CLEANVELOPE – PV AND BUILDING GREENING
STUDENTS DESIGN CONCEPTS OF REFURBISHMENTS IN NUREMBURG

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ABSTRACT: A task of the future, with regard to the social challenges of the transformation of the energy system and the adaption to the climate change, is to upgrade the energy efficiency of old buildings. The EU has set itself the goal of making the building stock almost climate-neutral by 2050. A forward-looking approach is to combine building greening techniques and photovoltaics (PV), as a number of synergy effects can be expected here.
A seminar in the master's programme at the Faculty of Architecture of Nuremburg Tech in summer semester 2019 examined how buildings can be upgraded between the conflicting priorities of building culture, renovation, solar technology and building greening. Using the example of the "Nordring" quarter (12 multi-storey residential buildings built in 1959) in Nuremburg, renovation concepts with building greenery and especially photovoltaics were proposed, which, in addition to a design upgrade, demonstrate that both strategies complement each other effectively. In 20 projects, different approaches, from cautious intervention to strong transformation, were developed and constructively deepened. The results show an enormous potential for upgrading of the building environment and housing stock.
Keywords: BIPV, PV façades, solar architecture, building greening

1 INTRODUCTION

The climate change requires new concepts in architecture and urban planning. A central task is the energy efficiency of old buildings. A forward-looking approach is to combine building greening techniques and photovoltaics (PV), as a number of synergy effects can be expected here.

Plants are an ideal natural design element for an ecological envelope concept. In recent years, green façades and green walls have been used more and more in the construction of modern energy-efficient buildings. [1] Due to adiabatic cooling processes, plants can also be used as natural air-conditioning systems in urban and building planning. In doing so, they fulfil a variety of other functions, such as natural air filtering of fine dust, absorption of carbon dioxide, noise reduction, etc. [2]

Façades are becoming increasingly important for solar activation of the building envelope, especially in an urban context, because, among other things, the roof surfaces of multi-storey buildings are often no longer sufficient for the integration of solar technology. Thermal solar collectors and PV modules are also important elements of solar construction and are now regarded as self-evident components of energy-efficient buildings and advanced envelope constructions. [3]

The combination of building greening and photovoltaics not only has positive effects for the design, both strategies can also complement each other functionally. Crystalline PV modules in particular react sensitively to temperature increases, i.e. the cooler the installation, the more efficiently solar electricity can be produced. Especially in the summer months, when there is a lot of solar radiation, a green environment can enable a better performance of photovoltaics.

The combination of green walls and PV is not new for architects. This combination has been considered in competitions and has also been implemented in buildings in isolated cases. [4] In the context of a seminar in the master's programme at summer semester 2019 [5] it was now examined how buildings can be upgraded between the conflicting priorities of building culture, renovation, solar technology and building greening. Using the example of quarter „Nordring" (12 multi-storey residential buildings from 1959) in Nuremberg (Fig. 1), renovation concepts were developed, which, in addition to a design upgrade, show that building greening and photovoltaics complement each other effectively. In 20 projects, different approaches, from cautious intervention to strong transformation, were developed and constructively deepened. The results show an enormous potential for the upgrading of the building environment and housing stock.

Fig 1: Aerial view of the quarter (Source: wbg) and model of the quarter (Photo: Michael Pfisterer)

2 THE PROJECTS

2.1 Linear buildings with north-south orientation

The buildings Gerngrosstraße 30 as well as Nordring 127 - 131 and Nordring 133 + 135 are three-storey buildings with undeveloped pitched roofs. They have a north-south orientation. The façades of the residential buildings, which are organized as two-winged structures, feature regular arrangements of single and double-wing windows; Gerngrosstraße 30 and Nordring 127 - 131

have balconies to the south. In addition to structural similarities, the location of Nordring 127 - 131 and Nordring 133 + 135 brings greater demands on the refurbishment concepts for noise protection.

The two works on the building at Gerngrosstrasse 30 already show typical refurbishment strategies using solar technology (photovoltaics) and building greening as examples. Tobias Moninger and Julia Spreng remove the existing roof and provide a "balcony shelf" as a horizontal extension for the entire south side. The modular extension with differentiation in room height ends with the front edge of the balconies. The vertical extension is clearly visible with the wooden sheathing opposite the thermal insulation composite system. To the south, a multi-layered façade is proposed, in which sun protection, green walls (climbing plants in troughs) and PV panels (monocrystalline cells) are arranged in high-form façade modules. The plants also take over functions of sun and privacy protection. The flat roof is greened and equipped with south-facing photovoltaics. (Fig. 2)

Fig. 2: Moninger / Spreng, elevation 1:20

In addition to new thermally separated loggias in the area of the demolished balconies, Yazan Doudieh and Hendrik Sell propose a full-area building greening with climbing plants, whose circumferential gutters restructure the building floor-by-floor. As an energy envelope, the partially two-storey solid wood extension with pitched roof is in the area of the opaque surfaces completely equipped with frameless PV modules (anthracite-coloured, non visible monocrystalline cells) in a curtain-type, rear-ventilated construction. (Fig. 3)

Fig. 3: Doudieh / Sell, rendering

In their project "Green Prospects" (Nordring 127 - 131), Gabriel Barklam and Martin Riemann replace the existing pitched roof by a single-storey extension and place in front of the south side a four-storey structure

Fig. 4: Demirkol / Salihoglu, south elevation (1:100)

with largely identical solid wood modules. Loggias (with horizontal PV and wooden sliding shutters) with open areas (vegetable beds and climbing plants) are created for each apartment. Large-scale PV modules are arranged above the new green roof. This approach pursues a homogeneous appearance with the multi-layered new spatial zone, in which old and new are no longer legible (Fig. 4). Sevil Demirkol and Muhammet Mustafa Salihoglu follow a similar concept. Vertical frames, with integrated plant boxes at the new balconies, are placed in front of the south side. In the area of the opaque wall surfaces, climbing plants and PV modules are arranged alternately. To enhance the open space close to the building, a noise protection wall made of wooden frame elements is proposed. The existing pitched roof remains a temperature buffer; the south side is designed as a fully integrated PV generator.

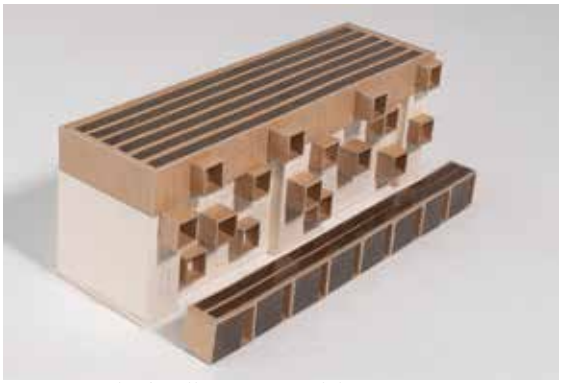

Fig. 5: Honke / Kellermann, model 1:50

In the neighbouring building (Nordring 133 + 135), David Honke and Max Kellermann as well as Annika Leiter and Sonja Silano focus on a single-storey noise protection wall. In the former, wooden pavilions serve as protection. They collect energy and allow green common areas shielded from the street to the south. The single-storey extension with the wooden cladding, in conjunction with alternately arranged loggias, clearly marks the vertical and horizontal expansion. The building greening close to the apartments is reduced to potted plants in the loggias. (Fig. 5). At Leiter and Silano, the noise barrier with a green wall to the street, also improves the quality of the air, while spatial domains differentiate the common area. In addition to occasional wooden modules arranged in front of the living rooms with potted plants, generous, greened loggias are offered in the addition of another storey. The south-facing sloping roof area is used entirely for solar power generation.

Fig. 6: Cimino / Rolof, model 1:50

2.2 Linear buildings with east-west orientation

The buildings at Nordring 137 - 155 and Schopenhauerstraße 32 - 36 are four-storey linear buildings with pitched roofs, also not developed, which are arranged east-west. The building sections, each of which is organised as a two-span structure, differ slightly in the length of the buildings and in the access.

For Nordring 137 - 139, Federica Cimino and Diana Rolof propose an extension with a pitched roof. While the east façade is given a new cladding of vertical wooden boards, in the west a balcony zone that changes floor by floor is placed in front of the living rooms. The building greening is placed on the south side and also serves as a horizontal end to the open space. On the gable wall in the north, ten façade modules with moss are arranged in five horizontal bands. On the south side, PV modules arranged in the same design add to the roof system. (Fig. 6)

In the neighbouring building Nordring 141 - 143, the vertical extension is carried out via a single-storey addition with a flat roof. Hüseyna Koc and Melek Sakanci leave the narrow sides largely untreated, but present the east and west façades with a spatial structure over the entire surface. In addition to the living spaces, room modules are proposed as loggias, which penetrate the level of the metal mesh as a climbing aid. The building greening is done via plant boxes on each floor. The new flat roof is fully equipped with east-west oriented PV modules. (Fig. 7)

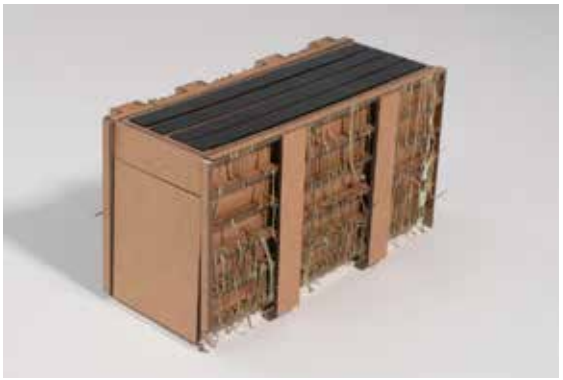

Fig. 7: Koc / Sakanci, model 1:50

At the linear building located to the east, Franziska Kopf and Lisa Schubothe react on the basis of sun position studies and existing trees with horizontal extensions mirrored over the diagonal. Thus, the northern apartments get a thermal buffer zone in the east, the southern apartments in the west. The new pitched roof has an additional gallery level in the area of the ridge. As an extension of the roof, the glazed areas of the conservatories with greening are fitted with semi-transparent PV modules; the opaque roof surfaces and the upper third of the south wall are fitted with anthracite, monocrystalline PV shingles mounted over the corner.

Fig. 8: Models Nordring 137 - 153

Marius Sperger and Sarah Strohbach envisage extensions of the living spaces for Nordring 149 - 151 both in the east and west. The balconies will alternate in the supporting structure floor by floor. While on the gable sides and along the posts ground-based climbing plants grow upwards, plant troughs and raised beds for planting vegetables are provided in the area of the balconies. The two roof areas are fully equipped with a roof integrated PV generator.

Marco Burger and Johannes Poerschke do not see any vertical extension for Nordring 153 - 155. The existing roof space is retained as a thermal buffer. The outer wall will have a wooden façade with vertical sheathing all around and spatial expansion is planned on both long sides. Mobile plant gutters with climbing plant trellis are arranged in sections at floor level as movable sun and sight protection. The upper end is formed by vacuum tube collectors. The roof area is divided into smaller fields of double-rowed rooftop PV systems. The concept is supplemented by a rainwater management system. For noise protection, between the multi-family dwellings a building made of prefabricated concrete elements is proposed, whose south-facing sloping roof surface is on the one hand a PV generator, while the upper third ends with a planting box for the green projecting wall. (Fig. 9)

Fig. 9: Burger / Poerschke, rendering

A new aspect is introduced by Sandra Keß and Charlotte Strohbach at Schopenhauerstraße 32 - 36 with their „Bee Green“ renovation concept: urban biodiversity with beekeeping. A part of the roof area of the extension

Fig. 10: Dieterich / Kühn, model 1:50

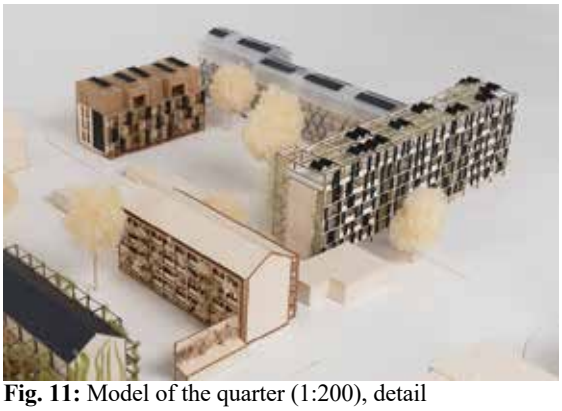

Fig. 11: Model of the quarter (1:200), detail

will be used for beekeeping, the rest for solar thermal energy. On the ground floor, the students propose a public use, including a „honey café“. The horizontal extension in the east and in the west will take place from the 1st floor on. The end is formed by alternating green areas on each floor (climbing plants in boxes) and PV panels, which are mounted at the edge of the roof as protection against the weather. In front of the brick façade on the gable side in the south, a large cable net trellis extends the green façade.

Carmen Dieterich and Franziska Kühn call their approach for the same building “invasive to the maximum“. In addition to the horizontal extension, a narrow zone with window seats in the east, deep balconies in the west, the living space is significantly increased with a complete storey plus extended pitched roof. Troughs for plants shrubs are integrated into the structure placed in front, made of prefabricated reinforced concrete elements. The extended roof and the south façade are fully covered with anthracite CIS thin-film modules. (Fig. 10)

2.3 Residential buildings

The two flat-roofed buildings in the east of the quarter, Nordring 159 (five-storey) and Gerngrosstrasse 32 (three-storey), located in the north-east along Otto-Geßler-Strasse, differ in the organisation and development of the living spaces. Both buildings were originally designed as 1-room flats and were accessible via a courtyard-side access balcony, Nordring 159 in the north and Gerngrosstraße 32 in the west. At the end of the 1980s, the building was redesigned by merging rooms into 4-room flats."

With their “active building skin“ concept, Eva Grotter and Marie Christine Häußler house Nordring 159 with a new steel structure on the long sides and above the single-storey addition. This construction replaces the existing access balcony in the north and takes up the private living space extension in the south. Semi-transparent PV modules serve as privacy and sun protection in the area of the balconies; while potted plants are largely provided there, self-climbing plants grow upwards along the columns. In contrast, one funds large areas of façade greening in the north along the access balcony. Above the top floor, a multifaceted roof garden is created, especially for growing vegetables. As protection against the weather, photovoltaics are arranged in a flat east-west orientation over partial areas. (Fig. 11)

The approach of Fatemeh Sedrehneshin and Vanessa van Zoest is also characterised by a strong transformation. A steel construction is placed in front of the long sides in the south (balconies) and north (new arcade). The spandrel areas and the prismatic triangular surfaces connecting the floors and inclined to each other are alternately covered with greenery and photovoltaics. Due to their spatially layered arrangement, certain synergies are created and the concept shows a dynamic façade design. Instead of adding a storey, it is proposed to create an indented roof garden.

Eslam Mohamed Ahmed and Felix Prommersberger also replace the access balcony in the north with a thermally separated support structure and place glazed balconies with PV parapets in front of the living areas. In contrast to this clear horizontal arrangement, the areas in front of the former kitchen windows are designed as vertical zones for climbing plants. The new flat roof is designed as a PV generator with east-west modules covering the entire surface.

Fig. 12: Oebius / Zahl, rendering

The two concepts for the building at Gerngrosstrasse 32 address further variations. In addition to adding another storey to the three-storey building, Philipp Oebius and Tina Zahl propose a spatial extension along Gerngrosstrasse as a urban redensification following extensive shadowing analyses. In addition to further additional living space, a “photovoltaic roof garden“ [6] with an intensively planted terrace will be created on level 4. A pergola made of solid structural timber with south-facing sheds and semi-transparent PV modules will provide shade and generate solar power. In the existing building, plant troughs are arranged on the ceiling level all the way around from the first floor and east-west oriented PV modules are arranged on the extensively greened flat roof. (Fig. 12)

Julia Hager and Daniel Jäger extend the pergola with balcony areas and complete the building with an additional attic storey, whose western façade flushly

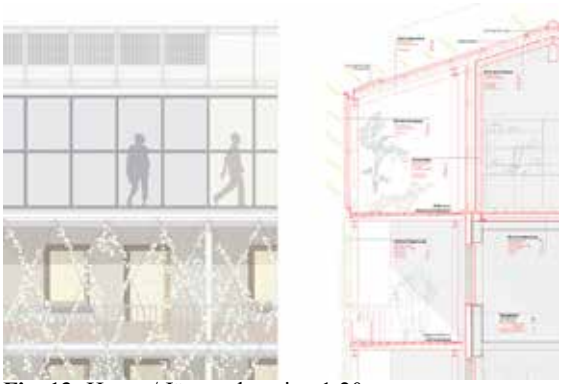

Fig. 13: Hager / Jäger, elevation 1:20

covers the new outdoor areas. The special feature of the glulam attic storey is that its entire enveloping surfaces are designed with polycarbonate multiwall sheets as air collectors. A thermal buffer zone is placed in front of the outer wall as a common area. While on the east façade vertically tensioned wire ropes serve as a climbing aid, in the west the wire ropes are arranged diagonally in front of the building-high metal wire mesh. On the sloping roof surfaces, PV modules are positioned in areas below the ventilation openings on the ridge. (Fig. 13)

2.4 Point blocks

The two buildings, which were erected south of the road, form a special structural form. They are five-storey point houses with an H-shaped ground plan. The buildings have two very different façades. On the east and west sides there are perforated façades with plaster surfaces (in the planning permission, a slab grid is still visible), while in the north and south, wall panes are designed as fair-faced brickwork, which only have openings with the vertical row of kitchen windows in the area of the "constriction".

Giulia Seltmann and Moritz von Frankenberg-Carbon leave the wall panes at north ring 144 as a characteristic feature and propose an internal insulation. The building will be raised by one storey and a scaffolding construction with balconies will be placed in front of the east and west façades. Narrow channels for climbing plants are fixed at ceiling level, with horizontal PV sliding elements in front of them as privacy and sun protection. In the area of the attic, semi-transparent PV modules provide weather protection. Additional balconies are provided in the recesses at a distance from the staircase. The flat roof is extensively greened with PV modules arranged in east-west sections. (Fig. 14)

Fig. 14: Seltmann / Frankenberg-Carbon, rendering

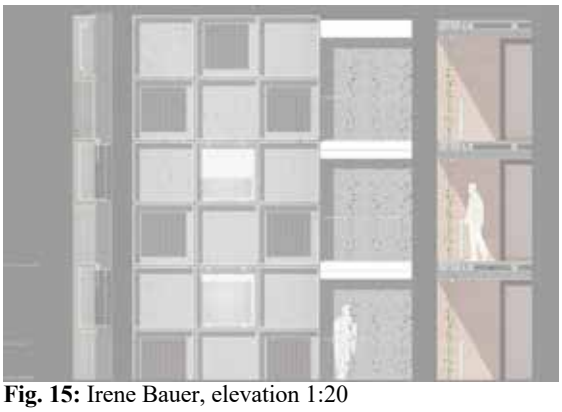

Fig. 15: Irene Bauer, elevation 1:20

The square kitchen windows in the wall panels form the dimensional reference for Irene Bauer's renovation concept for the Nordring 142 building. She is developing a kind of modular system with four different elements made of fibre concrete. Their geometry has been chosen in such a way that even the basic module has sound insulation functions. The other modules contain sun protection, a green wall, a dust filter, and finally photovoltaics for electricity generation. These are arranged differently depending on requirements and exposure and are presented as a self-supporting structure to the insulated exterior walls. In the recesses in the area of the staircase, common areas close to the apartments with climbing plants arranged floor by floor are proposed as filter layer. Above the existing, undeveloped top floor a roof garden is created, framed by a pergola and zoned into communal and play areas with space for raised beds for urban gardening. (Fig. 15)

3 (INTERIM) CONCLUSION

The students proposed different renovation strategies for the buildings. In the concepts with building greening and solar technology, the use of wood and wood-based materials for energetic refurbishment is often the alternative to the common thermal insulation composite system. The use of plants and photovoltaics differs in the façade and roof area. In some of the projects, supplementary noise protection structures are proposed for upgrading and expansion.

In the façades, building greening and PV are often functionally separated. Climbing plants are used in gutters arranged floor by floor. The advantages of radiation permeability are specifically used for privacy and sun protection. In connection with the newly created open areas close to the apartments (balconies and glazed loggias), there are also approaches that allow the cultivation of herbs with raised beds. In the ecological building envelope concepts, the plants function primarily as an atmospheric design element, without neglecting their function as natural air conditioning.

Combinations largely refer to extensively greened flat roofs with flat-sloping PV modules. This shows that, taking into account the basic requirements of both systems, functioning, integrated solutions can be implemented. In some projects, the top of the building becomes a PV roof garden with an intensively planted terrace, which connects urban gardening with common areas.

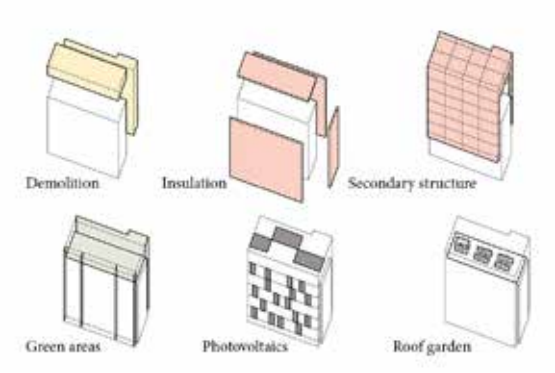

Fig. 16: Grotter / Häußler, concepts

In the case of photovoltaics, in some examples solar thermal technology is used, in the façade (semi-transparent) modules in the parapet and as storey-high visual and sun protection elements are installed. (Fig. 16) Particularly in multi-storey residential construction, vertical building surfaces are becoming increasingly important for solar activation, as the roof surfaces are often no longer sufficient for the integration of solar technology.

Conceptually, references to well-known implementations, such as wagnis4 in Munich (2014) by A2architekten Freising with FreiRaumArchitekten Regensburg, can be seen. At the same time, there are also references to advanced concepts such as Günter Pfeifer‘s “cybernetic planning“ [7] with large-area air collectors or independent approaches to a modular system with small modules. One work proposes a change of use on the ground floor and combines biodiversity with urban beekeeping.

The solutions developed in the course of a seminar in the master‘s programme open up the possibility of integrating current topics of the social challenges of energy system transformation and climate adaptation into architecture teaching, and last but not least a fruitful knowledge and technology transfer to relevant research activities in the field of teaching “construction and technology“ [8].

Students teams

Gabriel Barklam, Martin Riemann / Irene Bauer / Marco Burger, Johannes Poerschke / Federica Cimino, Diana Rolof / Sevil Demirkol, Muhammet M. Salihoglu / Carmen Dieterich, Franziska Kühn / Yazan Doudieh, Hendrik Sell / Eva Grotter, Marie Christine Häußler / Julia Hager, Daniel Jäger / David Honke, Max Kellermann / Sandra Keß, Charlotte Strohbach / Hüseyna Koc, Melek Sakanci / Franziska Kopf, Lisa Schubothe / Annika Leiter, Sonja Silano / Eslam Mohamed Samir, Florian Prommersberger / Tobias Moninger, Julia Spreng / Philipp Oebius, Tina Zahl / Faterneh Sedrehneshin, Vanessa van Zoest / Giulia Seltmann, Moritz von Frankenberg-Carbon / Sarah Strohbach, Markus Sperger

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Photos of the models: Michael Pfisterer