Retrofitted Buildings Go Solar-Active!

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Abstract

In future the key focus must lie on the development of renovation-concepts in order to improve the energy-efficiency of the building-stock and on increasing the use of renewable energy sources in their operations. There are actually a lot of "best-practice" projects with building integrated collectors, especially for newly constructed buildings, but the implementation of pre-fabricated large-scaled modules with integrated collectors during renovation is still in an early stage of development. In future a considerable increase of the renovation-rate (from 1-1.5% up to at least 3%) needs to be realized, with „best-practice" projects emphasizing their advantages.

The renovation-concept of the residential area "Dieselweg" in the south of Graz (comprising over 200 apartments) which was initiated by its owner – the housing association GIWOG – together with the office "ESA-Energiesysteme Aschauer" and "gap-solution" shows the possible potential within retrofitting; the improvement of the thermal envelope; the application of renewable energy sources and retrofitting occurs while the occupants stay in their apartments – a comprehensive concept based on pre-fabricated façade-modules with partially integrated solar thermal collectors.

1. Future renovation concepts

1.1. Forwarding the use of solar thermal energy within the existing building stock

It is a challenge for all EU Member States to increase their ratio of energy generated by renewable energy sources – but how can this be achieved? Solar thermal can contribute to low-temperature heat demand – a study commissioned by the ESTIF (European Solar Thermal Industry Federation) explains the long-term potential [1]: To reach the ambitious goals of 47% solar thermal coverage, the "Full R&D and Policy Scenario" has to be followed. Presuming a significant reduction of low-temperature heat demand (within the EU 27) of about 31% by 2030 together with the annual growth rate of 26% of installed collector areas, the deployment should lead to a solar thermal coverage of up to 47% of the entire low-temperature heat demand. This indicates a collector area of 8 m^2 per inhabitant. One important factor to meet this scenario is the question whether enough suitable roof, façade and land area is available to install collectors. By 2008 about 0.5 m^2 collector area per inhabitant were installed in Austria (only exceed by Cyprus and Israel) – an increase up to 8m^2 per inhabitant is very ambitious and can not be reached without applications within the existing building stock. Within the aforementioned study the suitable area available on existing roof and façade surfaces was estimated – the limiting factors are given by the orientation, constructive obstacles, heritage-protection of historical buildings, shading effects or the use for other purposes (windows,..). Related to the necessary 11% percentage points increase in order to reach our 34% renewable target in Austria – and a contribution of 40% solar thermal energy it would be necessary to use 38% of suitable roof and 25% of suitable façade area.

1.2. Focus on high-performance renovation

A significant part of our energy consumption is caused by existing buildings built between 1945 and 1980. The energy-performance of these buildings is poorer than of all others. Therefore the key focus in this field should lie on the development and implementation of innovative renovation-concepts in order to improve the energy-efficiency of this building stock. Advanced retrofitting needs comprehensive concepts, regarding the entire envelope as well as building services, energy-efficiency measures and the integration of renewable energy sources. In order to improve the thermal performance generally thick layers of insulation are needed and thermal bridges have to be eliminated to the greatest extent. Critical success factors are the adaptation of already approved passive house technologies (for new buildings) and their economic implementation within renovation procedures. So it is important to find repeatable solutions, which offer more advantages than only an insulated building shell.

1.3. Focus on application of pre-fabricated modules within renovation

Pre-fabrication offers a production process with a controlled quality standard. The majority of the construction phase is not dependant on weather conditions. Additionally a major part of our existing building stock consists of simple repeated building and façade structures. This enables serial production of standardized modules, a much shorter reduced construction period and less discomfort for tenants during the construction phase.

2. “Best practice Dieselweg”, Graz

2.1. Initial situation

The residential area “Dieselweg” in the south of Graz consists of a building stock which represented a typical building structure for a great number of social housing settlements in Austria. Why was it typical? The building stock has 3-4 stores. The area is suburban (can be compared with the situation of small towns in Austria) and the buildings were built in the 1950s, 1960s and 1970s. These building structures can be found in a great number all over Austria. Due to the fact that since the time of construction no improvement measures had been carried out the building stock showed a very poor and energy inefficient situation. The existing building structure, comprising five single buildings and one long building-row had no insulation of exterior walls, the cellar ceiling or the floor to the attic. Therein the 204 apartments were heated with single heating devices – using solid or fossil fuels or electric heating devices. Due to poor structural condition and energy performance the heating costs were high and the thermal comfort and living quality were low. But the most challenging circumstance was the fact that it was considered to be impossible to resettle the tenants during constructions works. The task to renovate the residential area “Dieselweg” can be stated as representative for current renovation works and therefore feasible solution-sets have a great potential of further reproduction. 2007 the housing association “GIWOG” overtook the residential area “Dieselweg” and initiated a comprehensive renovation concept together with the office “ESA-Energiesysteme Aschauer” and the company “gap-solution”. The solution for the “Dieselweg” was based on two facts: the essential improvement of the thermal envelope with pre-fabricated façade modules and the implementation of a new and innovative solar-active energy concept. Both should lead to a significant reduction of the heating demand (about 90%) in order to reach passive house standard within renovation and thus contribute to an increased thermal comfort and living quality. Furthermore the decrease of running costs for space-heating and DHW-preparation should spare an increase of rents. Moreover the GIWOG – as housing association – predicted lower resulting monthly charges for the tenants.

2.2. Implementation of pre-fabricated facade modules for renovation

The thermal envelope was renewed by assembling pre-fabricated façade modules onto the front of the existing exterior walls. Design and visual appearance were done by the architectural office Hohensinn. The technical development of the module was done by gap-solution by advancing a concept, which was already implemented within the renovation-project "Makartstrasse" in Linz. The module is based on a timber frame construction and a solar comb covered with glass panels.

Figure 1: Layer composition of the basic façade module (Source: gap-solution)

On the left side of Figure 1 the existing wall is depicted - followed by a levelling slat, which the pre-fabricated module is assembled on. The basic frame is made of wood; in-between a first layer of insulation. A solar comb is mounted to the outside upon a MDF-board followed by a ventilated airspace and covered with a single-pane safety glass. On the back of the wooden frame construction an OSB-board completes the pre-fabricated element. This façade module is carefully put together in the fabrication hall. Figure 2 shows the timber frames with insulation inside and the integration of further components like windows and single room ventilation devices with ducts for supply and exhaust air.

Figure 2: Assembling procedure of the prototype in the production hall of the carpentry "KULMER Bau"(Source: AEE INTEC)

Figure 3: Serial production in the fabrication hall “KULMER Bau”(Source: gap-solution)

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.

Figure 4: Transport on-site and assembling procedure (Source: gap-solution)

2.3. Solar-active (energy-) concept

The idea behind the renovation concept is a solar-active solution-set, which is achieved by the specific composition of the pre-fabricated module in order to improve the U-value of the exterior wall and by the energy concept based on solar energy sources.

First - due to the specific composition of the façade module with the solar comb combined with the covering glass-panel - the incoming sunlight is transformed into thermal energy. Thus on the outside of the exterior wall the air-temperature is increasing – a lower difference between outside and inside temperature provides a decrease of transmission heat losses.

Second, regarding the energy concept, all south-oriented modules received integrated solar thermal collectors, which were assembled in the fabrication hall into the pre-fabricated modules. The collector dimension was adapted to fit in the given wooden framework (Figure 5).

Additionally every flat roof and the roof of the carport were equipped with solar thermal collectors – all this leads to an installed area of $3m^2$/ living unit aiming to reach a “solar-autarchic” residential area [3].

Figure 5: Assembling of façade modules with integrated solar thermal collectors (Source: AEE INTEC)

Buffer storage tanks which are positioned in the cellar of each building are provided by all solar thermal collectors and by a ground water coupled heat-pump.

Figure 6: Heat pump and buffer storage tank (Source: AEE INTEC)

The heat dissipation follows the “climate wall” concept, which was developed by the engineer’s office “ESA-Energiesysteme Aschauer” and “gap-solution”. Small heating pipes inserted in insulating wall panels were installed on the outside of the exterior walls (Figure 7). The entire insulation is outside this dissipation system – so the exterior wall acts as a wall heating system.

Figure 7: Heat dissipation system installed on the outside of the exterior wall (Source: AEE INTEC)

2.4. Perceptions from the renovation concept “Dieselweg”

The pre-fabricated façade modules with integrated solar collectors are able to achieve heat transfer coefficients which can not be reached by common insulations systems. Not only the specific “climate wall concept" but also the integration of solar thermal collectors in front of the existing wall improves the U-value. The project "Colourface" completed by the AEE in cooperation with Fraunhofer ISE, focused on introducing new colours for absorbers, but additionally, the effects of building integrated collectors were investigated. Due to nearly similar building physical effects between building integrated collectors and collectors integrated in pre-fabricated façade modules a lot of analogical implications can be found: like the aforementioned improvement of U-values if the collector is not mounted rear-ventilated, but rather integrated into the façade or the façade module. Results of "Colourface" [3] showed that even in winter days with low solar radiation, the "effective" U-value shows an improvement of approximately 21% compared to the "static" U-value. Improved U-values on the exterior wall or lower thickness of walls are very important issues during feasibility calculations – reduced energy consumption and a higher share of usable/ rentable net floor area enlarges property value. Additionally, the integration of solar-thermal collectors changes a former "passive" component to a "solar-active" building shell.

One doubt – coming from lessons learnt of transparent insulation systems – is the expectation that higher outside temperatures will intensify overheating in summer. Another research task of the aforementioned project "Colourface" was to investigate effects of façade integrated solar collectors due to the temperatures emerging on the rear side of solar collectors. Solar collectors integrated in pre-fabricated elements reveal a non-rear-ventilated system – therefore the insulation of the collector may coincide with the insulation of the facade module.

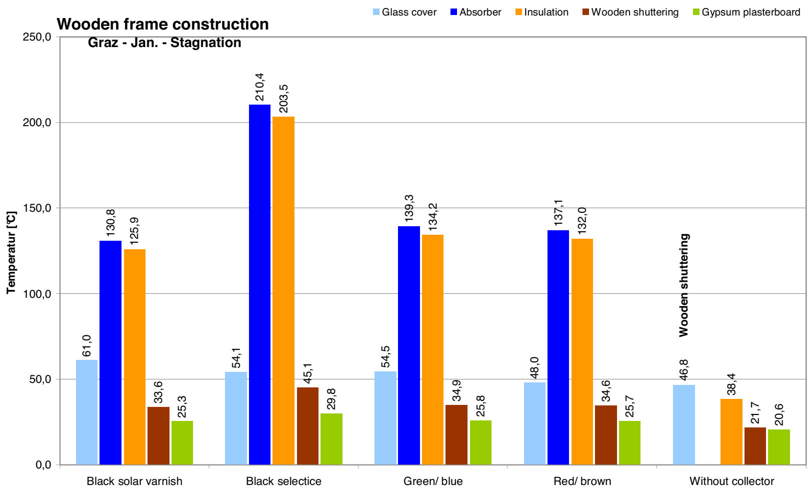

Figure 8: Temperatures in specific sections of a wall (light-weight timber construction) during January in case of stagnation (Source: Colourface – [3])

Simulations and test set-ups within "Colourface" showed that temperatures about 200°C may occur on the back of the collector (Figure 8). From there it is essential to fulfil the requirement that components and insulation of the pre-fabricated module should resist temperatures above 200°C.

Due to potential overheating of rooms behind integrated collectors in summer the report on building physics [4] illustrates the implications (Figure 9): Even during summer the increase of temperature in the room behind the integrated collector will not exceed 1K – if a static U-value of 0.35 W/m^{2}K (heat transfer coefficient of the wall in combination with insulation layer behind the collector) is guaranteed. The fact that adequate layer composition prevents overheating in summer is often mentioned in literature [5].

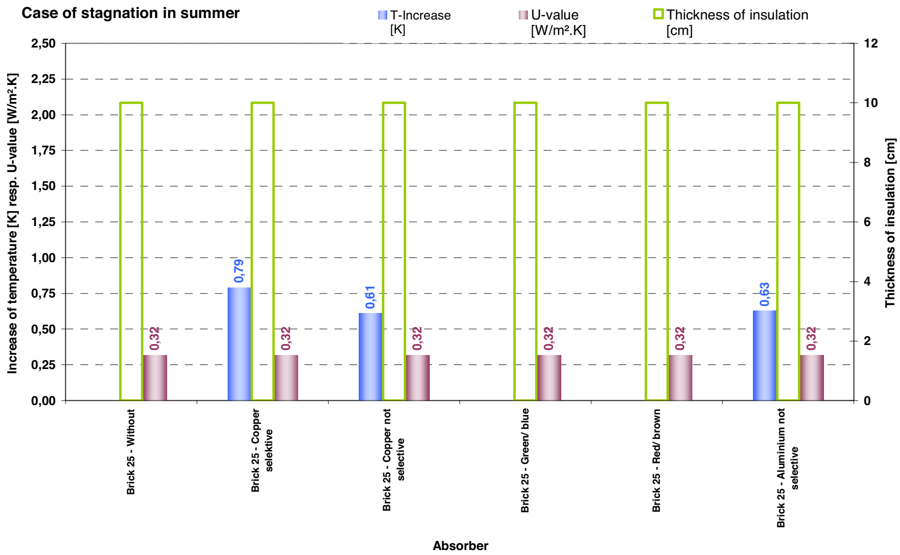

Figure 9: Increase of temperatures in case of stagnation during summer (Source: Colourface [4])

Apart from building physics the project "Dieselweg" contributed to the experiences of renovation works carried out while tenants can remain in their apartments. The relocation of people during the renovation is not only an issue of logistics and resultant costs; it is moreover a social aspect. Hence the chosen renovation concept – the "lived-in" construction site – implies an additional effort due to safety regulations to prevent hazards for occupants, but on the other hand it reduces effort and costs for relocation and provides social security.

Modular construction is more often used for new buildings – the advantages of short construction periods in combination with a larger independence on weather conditions and the possibility of serial production enables economic concepts. The use within renovation concepts is not wide-spread at the moment. Currently a common and economic renovation method– even to reach passive house standard – is to bring up a composite heat insulation system. Concerning this method, however, no further development or improvement is possible. The thickness cannot be increased any more because of the hazard of freezing condensate on the outside of exterior walls during winter. As well as the assessment of building and construction disposal shows only a moderate result for composite insulations systems compared with assembled façade systems [6] – even if cork or wood fibre are used as insulation material. Mineral wool and EPS-F used as composite insulation system are even worse and can be found within the last third of the evaluation matrix.

Within the project "Dieselweg" it was a main issue to reach a renovation concept which is below common rates for pre-fabricated systems. With reference to the builder [5] a certain project-size is needed. This way of construction requires a basic expenditure – pre-fabrication longs for a more detailed and precise planning and preparation phase. But in the end it is possible to reduce the assembling procedure. Within the "Dieselweg" it was possible to reach an assembling performance of 300 m^2/ crew/ day [2] – this makes the whole procedure more economic and reduces discomfort on occupants.

3. The future is solar-active!

Even if there are a lot of “best practice” projects for building-integration of solar thermal collectors within new buildings – the development of pre-fabricated modules is in an early stage of development. The concentration of the development of concepts for pre-fabricated modules must be intensified; research to integrate a larger scope of different components into modules; development of multifunctional elements or solutions for south oriented façades (to solve the discrepancy between glazed areas for visual contact as opposed to areas for energy gain). Advanced pre-fabricated module kits are able to contribute to economic feasible and sustainable renovation and offer further on advantages for builders and occupants. However, façade and roof pre–fabricated modules bear a great potential for energy-efficient renovation and solar thermal solutions as a future “solar-active” technology for buildings today.

4. Acknowledgements

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