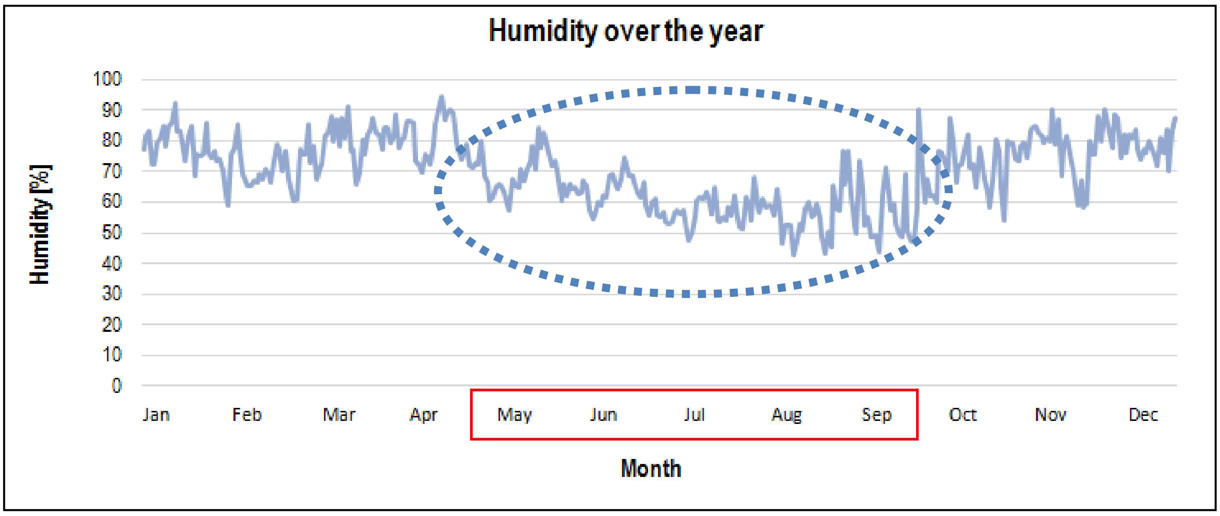


Figure 6: Graph of humidity over the year

2.3.4 Wind

The wind blows mainly from east to west and reaches an average speed of around 8 m/s, which is equal to 29 km/h. This speed is assigned to Category 5 of the Beaufort scale and it means “fresh breeze”. This situation plays an important role in the implementation of the concept later on.

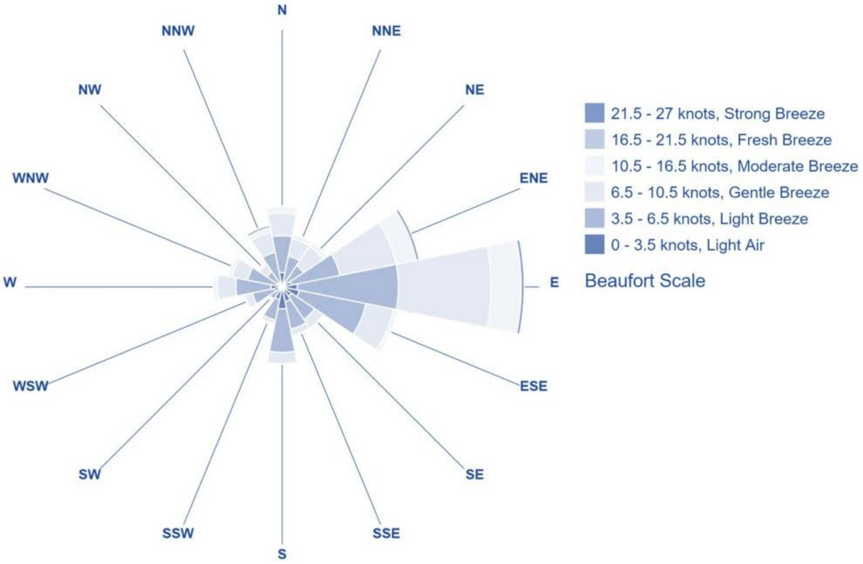


Figure 7: Wind rose of Brasilia

The last two chapters have explained and described the current situation, whether the building itself or the weather characteristics of Brasilia. The next step describes the core idea and what the advantages are:

2.4 Main Design Criteria

As already mentioned, the concept encompasses two core ideas. The building should not only be improved energetically, but also the environment, the surrounding area and the living conditions as such should be increased. Therefore, the main design was dependant on these two key factors.

By far the most striking change in the new design is the introduction of so-called pool terraces within the building. Three rows of these terraces (from the bottom to the top) were added to the building. The main idea was to remove the facade elements (windows and sun protection devices) on the east and the west façade. The entire interior construction was removed as well to create a now new open space with just the ceiling. The ceiling thus forms the floor of the “pool-terrace”. The still existing corridor of the building continues on the open space and crosses the pool. To get the terraces even more airy large recesses are made in the ceilings.

The figure below shows a first impression of the idea:

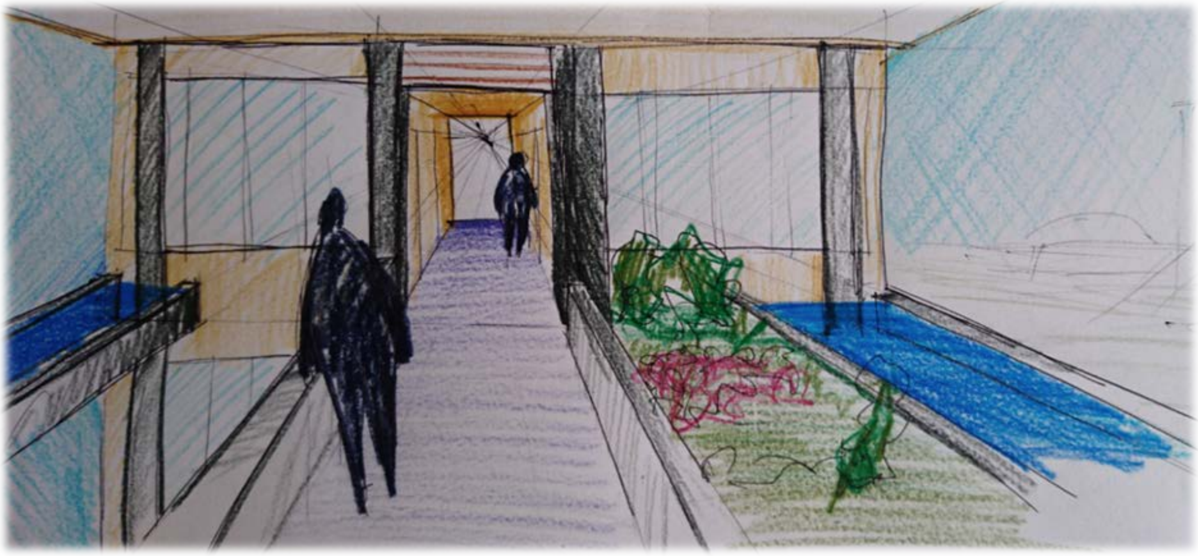


Figure 8: First sketch of the main idea

The construction of such pool terraces had the following reasons:

Humidity
- with the help of new water basins the climate becomes more humid

Cooling
- the water from the basins will evaporate and cool down the whole area

Air-Quality
- because the climate is becoming more humid the air-quality gets better

Environment
- surrounding area gets nicer because of new free spaces, water basins and nature

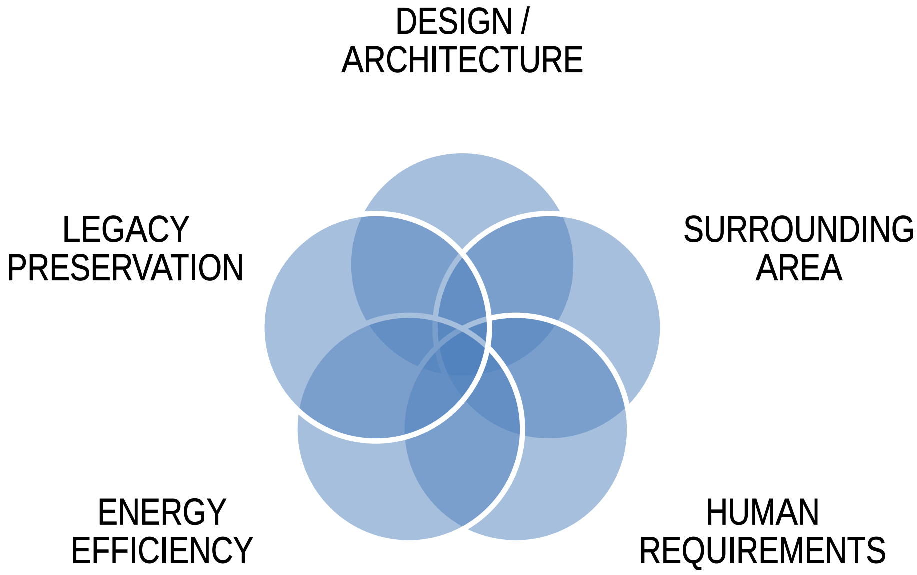
The following sketch of the system shows the location of the individual "pool rows", which are located on every second floor up to the top.

Figure 9: Location of the pool terraces

Of course, this has not been the only idea to retrofit the building, but it is the most striking one. How exactly this system works and what needs to be considered will be discussed in more detail in the "Conceptual Design" chapter. Other measures concerning the facades or the interior are mentioned in that chapter as well.

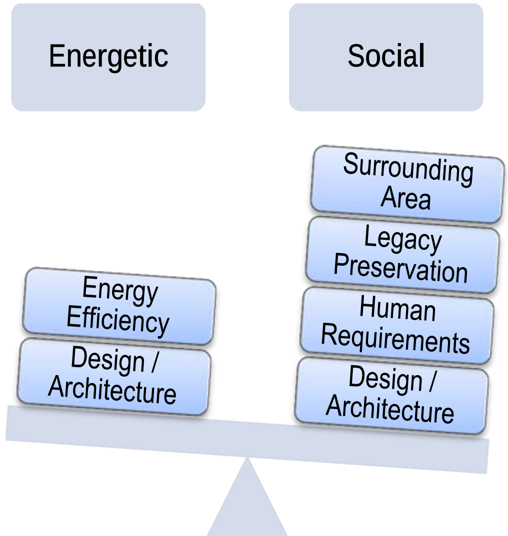
But first the following section describes how the group has worked out the final concept and what path was taken.

2.5 Conceptual Design



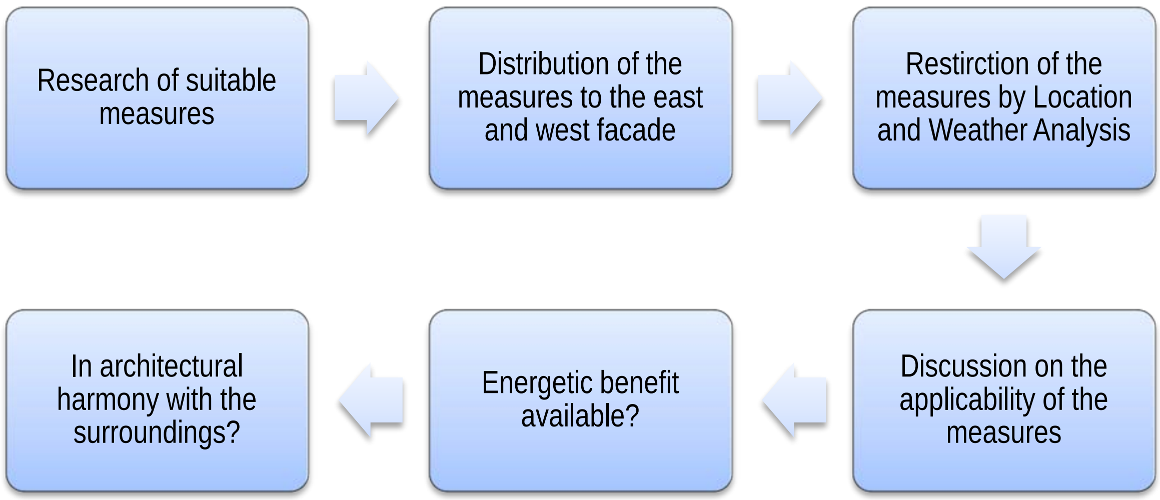
First and foremost, the group decided which main points of the retrofit process were considered important and which are changed in a targeted manner. The **5 key factors** mentioned above were eddited and issued as a target.

The 5 key factors can be sorted into two areas that are important for the concept. "Surrounding Area" and the "Design / Architecture" aspects play a role in both areas:



It was extremely important that the overall concept is coherent. Therefore, the group first researched the Internet and looked at the lecture notes once again. A consideration took place which methods are applicable and which would be energetically worthwhile. At the same time, social aspects and the architecture of the building as such were reflected upon. Which architectural measures can be applied and implemented in order to increase energy efficiency on the one hand and, on the other hand, to generate something architecturally demanding. Benefits and architecture should be in harmony. The mentioned above scale (with the key words) shows that everything is as far as possible in balance.

The following image shows briefly the decision-making processes:



Subsequently, the individual measures that have been used to retrofit the building are presented. In addition, the key results which were achieved in the workshop will be stated.

As already mentioned in the above shown image the measures to the east and the west façade are distributed. The analyze of the location and weather data shows that the east facade does not have to be changed as much as the west facade. This is because the east side has not heated up so much in the morning hours. Additionally, by night ventilation and thermal mass the building has become quite cool in the morning.

As the title "Go with future, preserve legacy" has already revealed, the preservation of the heritage of Oscar Niemeyer was important to the group. For this reason the decission was made to make as little changes as necessary to the external east facade. Thus, at least the east facade would correspond to the architectural heritage of Oscar Niemeyer. However, in order to meet the energy requirements, the western facade has to be changed.

The following list describes the implemented measures, sorted according to the east and west facade:

EAST FACADE

- Reduction of existing glass surface with the help of filled panels in the bottom part of the three-part-windows
- Replacing the old window and frame (upper and main part) with a more energetic window (solar protection glazing) plus frame
- Upper part of the window is automatically operated for night ventilation
- Supplement by a perforated blinds system with double control (Internal, separately opening sun protection)

WEST FACADE

- Reduction of existing glass surface with the help of filled panels in the bottom part of the three-part-windows
- Installation of a green facade in front of filled panels for additional protection of solar radiation and glaring
- Replacing the old window and frame (upper and main part) with a more energetic window (solar protection glazing) plus frame
- Upper part of the window is automatically operated for night ventilation
- Installation of vertical perforated sun protection devices (for upper and main part of window)

The most striking change of the building is the construction of the pool terraces which were already described in "Main Design Criteria". The core idea behind these water basins was that the wind blowing from east to west (according to the "Climate Analysis"), is blowing through these terraces / holes in the building and transports the water (vapour) which was heated by the sun and evaporated. The cold and fresh air would then be sucked in by turbines / fans and transported through a special pipe system into the interior of the building. First, the idea was just a single set of these terraces which would be located in the middle of the building. But further deliberations and constructive criticism from the workshop participants resulted in a further distribution and a better arrangement of these pool terraces over the entire building length. By expanding into three such rows the transport pipes of the fresh air were substantially shortened. This also makes the performance of the turbines / fans much smaller, which in turn will save more energy, which is the primary goal.

2.6 Final Concept

In order to complete the concept, the following chapter provides an overview of further measures which have been taken and the thoughts behind the individual processing steps. The following sections are showing the measures of the applied new east and west facade and the proposed ventilation system for cross and night ventilation:

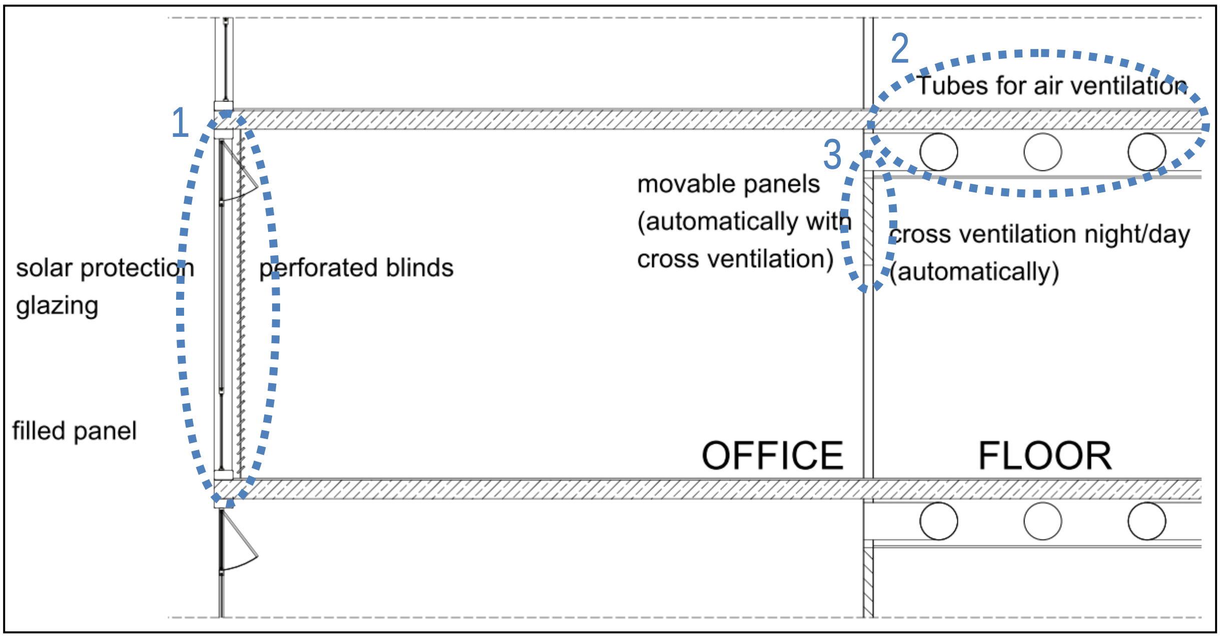


Figure 10: Section of east facade

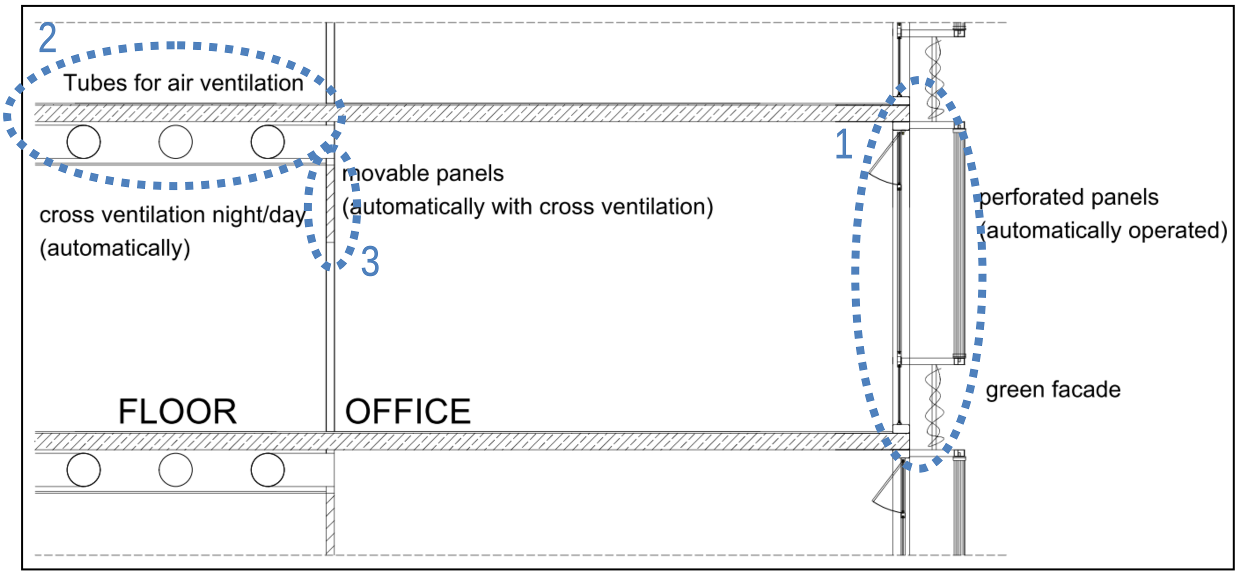


Figure 11: Section of west facade

1- Already described on page 13. At this point another listing is omitted.

2- The tube system is transporting the cool air from the water basins to the rooms and offices. It is powered by special fans that carry the air through that system.

3- Integration of openable and automatically operated glass panels in the upper hallway-wall. Therefore bilateral daylighting (material of the panels is glass, daylight from both sides of the building) and cross plus night ventilation (openable panels) are possible, because the glass panels operate simultaneously with the upper window openings on the facade (blue: fresh air; orange: used air).

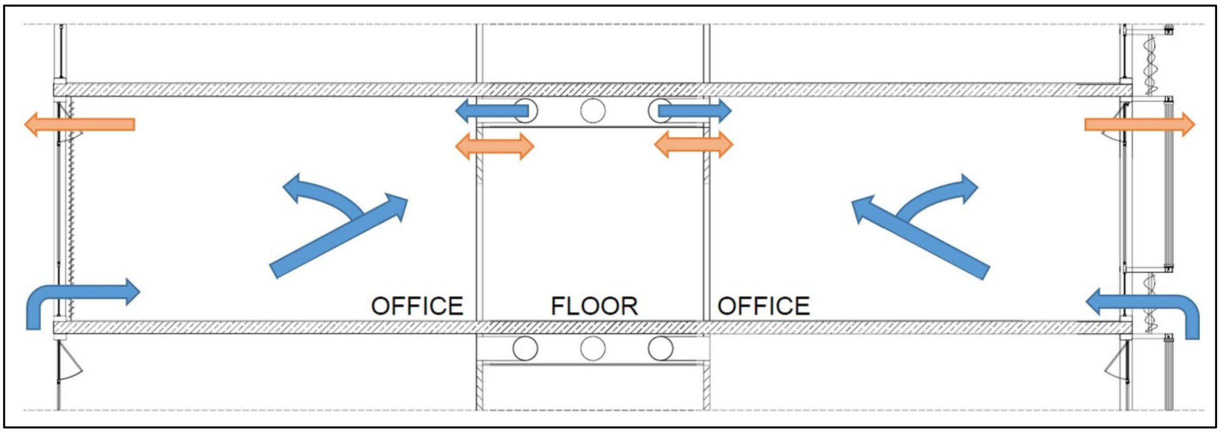
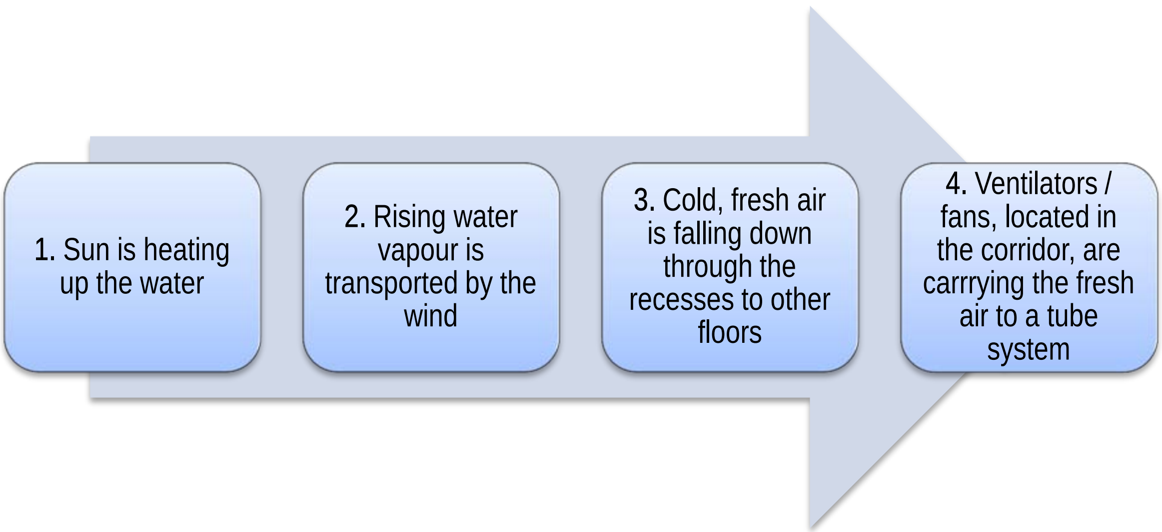


Figure 12: Section of building with ventilation directions

The next image is a first rendering of the established pool terraces to the building. The new facade, including the perforated solar protection panels and the green facade elements in front of the filled panels in the bottom part, is also visible. Due to the high number of new water basins, the climate is generally improved as the humidity increases. The chapter "Climate Analysis" had already shown that it is mostly dry in Brasilia. The water pools should counteract this fact.



To make the entire system even more effective, the ceilings have been cut out (red dashed rectangle) to provide a chimney effect that ensures that the cold and fresh air falls down into the individual floors and creates even more air turbulence.

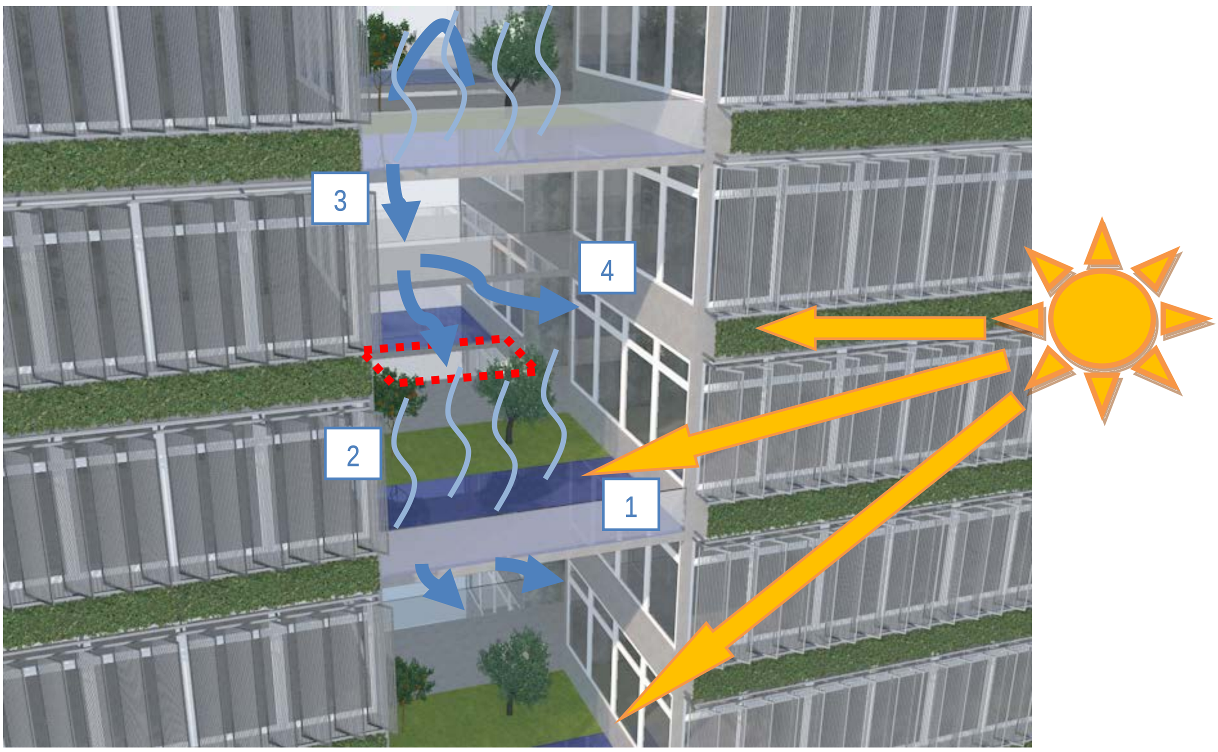


Figure 13: Idea of water basins and the functionality

2.6.1 Renderings of new facades

Figure 14: Rendering of new east facade

Figure 15: Rendering of new west facade

2.6.2 Pre-dimensioning of the Systems

This chapter deals with initial calculations concerning energy consumption, energy production, water savings and the room comfort as such. For this, manual calculations as well as special software were used:

Energy Consumption / Demand

1. System parameters and energy demand

Air-conditioning [kW] Condenser unit (average)	Air-conditioning [kW] Evaporative unit (average)	Lighting Density Power [W/m²]	Equipment [W/m²]
78,00	7,00	7,90	19,40
Hours of operation: 8 h/d 21 working days / month 12 months / year	Hours of operation: 8 h/d 21 working days / month 12 months / year	Hours of operation: 8 h/d 21 working days / month	Hours of operation: 8 h/d 21 working days / month
157.248,00 [kWh/a]	**14.112,00** [kWh/a]	**276.163,78** [kWh/a]	**678.174,34** [kWh/a]

Total Area:
102,00 x 17,00 = 1.734 m² x 10 floors → 17.340 m²

In Total =	**[kWh/a]**	**1.125.698,11**

2. Annual Energy Consumption

Month [-]	Consumption [kWh]	Month [-]	Consumption [kWh]
January	190.731,00	July	205.353,00
February	221.874,00	August	199.786,00
March	217.172,00	September	215.131,00
April	242.270,00	October	258.113,00
May	232.141,00	November	258.699,00
June	199.623,00	December	238.676,00

In Total =	**[kWh/a]**	**2.679.569,00**

3. Comparison:

$$\frac{1.125.698,11}{2.679.569,00} = 42\ [\%]$$

of the total energy consumption is spent solely by lighting, equipment and air-conditioning

Air-conditioning	**6,4**	[%]	↘ can be reduced! Operation hrs: ~ 2 h/d by retrofitting
Lighting	**10,3**	[%]	→ quite good lighting devices existing
Equipment	**25,3**	[%]	↘ can be reduced by more energy-efficient euqipment

The annual energy consumption was taken from the publication of the ministry [3]. It is obvious how high the annual consumption of energy is and that these given values must be clearly minimized. 42% of the total consumption is spent solely by lighting, the equipment (computers, printers, etc.) and of course the air-conditioning.

It is noticeable that the lighting is energy-efficient, so that the energy consumption of the equipment and the air conditioning must be reduced. The consumption of the lighting is however automatically reduced by the benefit of more daylight. With the help of the new retrofitting concept the operation hours of the HVAC can be lowered, whereby the consumption can be reduced. Also the old equipment, which consumes a lot of energy, is decisive. Here, new devices and a more energy-conscious use can help to reduce the consumption.To save even more energy, a concept of energy generation was developed:

2.6.2.1 Energy production (PV-Units)

The concept also includes the production of electricity with the help of photovoltaic systems which are installed on the rooftop [4]. The total area of the PV-units is approximately 2/3 of the roof area. This means that an area of 1.250 m² is used for electricity generation. The following input parameters were used to calculate the monthly power generation by the PV units:

Total area of PV-units:	A_{PV}	=	1250,00 m²
Based peak performance coefficient	k_{pk}	=	0,135 [-]
Peak performance	P_{pk}	=	168,75 kW_p
Reference solar irradiance	I_{ref}	=	1,00 kW/m²
System power factor	f_{perf}	=	0,80 [-]

The following table shows the calculated values, which are of course dependant on the solar radiation value I_{sol} [5].

Table 1: Energy production (PV-Units)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Σ
I_{sol}	[Wh]	5,25	5,50	5,13	5,27	5,05	5,00	5,19	5,69	5,77	5,43	5,06	4,91	63,25
d_{mth}	[-]	31	28	31	30	31	30	31	31	30	31	30	31	365
E_{sol}	[kWh]	162,75	154,00	159,03	158,10	156,55	150,00	160,89	176,39	173,10	168,33	151,80	152,21	1.923,15
$Q_{t,prod,PV,j}$	[kWh]	21971	20790	21469	21344	21134	20250	21720	23813	23369	22725	20493	20548	**259.625,25**

The result is an energy production of nearly **260.000 kWh per annum**. Because the energy consumption over the year is extremely high (2.680.000 kWh/a), the value of coverage ratio is only around 10%. This value does not initially appear large, but any energy saving is valuable. The PV system is also installed quickly and easily. The roof and the horizontal alignment of the modules are optimal due to the very high sun in Brasilia. The next graph shows the energy consumption and the energy production in comparison:

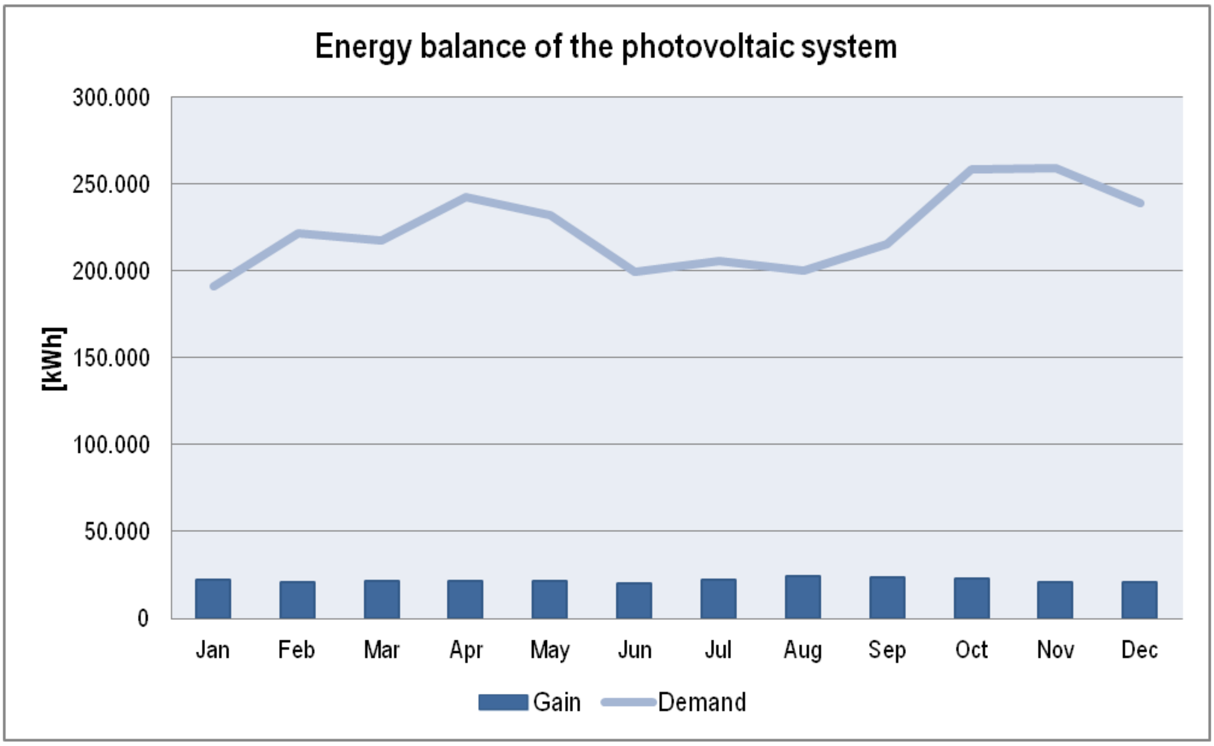


Figure 16: Graph of energy balance of the PV-units

2.6.2.2 Water savings (rainwater-usage):

A smart rainwater-usage of the entire area is also part of the overall concept [6]. The roof area and also the outdoor facilities offer excellent areas to collect rainwater and store them underneath the building.

For surplus calculations, the area for the outdoor facilities was assumed to be triple the building area. The following calculations show the rainwater gain and the water consumption / demand.

At the end a comparison of both values reveals the expected saving of fresh water, which accounts for 68%. More than 2/3 of the fresh water amount can be saved by using rainwater.

Storage-design Rainwater-usage

1. Annual Rainwater Gain

Precipitation [l/m²/a]		Roof Surface Area [m²]		Drainage Coefficient [-]		Rain Income [l/Jahr]
1.668,00	x	1.734,00	x	0,80	=	**2.313.849,60**
according to "Climate Analysis"		Roof Surface Area 102,00 x 17,00 = 1.734 m²		Flat roof, gravelled = 0,80 [-]		

Precipitation [l/m²/a]		Surrounding Area [m²]		Drainage Coefficient [-]		Rain Income [l/Jahr]
1.668,00	x	5.202,00	x	0,75	=	**6.507.702,00**
according to "Climate Analysis"		Surrounding Area 102,00 x 51,00 = 5.202 m² (= 3x Roof Area)		traffic area (50%) = 1,00 [-] vegetation area (50%) = 0,50 [-]		

Storage / Rainwater Gain = **8.821.551,60**

2. Annual (Rain)Water Demand

Flushing:

Quantity of Users:	~	1.200,00	Pers. ~(0,07 p/m² x 17.340 m²)
Amount of flushing:	~	34,00	l/Pers./d
Working Days:	~	250,00	d

1.200,00	x	34,00	x	250,00	=	**10.200.000,00**

Green facade irrigation

Dropper:	~	1,70	l/h	= 40,8 l/d
Length of West facade		102,00	m	x 11 floors = 1122,00 m
Distance of droppers:		2,50	m	→ 1122/2,50 = 449 units
Arid months:	~	May to September → 5 x 30 = 150 days		

40,80	x	449,00	x	150,00	=	**2.747.880,00**

(Rain)Water Demand = **12.947.880,00**

3. Comparison:

	12.947,88	[m³]	Demand
-	8.821,55	[m³]	Savings
	4.126,33	**[m³]**	**New Demand**
→	**68**	**[%] less fresh water-usage**	

2.6.2.3 Room comfort (PRIMERO®-Software):

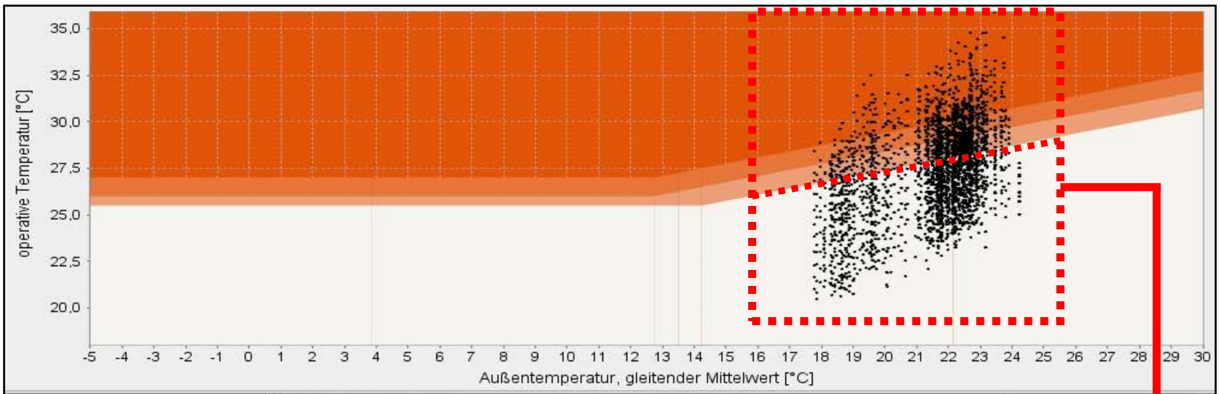
The software PRIMERO has been used to check to what extent the users are satisfied with the conditions in the rooms and offices [7]. For this purpose, a basic variant was first created and then a planning variant. The planning version was designed to meet the goal to exceed 90% user satisfaction by max. 10%. In order not to calculate every room of the entire building, the decisive room was determined: It is the office on the last floor in the north-west corner of the building.

The following table gives a brief overview of the adjusted and changed parameters of both variants:

Basic Variant			
Single glazing: U-Value = 5,8 W/m²K g-Value = 0,86 τ_{vis} = 0,90 Frame: U < 3,2 W/m²K	Intensity of use: lighting = "high" equipment = "high"	Ventilation: No cross / night ventilation available	Solar protection: Totally closed when sun is shining (dysfunction / wrong usage of user)

Planning Variant			
Solar protection glazing (argon): U-Value = 1,3 W/m²K g-Value = 0,26 τ_{vis} = 0,32 Frame: U < 2,0 W/m²K	Intensity of use: lighting = "medium" equipment = "medium"	Ventilation: Cross / night ventilation available	Solar protection: "Cut-Off" when sun is shining on facade (automatically operated / Intervention by user possible)

The two programmed versions have the following results:



	Überschreitung der Komfortgrenzen 94%, 90% und 80% Zufriedener [%]								
	Klassifikation		Bewertung der Komfortkategorien						
			I		II		III		
	I/II/III	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	erfüllt [h][%]	Über-schreitung [%]	Ferien von bis
B	-	-	1153 / 40%	60%	1653 / 58%	42%	[illegible]	29%	-
1	-	-	2053 / 72%	28%	2542 / 89%	11%	[illegible]	4%	-

Figure 17: Output and result of PRIMERO-Software (Basic)

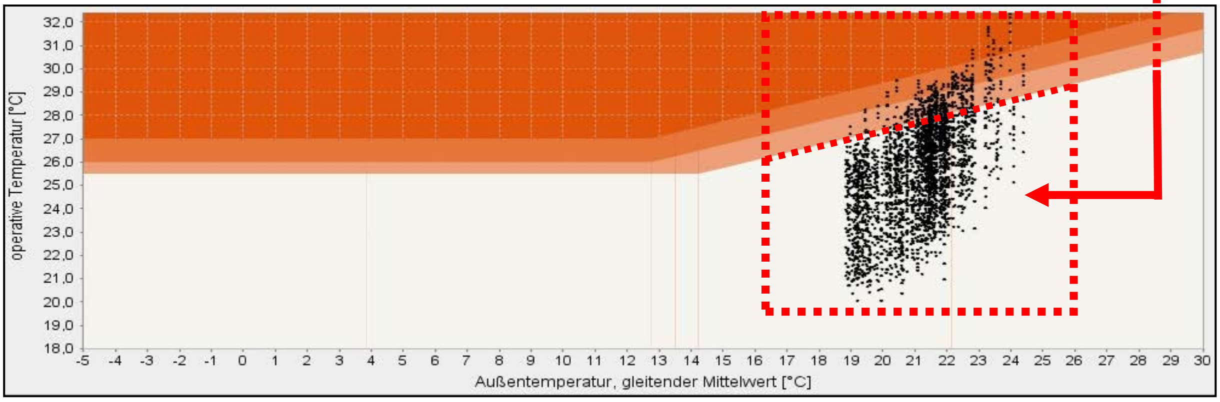


Figure 18: Output and result of PRIMERO-Software (Planning)

<u>Rating of the comfort category (II):</u>

Transgression of:

Basic Variant: 42% → Planning Variant: 11%

The green facade was not included in the calculations. This also leads to a comfort increase, so the 10% limit of transgression is maintained. Another advantage is the higher percentage of daylight in the rooms. Due to the "Cut-Off"-position plus the perforated sun protection panels a further comfort gain and therefore a lower energy consumption by artificial lighting is recorded.

3. Conclusion

The main concept has already been explained in more detail in the previous chapters. In summary, it can be said that many individual changes have been made which implicated the desired improvement of the building.

By incorporating the pool terraces into the building, the energetic as well as the social part of the concept could be considered. On the one hand, the air humidity is increased by the evaporation of the water, while at the same time the fresh and cold air is transported by the wind and directed into the office rooms via the special tube system (with fans) above the corridor. In order to increase the effect of the air circulation, recesses have been built in each ceiling, which allow the cold air to "fall down" and thus also the other floors (with no extra water basins) are reached.

On the other hand, new social spaces have been created, where the employees can meet, catch a breath or simply enjoy the view. The facade remodeling will also prevent the individual rooms from overheating. The cool air gained by the pool terraces, also ventilates the rooms sufficiently. In order to realize cross ventilation, a concept was developed that uses the hallway as well. Night ventilation is also enabled by the new facade and the hallway.

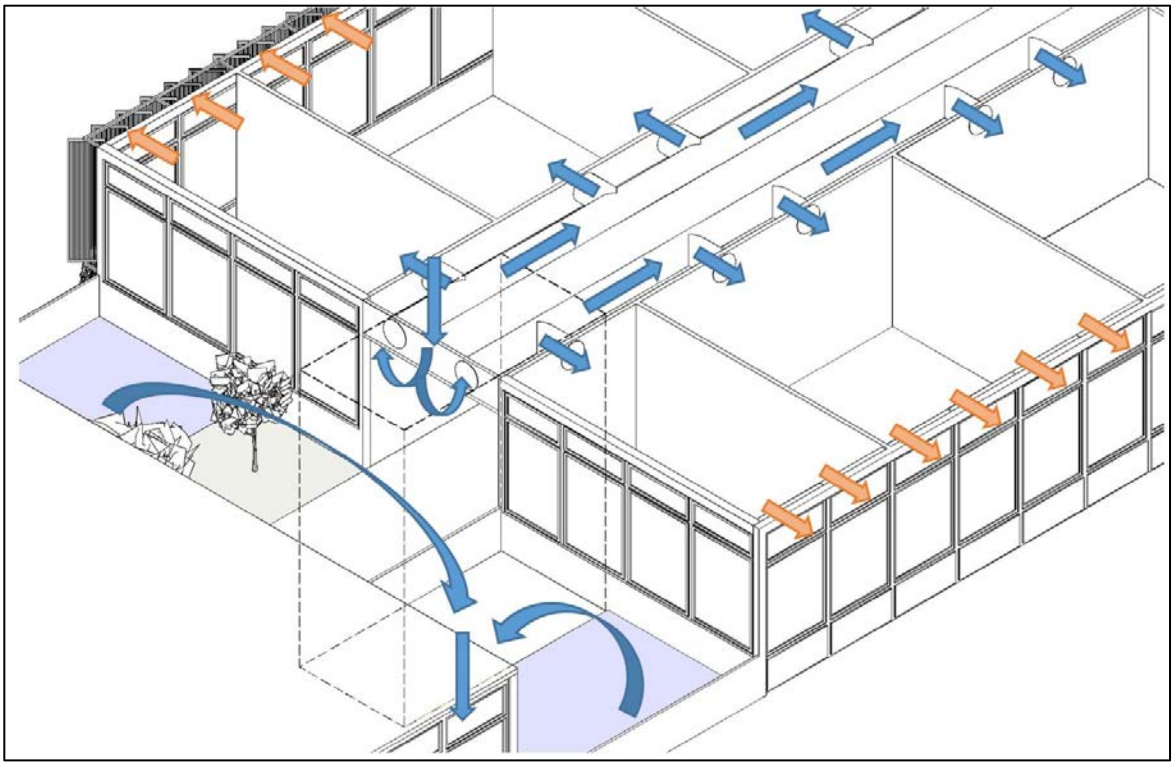


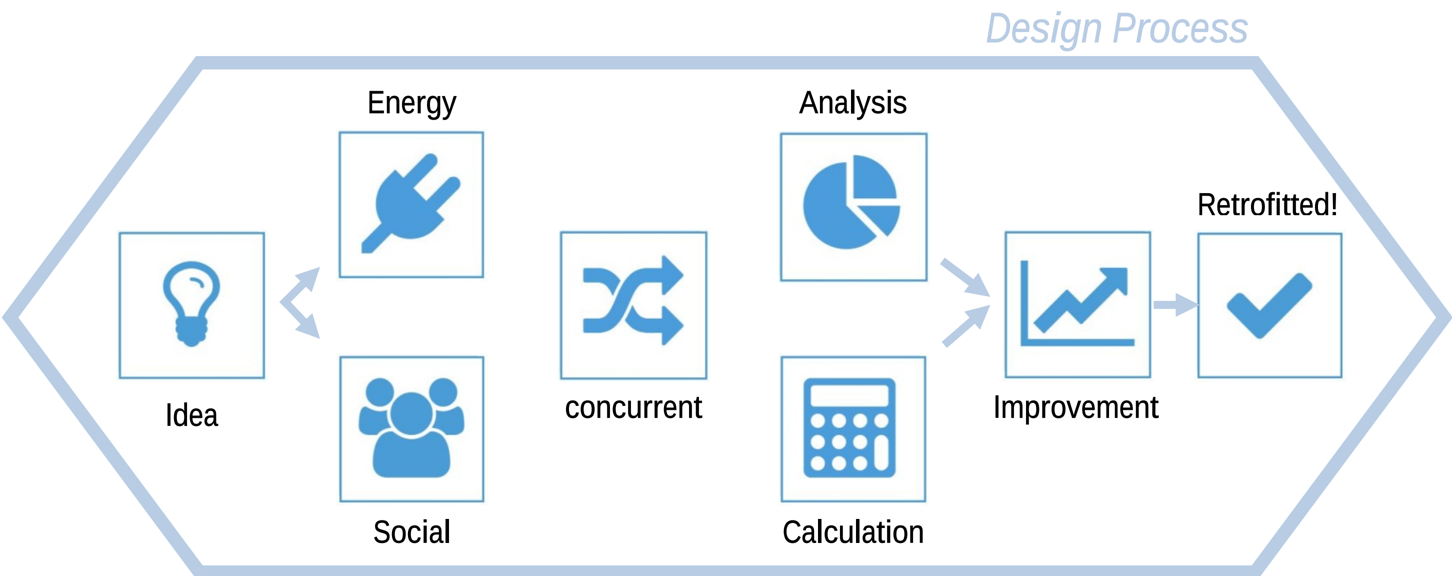
Figure 19: Isometry and visualization of ventilation

The layout / division of the window elements have not changed from the external point of view and are similar to the windows of the existing buildings. This allows the transformation to be seamlessly integrated into the wider surroundings with the existing buildings. This fact is especially noticeable at the east facade which should preserve the legacy of Oscar Niemeyer. The north and south facades remain as they are. The west facade differs slightly from the original. However, this was necessary to realize the energetic advantages. Of course, the "holes" in the facade are an initially sharp deviation. Nevertheless, the building fits still into the overall picture.

It is also worth mentioning that the roof was completely redesigned to create more social areas. There are gardens, cafes and restaurants. It also offers space for the PV system and rain collection areas. The outdoor area around the building will also be redesigned. Rainwater collecting basins or infiltration areas are realized in order to use more rainwater. Aesthetic reasons also play a role here.

Both parts of the concept (energetic and social aspects) were implemented in this way. The new building saves both energy and water and even generates energy by the use of the existing sunshine. Many new social spaces have been created, and the former depressing dark rooms are now brighter and friendlier by using more daylight. Also the corridor, whether inside or outside as a crossover, can now bid to exchange and linger.

The analysis with PRIMERO has shown that the existing building is not too bad from a purely energetic point of view. However, a lot had to be improved to increase the room comfort for the users. At the same time, the human requirements had to be considered. All in all, the measures have led to the realization of an energetically efficient building, which can also score with social aspects.



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Hamburg, September 2017