# PREFAB SYSTEMS FOR LOW ENERGY/ HIGH COMFORT BUILDING RENEWAL

## IEA: ECBCS-ANNEX 50

**PROJ. NR. 811574**

## AUSTRIAN

## MODULE DOCUMENTATION

**CONTRACT:**

**GZ 606.013/24-III/I3/2006**

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# 1 Introduction

## 1.1 Definition

In future the key focus must lie on the development of renovation-concepts in order to improve energy-efficiency of our building-stock and on increasing the use of renewable energy sources in their operations. It makes sense to use technologies, which have been proofed successfully within new passive houses and low energy buildings and adapt them for the renovation proceedings.

Objective is to find innovative and feasible concepts for the renovation of typical multi-family houses. Not only aiming on highest possible energy-efficiency but also on users comfort after and during the renovation works. This means to find a way that occupants may stay in their apartments during the renovation proceedings ("inhabited construction site") and to improve their living environment.

To find such concepts for renovation of typical residential buildings the IEA ECBCS Annex 50 focused on the development of multi-functional roof- and façade modules, which are highly pre-fabricated. These multi-functional modules get integrated active components - like collectors and pv-plants - and supply lines or distribution infrastructure (plug-in-and-play-modules). Finally the development should lead to system, which makes high-performance renovations feasible and affordable.

## 1.2 Energy-efficient building renovation

Using pre-fabricated facade modules it is possible to improve the U-value of the existing exterior walls. The thickness of the insulation or the U-value of the entire system (old exterior wall and new façade module) should be oriented on passive house standard. Further it is necessary to integrated passive house windows into the system. Aim is to get a construction free of thermal bridges. Not only existing thermal bridges should be eliminated. The junction and fixing of the new façade system has to be done without generating thermal weak points.
The integration of solar combs into the façade module leads to even better U-values - and an improved thermal envelope. But within renovation it is very difficult to reach a standard like it is possible in new buildings. Therefore the integration of solar collectors and PV-plants into the pre-fabricated system contributes to active and nearly $CO_2$-free energy generation within the envelope.

## 1.3 Ecological aspects

Due to the chosen material – timber – a high ecological quality is achieved. But is essential to consider the restrictions which arise by using timber-based constructions. Depending on different standards and building codes the application of timber within the façade is limited to buildings up to 4 levels.

## 1.4 Acceptance by users

The assembling procedure is done from outdoor due to the pre-fabrication process shorter than usual. So the disturbing effects on users during the renovation are reduced significantly. It is only the removal of the old windows and the cladding of the window-reveal that has to be done from the inside. This makes the "inhabited construction site" possible.

## 1.5 Quality of completion

Pre-fabrication offers beside other advantages a very high quality-standard: starting with a high standard of work-planning the procedure in the production hall is highly predictible and can be controlled easily. Further the entire process is independent from the weather conditions.

# 2 Approach

## 2.1 Partners from the industry

The project team consisted of:

- GIWOG - Gemeinnützige Industrie-Wohnungs AG, Oberösterreich (builder)
- gap-solution GmbH, Leonding (contractor)
- Energiesysteme Aschauer / Futus Energietechnik GmbH (energy-engineering)
- Hohensinn Architektur GmbH, Graz (architect)
- Kulmer Holzbau GmbH (carpenter and subcontractor)

The project was funded by:

- Austrian federal Ministry of Transport, Innovation and Technology (Program "Building of Tomorrow")
- Federal Government of Styria

Starting point of the project was the idea of the builder GIWOG to carry out a high-performance renovation with pre-fabricated modules and an innovative energy concept. But the innovation should be visible by a shining architecture – the design was done by the office of the Hohensinn Architektur GmbH. The entire renovation concept – the improvement of the thermal performance, the development of the pre-fabricated modules and the energy concept was coordinated by the engineering of the office TB Energiesysteme Aschauer and gap-solution GmbH.
After a careful planning the carpenter Kulmer GmbH Holzbau assembled a prototype. A series of discussions concerning statics, building physics and critical details led to the final module, which was proved and checked by all relevant project partners. Not until then the serial production started.

## 2.2 Scientific partners

The AEE – Institute for Sustainable Technologies (AEE INETC) was involved as consultant on building physics, energy efficiency and on the development of the module.
Additionally a monitoring-procedure and an evaluation of the results are done together with gap-solution. Therefore spot-measurements and questionnaires are carried out.

# 3 Pre-fabricated facade modules

## 3.1 General information

The pre-fabricated facade modules are mounted on a substructure made of timber, which is mounted on-site onto the façade-surface. The substructure acts as levelling lathing and hosts installations like wiring and pipe-work. Therefore the entire heat dissipation system and all supply-lines are installed in this layer – the intermediate space is filled with insulation material.
The large-scaled façade modules have a length of 12 m and are 3 m high – so it is possible to transport them with a low-loader to the construction-site. The assembling procedure on-site was done by a truck-mounted crane and additional mobile-cranes.

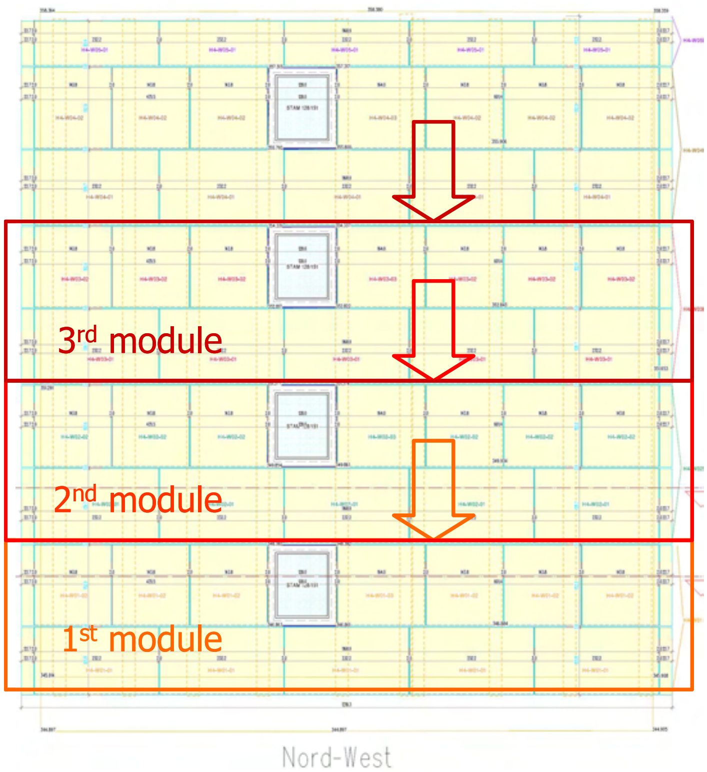

Picture 1: Former building stock (Source: AEE INTEC)

## 3.2 Basic module und prototype

The visual appearance and design was done by the architect. But the solar comb had to be integrated into the architectural concept – as visual part. The development of the basic module considered an integrated window and a decentralised ventilation device. Further the floor-to-floor height defined the height of the module (about 3 m), because the intermediate floors provide a good fixing-subsurface.

The junction between the single modules was done by tongue-and-groove system. The assembling procedure started at the bottom – the first module rested on a steel-angle bearing. Afterwards all previous modules were on the lower ones.
But it was carefully obeyed, that all junctions, fixings and the entire construction was free of thermal bridges.
To prove the construction system a prototype was assembled – but not until all discussions on statics, buildings physics and critical details were finished the type approval was submitted.

Picture shows the module system exemplary – a work plan as a view on the gable of one of the building blocks. The first module reaches from the line of the floor between cellar and the upper line of the window. The depicted vertically joints are only the edges of the glass-panels, covered by cover strips.




Picture 2: Work plan showing the module system for a gable of one building blocks

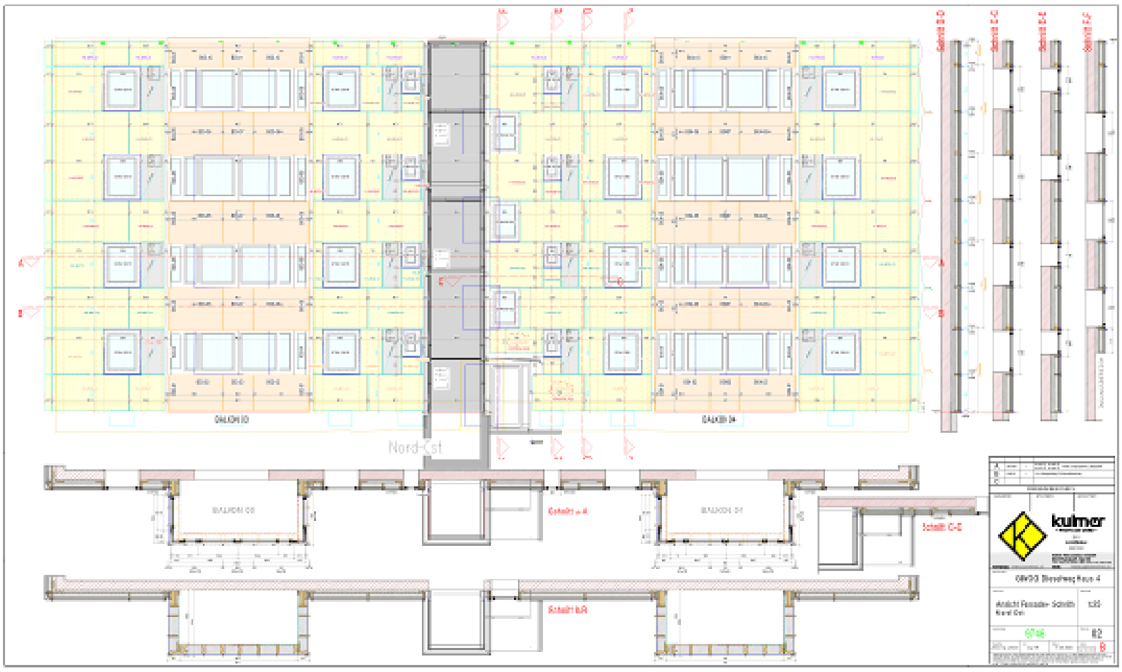
(Source: gap-solution GmbH)

Picture 3: Assembling the prototype in the fabrication of carpentry Kulmer Bau (Source: AEE INTEC)

Picture 4 shows the layer composition of the basic module. On the left side the existing wall is depicted – followed by a levelling slat, which the pre-fabricated module is assembled on. The basic frame is made of timber; in-between a first layer of insulation. The solar comb is mounted on the outside upon a MDF-board followed by a ventilated airspace and covered with a single-pane safety glass. On the back of the timber frame construction and OSB-board completes the pre-fabricated element.


Picture 4: Layer composition of the basic facade module (Source: gap-solution GmbH)

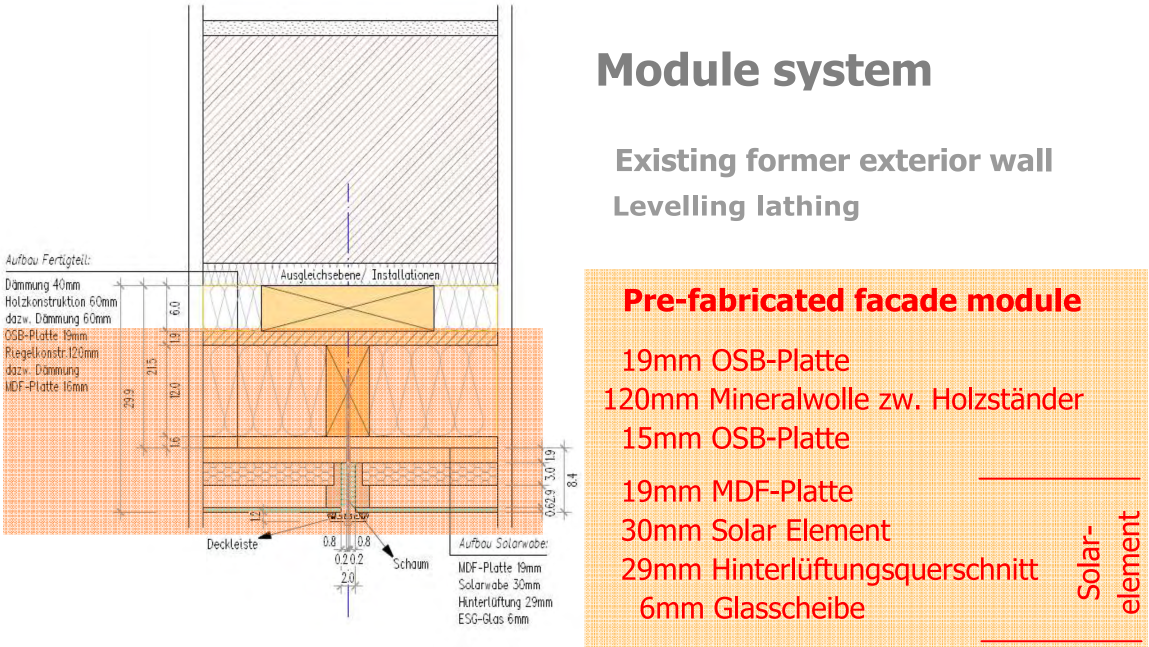
## 3.3 Views and sections



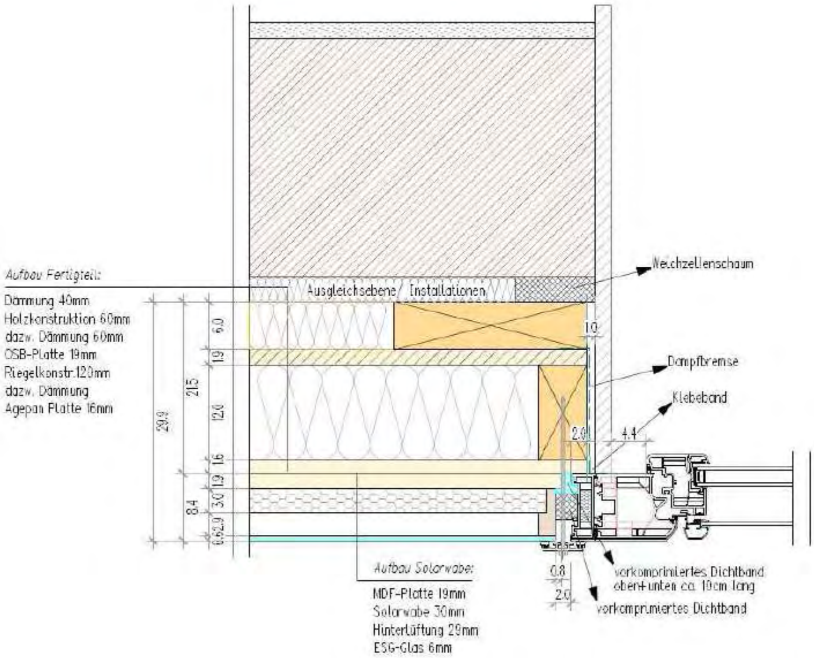
Picture 5: View of the facade (Source: Kulmer Bau)

## 3.4 Details of construction

The layer composition and thickness of insulation enables the basic module to reach passive house standard – finally it has a thickness of about 24 cm. The approval has done according to PHPP 2007 (7th edition of the Passive House Planning Package). The details depicted in

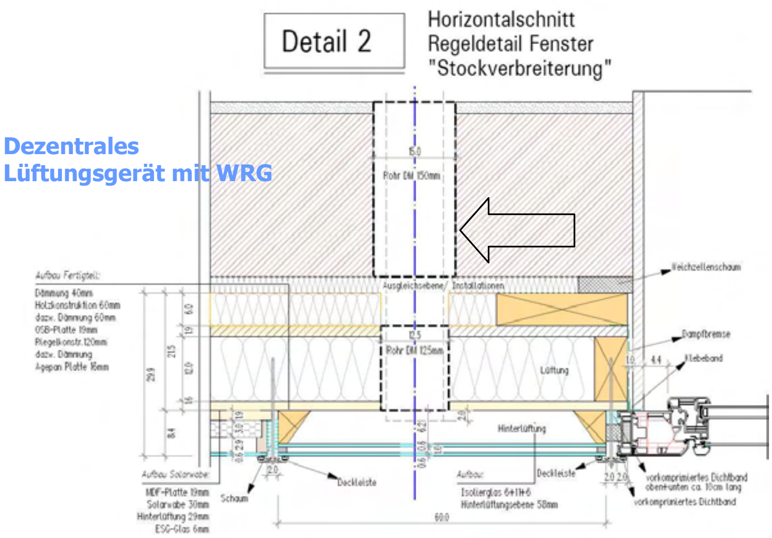



Picture 6: Detail of work plan showing the pr e-fabricated module on the levelling lathing and the existing former exterior wall (Source: gap-solution GmbH)



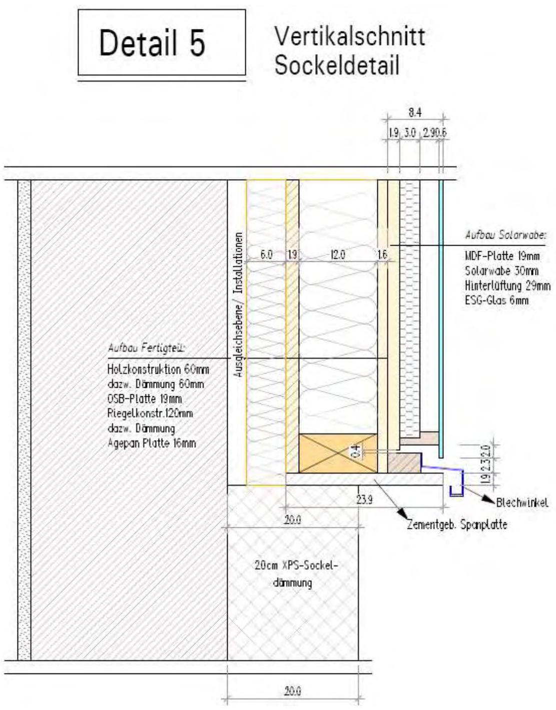

Picture 7: Detail of work plan showing junction between the pre-fabricated module and the integrated window (Source: gap-solution GmbH)

The basic module comprised a decentralised ventilation device with heat recovery. The ventilation device was covered with an opaque insulation glass panel. The inlet and outlet of the ventilation device was provided within the airspace of the rear ventilation behind the glass panel.




Picture 8: Detailed section through the ventilation duct – on the outside the insulation glass panel covers the rear-ventilated airspace. The ventilation duct penetrates the entire module and the exterior wall.

(Source: gap-solution GmbH)

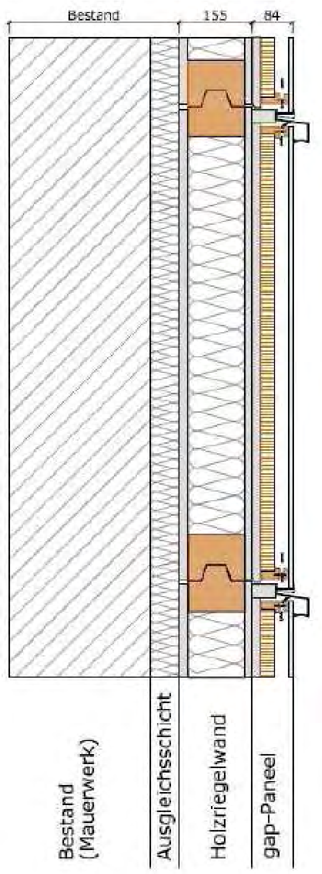



Picture 9: Detailed cross-section - showing the bottom of the first module within the plinth. The exterior wall, which is not covered by the module got a XPS-insulation

(Source: gap-solution GmbH)

## 3.5 Joining techniques of the modules

All horizontal joints are designed as a kind of tongue-and-groove junction (Picture ). This enables the correct module position and a vertical coupling of the modules. But the sealing against driving rain is achieved by horizontally arranged façade plates. The vertially oriented caulks are covered with cover strips and fixed with screws (Picture ).




Picture 10: Detailed cross-section showing the tongue-and-groove coupling between the modules.

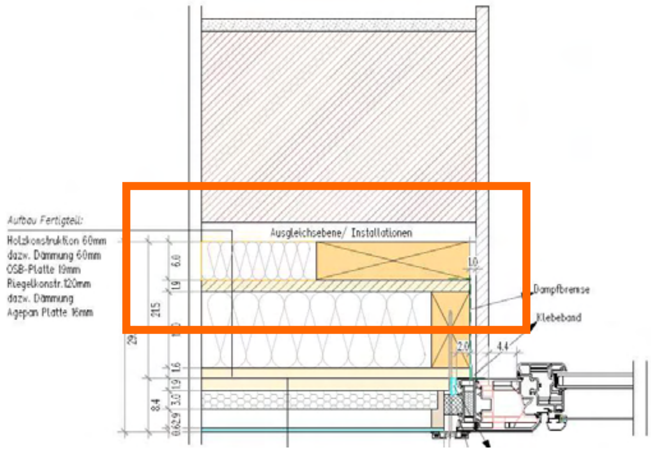
(Source: gap-solution GmbH)

Picture 11: The upper picture shows the vertical joints with the cover strips fixed by screws. The picture below shows the horizontally mounted façade plate to ensure the sealing against driving rain

(Source: gap-solution GmbH)

## 3.6 Installation and levelling lathing

The installation and levelling lathing – made of timber laths – provided space for the heat dissipation system, which was installed right on the outside of the exterior wall, and the supply lines for the heating system. The remaining space was filled with insulation panels.

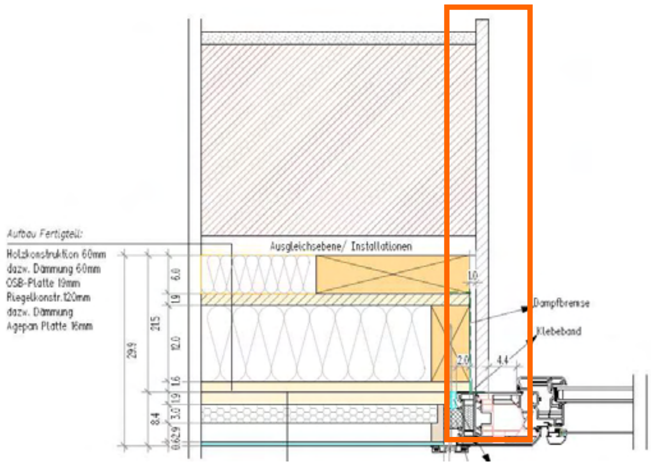



Picture 12: Detailed cross-section showing the levelling lathing (Source: gap-solution GmbH)

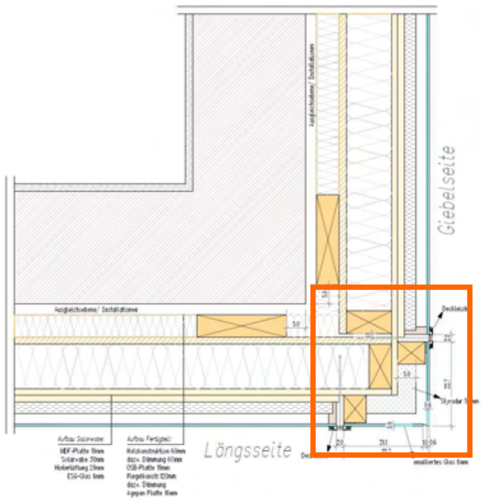
Picture 2: Photo during renovation works on the exterior wall with the levelling laths assembled on and in-between the insulation panels with inserted heating pipes.

## 3.7 Junctions

All junctions within window-reveals, building´s angles and attics are completed and closed after the assembling procedure of the pre-fabricated modules was finished.




Picture 14: Detailed cross-section showing the cladding of the window-reveal. At the junction between new window and the former exterior wall the vapour-barrier had to be closed carefully (Source: gap-solution GmbH)




Picture 15: Detailed cross-section showing a building's angle. The vapour-barrier had to be sealed between the two modules (Source: gap-solution GmbH)

## 3.8 Assembling during fabrication and transport on-site

Picture 3: Assembling procedure in the fabrication of the carpentry Kulmer Bau (Source: gap-solution GmbH)

The dimensions of the module allow a transport by low-loader to the building-site were it is installed by means of mobile cranes and assembling operators on the prepared levelling slat on the outside of the existing exterior wall. The mounting procedure starts with the lowest module – resting on steel angle brackets which are mounted on the plinth - the further modules are assembled above and connected together horizontally with tongue and groove joints.

Picture 17: Transport on-site and assembling procedure (Source: gap-solution GmbH)

## 3.9 Assembling procedure of the facade module

The pre-fabricated façade modules are assembled in the fabrication hall according to the detailed work planning. Afterwards they are transported with a low-loader to the building-site and lifted by a truck-mounted crane to their correct position at the façade. Assembling operators on mobile cranes are positioned on each side to help during the installation.

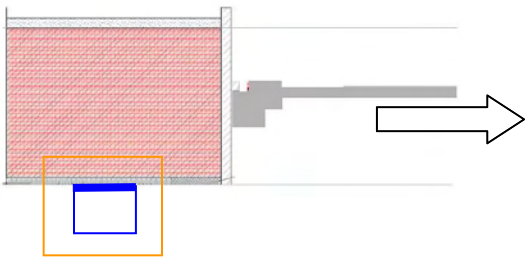
The installation on-site is based on three steps:

Step 0: Installation of steel-angle bearings at the plinth of the existing building, which will take over the vertical loads of the modules

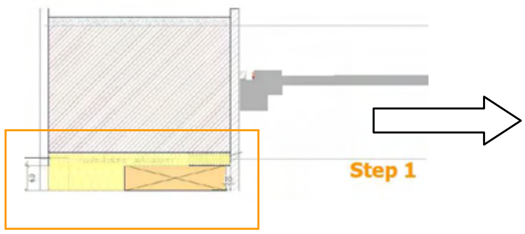
Step 1: Installation of the substructure made of timber laths. The substructure acts as levelling plane, hosts the heat dissipation system and the supply lines. The remaining space in-between is filled with insulation panels.

Step 2: Assembling the large-scaled facade modules by truck-mounted crane onto the prepared subsurface. Tow additional assembling operators, which are positioned on each side help during the adjustment and fixing.

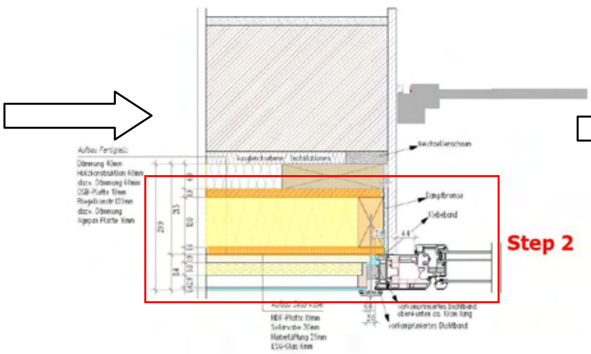
Step 3: Removing of the old windows from inside, closing vapour barriers and cladding of the window-reveal. Further all remaining adaptions (closing and sealing of all other vapor-barriers at angles and junctions).



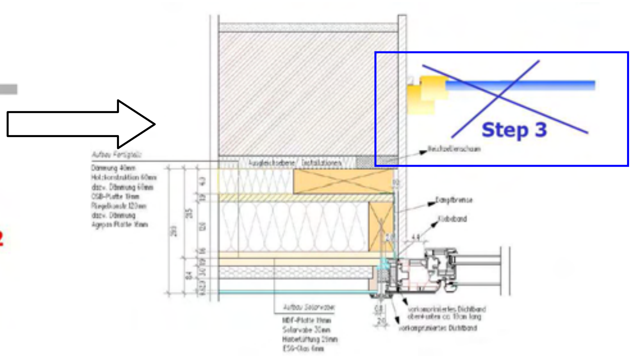
**1. Mounting and fixing the steel-angle bearing**




**2. Mounting levelling laths**




**3. Assembling facade module**

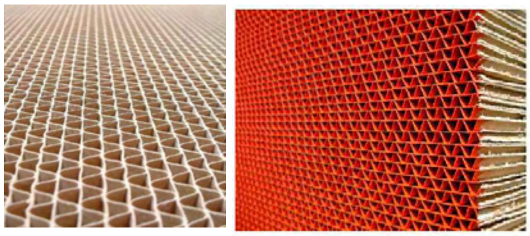



**4. Removal of old window inside**

Picture 4: Assembling procedure of the facade modules in detail
(Source of detailed drawings: gap-solution GmbH)

## 3.10 Building physics and energy-concept

The entire building envelope was covered with the pre-fabricated facade modules. The thermal performance of the module is achieved by a innovative concept, which was developed by gap-solution. Core of the development is the solar comb – a special comb made of cellulose. The solar comb is on the side of the module which is oriented to the sun and is covered by a glass panel. This rear ventilated air space protects the solar comb from weather and mechanical damages. To generate an attractive appearance the surface is painted in different colours. The light from the low sun in winter is falling through the glass panel and warms the solar comb. So the temperature on the outside of the system is increased. The temperature difference between warm inside and cold outside in winter decreases and heat losses are minimized. During summer the structure of the solar combs shadows itself due to the high sun.

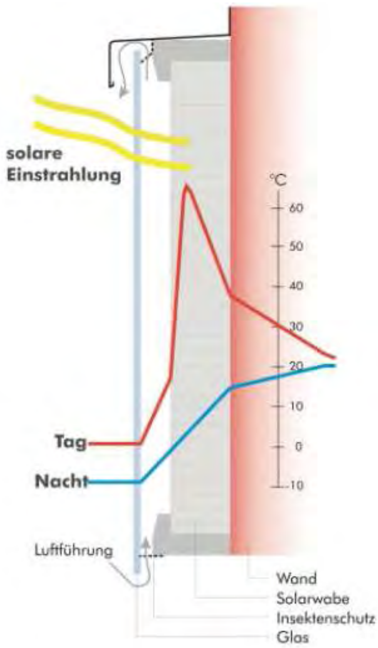




Picture 5: Solar comb in detail (the left picture show a com with painted surface (Source: gap-solution GmbH)

Key components of the energy-concept are:

- Large-scaled facade modules with solar combs (gap-Solution)
- Passive house windows with intergrated blinds (mounted in intermediate space between insulation gals panels)
- Single room ventilation devices with heat recovery
- Integration of former balconies within the new thermal envelope.





Picture 20: How the facade system with the integrated solar comb works. The pictures shows the temperature curve during day and night. (Source: gap-solution GmbH)

Picture 21: The prototype of the facade module. The timber frame and the ventilation slots can be seen.

(Source: gap-solution GmbH)

## 3.11 Heat distribution and dissipation system

The heat dissipation system follows the principle of thermal activation of building components. The heat dissipation system is installed on the outside of the existing exterior wall. As mentioned before these XPS insulation boards are installed within the levelling laths. These XPS-boards are equipped with inserted heating pipes. So the wall-areas below all windows are warmed from the outside.

Picture 6: Two views on the exterior walls during installation works. The heat dissipation (XPS-boards with inserted heating pipes) are assembled in the wall-areas below the windows (Source: AEE INTEC)

Picture 23: Heat dissipation system installed on the outside of the exterior wall (Source: AEE INTEC)

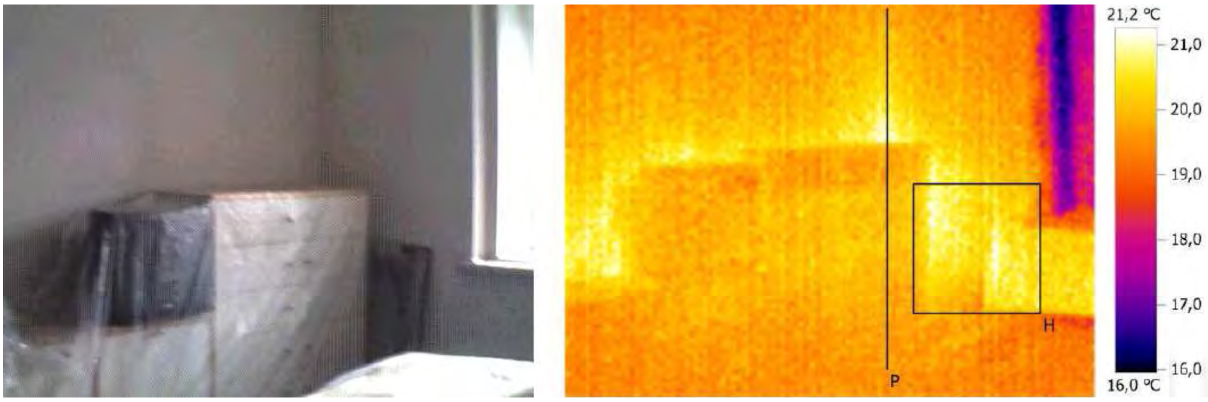
## 3.12 Integration of facade collectors

South-oriented facade got integrated facade-collectors (instead of the solar combs) – to contribute to the active energy generation. Due to the orientation of the buildings blocks these collectors were installed on the south façade of the long building row.

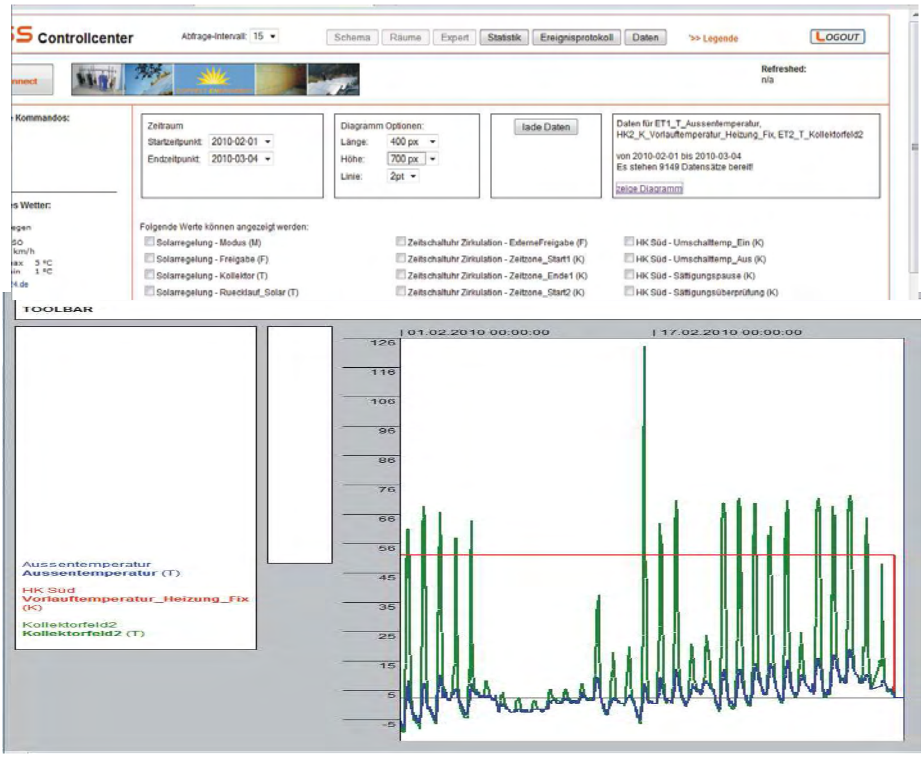
Picture 24: Assembling procedure of the facade modules with integrated collectors. (Source: AEE INTEC)

# 4 Monitoring und Evaluation

Within the research project a comprehensive monitoring is applied. So it is possible to evaluate the energy related key figures of the system and facade concept.




Picture 7: Views inside an apartment. The left pictures shows the realistc photography, the right one the joint thermo graphical analysis (Source: GIWOG).




Picture 8: Instantaneous data measurements by a data control system, available via web. (Source: FUTUS Energietechnik GmbH)

# 5 References

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[2] Willensdorfer A. (2010): "Wohnbausanierungen auf Passivhausstandard – Erfahrungsbericht". Symposium Mehr als nur Sanieren. Salzburg

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[5] http://www.futus.eu/