TREES **Training for Renovated Energy Efficient Social housing**

Intelligent Energy -Europe programme, contract n° EIE/05/110/SI2.420021

Section 3 Case Studies

3.5 Nürnberg – Jean-Paul-Platz (Germany)

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Contents

1. Before Refurbishment

The three-storey multiple dwelling „Jean-Paul-Platz 4“ in the south of Nuremberg (Bavaria), containing 6 flats, each with 149 m² living area, was built in 1929. In 2002, in the context of EC-Target 2-advancement, the refurbishment of the free-standing carriage-and-pair building was accomplished while it was inhabited.

Construction:

- External walls made of solid bricks (total thickness 41 cm)
- Storey-ceilings as wooden beam ceilings with insertions
- Cellar-ceiling: cavernous concrete elements between steel joists
- Attic not built out

The floor plans could remain unchanged except marginal modifications in two flats; one cellar-staircase was eliminated and the organisation of the cellar slightly altered.

Type	1930ies, 2-Spänner (carriage-and-pair), free-standing
Characteristic	Compact building with plaster fassade
Year of Construction	1929
Flats	6 (3 storeys)
Area	897 m² (heated) (6 * 149 m² / flat)
Volume	4028 m³
Surface / volume - ratio	0,45 resp. 0,42 m^{-1} (before resp. after renovation)

Table 1: Short description of the building

2. Refurbishment Measures

The following measures were accomplished:

- New boiler-room in the attic; chimneys partially demolished
- Plinth new developed (without digging)
- New roofing and sheets
- Rafter extensions for roof-overhang above external insulation
- Insulation of external walls with Thermoskin
- Insulation of cellar-ceiling and cellar-staircase
- Insulation of attic including sill and head of staircase; cement screed
- Windows completely replaced (including cellar windows)
- House-entrance door, attic and cellar doors replaced; flat-entrance doors tightened
- Staircase refurbished, including inter phone, letter-box facility and porch
- Canopied balconies for each flat
- New heating system installed, old gravitation system demolished
- Solarthermic system with buffer storage tank installed
- Central domestic hot water supply with new connection of all bathrooms
- Decentral ventilation system for each flat
- Electric installation outside of the flats modernised

Renovation of bathrooms and decorative repairs were accomplished seperatly by the inhabitants.

2.1 Constructional Thermal Protection

2.1.1 External Walls

The external walls were brought up with solid bricks and had a total thickness of 41 cm. Before the refurbishment their U-value was 1.4 W/(m²K). They were insulated with a Bonded Thermal Insulation System (“Thermoskin") with an insulation thickness of 20 cm, using insulation slabs of graphite modified polystyrene with a thermal conductance of λ = 0.035 W/(mK) (resp. Thermal Conductance Group 035). So the U-value could be diminished down to 0.15 W/(m²K).
The bigger insulation thickness was no problem, because rafter extensions were considered at the already accomplished new roofing.
The usage of glue was increased due to the uneven subsurface.

2.1.2 Top Level Ceiling

The attic was unused but ought to be walkable. Thus the wooden beam ceiling with insertions above the 2nd floor is the thermal closure to the top.
With a 25 cm polystyrene insulation (Thermal Conductance Group 035) under a 6 cm cement screed the U-value was reduced from 0.87 down to 0.12 W/(m²K).
Of particular importance is a decreasing obstruction of vapour diffusion on its way from the heated rooms outwards through the ceiling. Therefore on the uninsulated floor on the warm side of the insulation layer a polyethylene-foil was laid out – against on the cold side an oil paper with low diffusion-resistance (as sublayer for the cement screed).

The gapless tightened polyethylene-foil is also used as airtight layer of the top level ceiling.

Footnote 1: That is the same situation as in the steep roof, where the vapour-diffusion resistance of the room site should be a multiple of the covering above to avoid condensation water in the construction.
Footnote 2: The vapour-diffusion resistance of the polyethylene-foil is more than 30 m, the resistance of the upside covering (oil paper plus cement screed) less than 2 m.

In any case the choice of the used materials should be ensured by a calculation of vapour-diffusion.

2.1.3 Cellar Ceiling

The cellar ceiling is made up of steel joints with mounted cavernous concrete elements. The U-value including floor construction was 0.88 W/(m²K) before the refurbishment.
Thanks to the relative high cellar rooms of 2.15m an underside polystyrene insulation of 14 cm thickness was feasible. For fire protection reasons the corridors were insulated with slabs of mineral wool. (both insulation materials had λ = 0.035 W/(mK) resp. were Thermal Conductance Group 035)

The U-value of the insulated cellar ceiling is 0.19 W/(m²K).

2.1.4 Windows

Until the refurbishment the box-type windows from 1930 reimained in their original condition, but their extreme leakiness was complained by the inhabitants. Overworking them was senseless, as well as the simple glazed windows in the adjoining rooms and staircases. They were replaced by passivehouse-appropriate windows (3-pane thermal-protection glazing with thermal-bridge optimised glass spacer in an insulated plastics frame).
The mounting was carried out with mounting brackets, whereby the window are lying in front of the edge of the old external plaster with half of its depth. So an inner reveal with a depth of 37 cm arised, while outside the original view with ca. 15 cm was kept.

With this configuration not only the thermal-bridge effects were reduced but also a “crenel-look” due to deep reveals was avoided.

The insulation of the external wall covers the window frames by 7 cm.

Because of the unevenness of the external walls the adjustment in the insulation level was difficult. Small differences could be tolerated, but the depth of the window sills had to be matched accurately to the new plaster level.
According to the fire protection regulations the window lintels had to be insulated with stripes of incombustible material (e. g. mineral wool).

Fig. 1: Insulation of window lintels with mineral wool

2.1.5 Thermal Bridges

Basing on his detail planning, the architect had a coordination talk with the passive house institute in Darmstadt, and thereafter calculations for optimisation were generated by the passive house institute.

Plinth Area:
Because no measures of humidity blocking were pending and therefore no excavation of the cellar walls was necessary, for cost concerns the insulation of the plinth was led only 25 cm down under the soil.
The temperature level of the cellar brickwork underneath raised by an additional frost apron, that is a supplemental horizontal Insulation slab.
If there are excavation works anyway, the insulation of the plinth should be lead deeper down under the soil. This does not only reduce thermal bridge losses but also is a protection of the vertical humidity blocking layer.

Cellar Walls to rising brickwork in the Ground Floor:
The insulation of the cellar ceiling was continued to the linking cellar walls (inner walls and internal outer wall) with insulation stripes, 30 cm broad.

Sills:
By gapless insulation around the sill with 20 cm thickness lateral and 10 cm upside the additional thermal losses are reduced.

Windows:
Thanks to the window mounting with offset in front of the external wall as well as the insulation on the window frame (blind frame), the thermal bridge losses lateral and above are comparable to a new building.

2.1.6 Airtightness

A very good airtightness is one of the basic conditions for high comfort as well as secure and energy saving work of the mechanical ventilation – this is similar to new buildings.

The most important basic rule for an effective airtightness also in old buildings is the “rule of the closed airtight envelope”.

It reads as follows:
“A reliable airtightness is only reachable, if there is *<u>one</u>* *clearly defined, embracing uninterrupted airtightend envelope.”*

Before the beginning of the refurbishment a blower-door check was made, which proved an value of airtightness of n_{50} = 4.9 1/h.
Separate measuring of the eastern flats showed

in the ground floor: n_{50} = 4.2 1/h;
in the 1st floor: n_{50} = 6.2 1/h;
in the 2nd floor: n_{50} = 9.9 1/h.

(Footnote: That means an exchange of the room air 4 to 10 times per hour on a windy day in autumn or winter – unintentional, because this permanent draught is very uncomfortable and can’t be warmed-up so fast.)

That implies relative leaky wooden ceilings between the floors and especially to the attic.
The old unsealed box-type windows did their contribution to the high leakiness in all flats.

Concept of Airtightness

The sectional view shows the course of the airtight layer with the following details:

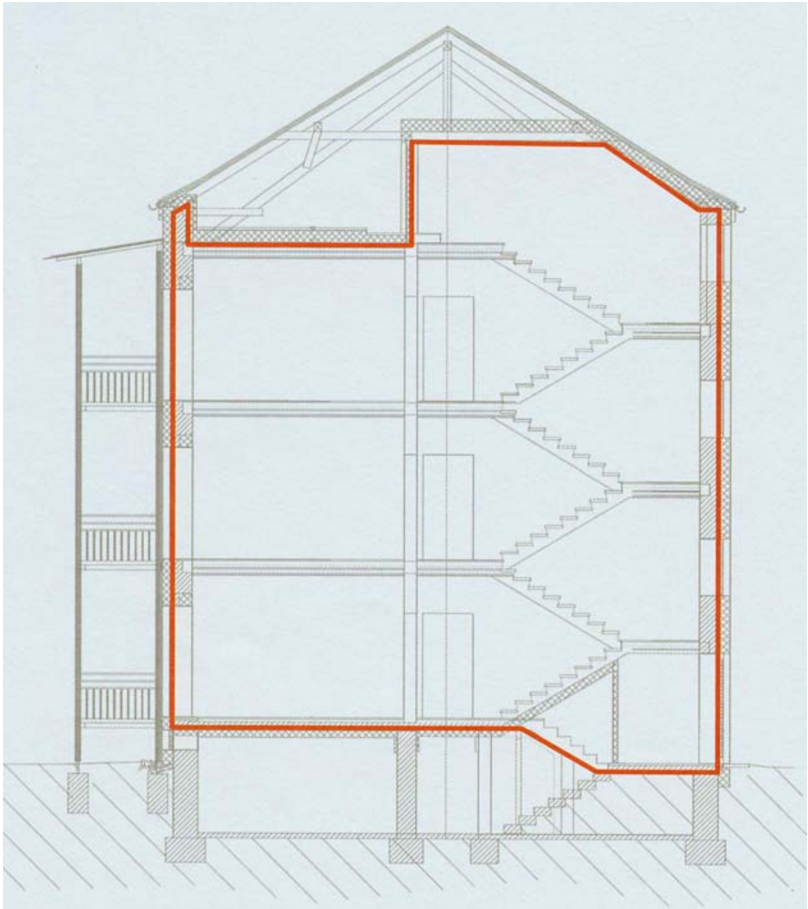

Fig. 2: Course of the airtight layer

External Walls:

At buildings with concrete ceilings, usually the internal plaster is the airtight layer, after leakages by cracks and at pervasions of installations were mended.

Though here the internal plaster layer is interrupted in the whole area of the support of the wooden beam ceilings; furthermore the cavities at the timber heads are open to the external walls.

Because of the ongoing inhabitation no incisive measures could be accomplished, so the airtightened layer was transferred to the outside of the exterior walls. For that the old external plaster was filled at the whole surface before the glueing of the thermoskin (especially at patches with slack, knocked off plaster and at cracks).

Fig. 3: transferring of the airtightning layer from inside to outside plaster of external wall

As a weak point the arising cellar brickwork remains, by which cold air from the cellar can infiltrade into the rooms of the base floor. But at this object the fully mortared brickwork, made of solid bricks, has proved sufficiently airtight. At brickwork with open grooves or made of perforated bricks this area has to be more considered.

Fig. 4: Remaining weak point at the cellar brickwork

Window Connections:
A fleece cladded butyl adhesive tape was led from the window frame upon the existing external plaster, which was pretreated with a moisture- and temperature-resistant additional glue. Furthermore the adhesive resp. sealing tape was inserted by plastering with the insulation glue.

Top Level Ceiling:
Contrary to a concrete ceiling the existing wooden beam ceiling is extremely untight. As in the case of the external wall it did not make sense to have the airtight layer on the underside of the ceiling, because the ceiling plaster (on straw mats) is mostly crossed by cracks and the connections to the inner and outer walls are tearing periodically.
Instead a sealing sheet (polyethylene foil) was carefully placed upon the existing timber floor and glued together airtightly. The foil was led round onto the uninsulated sill and inserted by plaster (again this plaster reaches to the filling of the external walls as the airtight layer there).
The pervasions of supporting joists were grouted with gypsum.

Important in any case is the arranging of the vapour retarding foil on the warm side of the insulation as well as the use of a relative diffusible upper sheet as sublayer for the cement screed (see also *2.1.2 Top Level Ceiling**). In any case the choice of the used materials should be ensured with a vapour diffusion calculation!*

Staircase at Cellar and Attic:
At the steep roof and the ceiling of the staircase the airtight layer was led on the room site. Moreover, these areas include numerous different connections (wooden ceiling against brickwork, pervasions of installations of the joining boiler room) and had to be planned and implemented carefully, analogue to the discussed details.

2.2 Building Services

2.2.1 Ventilation System

For each of the six flats a seperate air renewing facility with warmth recovery was installed in the storage rooms at the external wall. The pipes for the outer fresh and exhaust air are lying directly outwards; the two pipes for supply and exhaust air to the rooms are placed in the taken down ceiling in the hallway.
The outer fresh air is aspirated by an energy-saving ventilator (DC-fan), preheated in the heat exchanger by the (seperately flowing) warm exhaust air out of kitchen and sanitary rooms and, via the supply air pipe, it arrives in the living and sleeping rooms. From there it flows via the hallway room into the exhaust air rooms.

Below an ambient temperature of -4°C a preheating device (driven by the heating system and not by electricity) offers frost saveness.
The consumption of electricity for one flat is ca. 350 kWh per heating period. In return a high air quality is guaranteed and more than 80% of the warmth in the exhaust air is recovered.

Fig. 5: Ventilation pipes in the ceiling area of the hallways

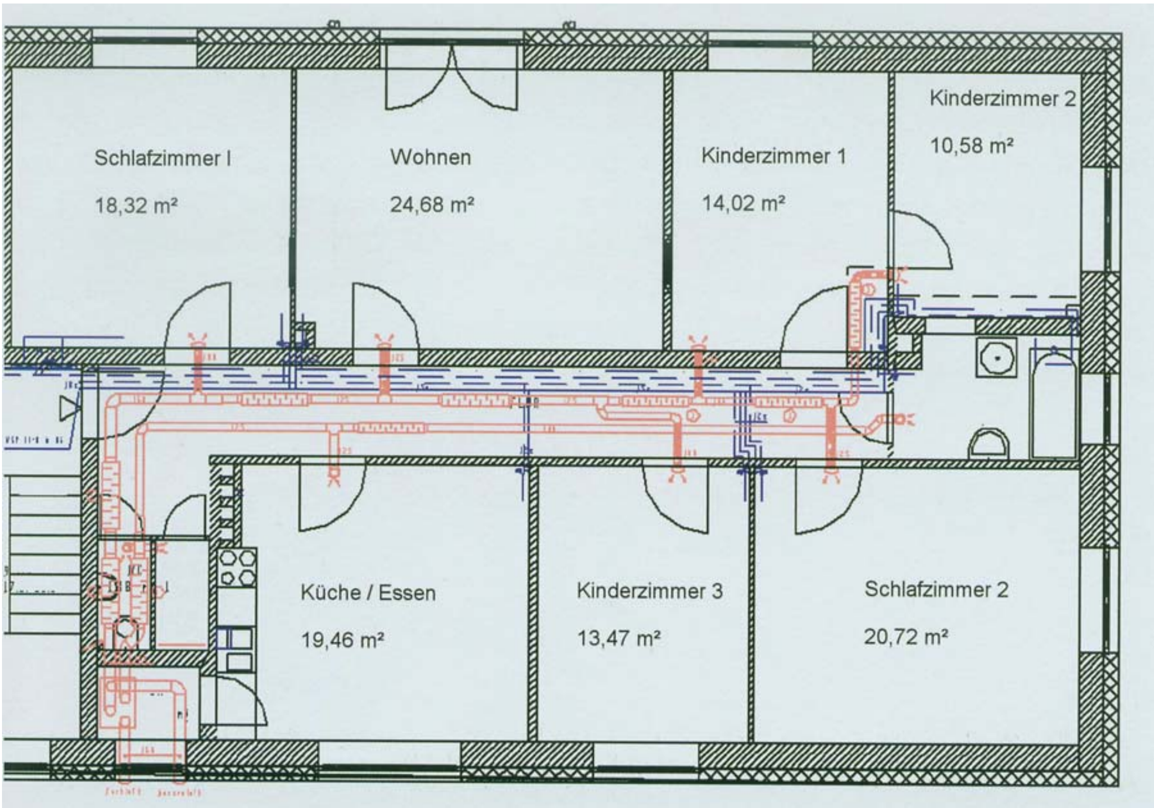

Fig. 6: Ground plan of a flat with air renewing facility incl. warmth recovery. (upper red pipe = supply air into living and sleeping rooms; lower red pipe = exhaust air from kitchen and sanitary room). Between two affiliated rooms the sound propagation is reduced by a silencer. The supply air is inserted into the living and sleeping rooms via wide throwing valves,
Because of the different situations at refurbishment objects no standardised solution is possible, but typical ground plans for system versions.

The installation of the ventilation pipes from the hallway to the rooms was easy and dust-free thanks to core drilling machines with exhaust device. Problems resulted due to unordered electrical lines and material changes between wooden bearers and slack brickwork.

For 5 inhabitants the airchange rate is adjusted at 150 m^3 per hour (for each person 30 m^3/h). The adjustment of the ventilation system, that means the balance between the volume flow of supply and exhaust air is very important for an immaculate performance. In the context of the accompanying research at the object Jean-Paul-Platz the adjustment of the assembling firm was revised by the passive house institute.

2.2.2 Heating System

Primary the heating ran with a central gravitation heating system. In the 60ies decentral one-floor heating systems were installed, but the old radiators and the volumnous pipes retained.
At the refurbishment the old heating system was completely renewed:

- Thanks to the low heat demand of the six flats one central boiler (gas, gross calorific value system) with only 30 kW power is enough – the boiler power is calculated accordingly to the requirements of the domestic water heating.
- Additionally a solarthermic system with 17 m^2 flat collectors and a buffer storage tank of 1,000 liters was installed, which is designed for summerly heat yield. Due to systematic reasons the integration of the heating system will not produce a big heating support.
- The new boiler room could be placed just on 6 m^2 in the attic beside the head of the staircase.
- The distribution of the heating pipes are lying parallel to the ventilation pipes in the ceiling area of the hallways (see also figure in 2.1.3, blue lines). The pipes are led on-wall at the inner walls of the rooms down to the radiators. An installation below the windows as a radiation shield isn't necessary thanks to the used high-quality windows – this can be set off as a saving of costs.
- The new heating pipes can be insulated optimal into the head covering of the hallway ceilings. This avoids undesired heat emissions, that would have occurred remarkable with the old gravity pipes.
  The heating distribution pipes and the DHW-circulation pipes were insulated at an average of 10 cm and completely led in the heated area.
  Also in the boiler room great importance was attached to an optimal insulation of the fittings to minimise needless thermal losses.
- Indeed the old radiators are big enough for a low-temperature system, but – like the old gravitation pipes – due to their big volume they are too slow for an agile heating control, which reacts fast enough on solar heating yields through the windows.

3. Quality Assurance

At the project Jean-Paul-Platz the quality assurance was organised by the passive house institute. Beside thermography it included pressure tests with blower-door-equipment and tracer-gas measurements.

3.1 Thermography

Thermography allows the disclosure of weak points like thermal bridges and gaps in the thermal insulating envelope, accompanying with the refurbishment. Thus amendments can be carried out immediately and cost-saving; though precondition is a sufficient thermal gradient between the heated rooms and the outer ambience.
First pictures were taken already while the insulation slabs were glued at the external walls. The following picture shows the thermography of the southern facade shortly before the finishing and the mounting of the balconies. Clearly recognizable is the high quality of the insulation, which is coloured only a little warmer than the ambiance (in comparison on the right side an uninsulated building, constructed in the same way). The insulation has no gaps, only the dowels are visible and, as thermal bridges, 4 stiffening anchors for the balconies.

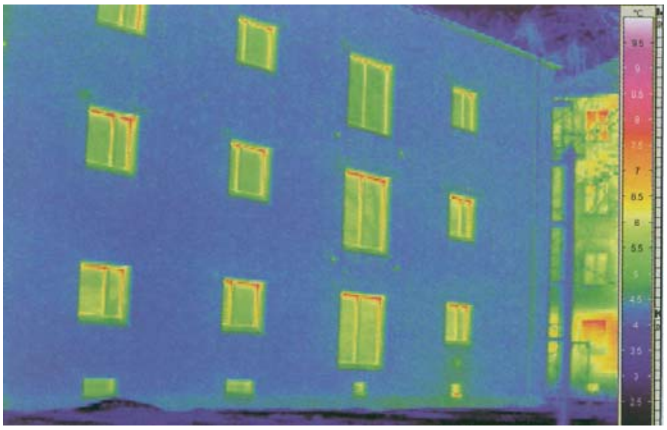

Fig. 7: Thermography of the southern facade shortly before the finishing

3.2 Blower-Door

By pressure tests with the blower-door-method leakages in the airtightened envelope can be located and an air changing rate ascertained, also accompanying with the construction works.
A simultaneous application of thermography while charging the building with over pressure or low pressure is recommendable: so an in- or outflowing plume can be detected exactly.

The figures are showing two check points:

- With the thermography at over pressure it could be proved that gypsum grouting is an ideal method to seal pervasions of wooden beams through the airtight layer of the upper ceiling, because there was no visible indication for outflowing warm air.

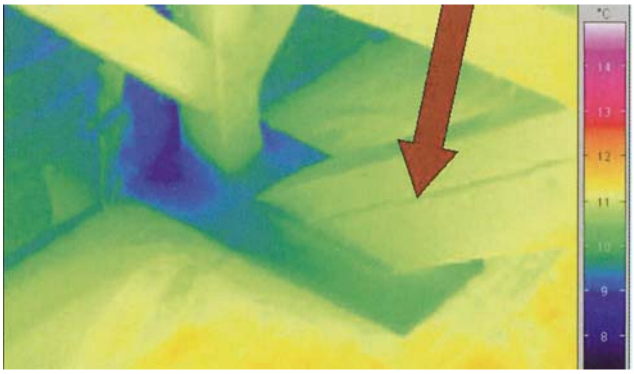

Fig. 8: Thermography of a gypsum grouting at a pervasion of a wooden beam in the attic

- However, in the transition of the insulation of the cellar ceiling to the insulation stripes of the cellar brickworks, there was convection through gaps in the insulation; but this could be stopped with the finishing filling plaster (but first, gaps in the insulation had to be filled with insulation material!).

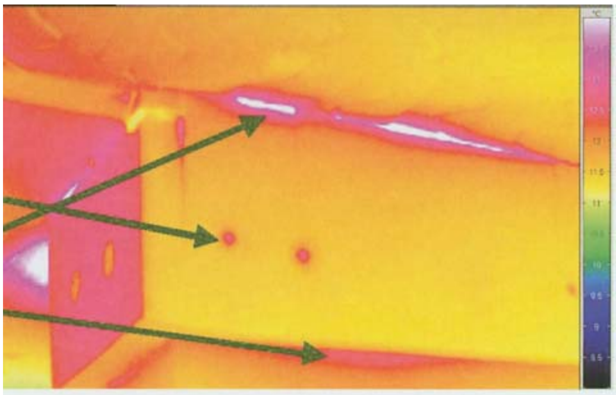

Fig. 9: Thermography of the supporting insulation stripe at the insulation of the cellar ceiling

Always important is the timely application of the „control"-methods: in any case an amendment of leakages and/or thermal bridges should be possible without greater effort.

That means controls

- ► After the installation of the airtight layer, which should be still accessible
- ► After the installation of the insulation layer, that means before the installation of the finish or enclosure (plaster, gypsum plasterboard etc.).

4. Results

4.1 Thermal Heat demand and consumption

The thermal heat demand was calculated by the architect with the passive house projection package ("Passivhaus-Projektierungspaket", PHPP) resp. by Euronorm EU 832 and amounted 204 kWh/(m²a) before and 27 kWh/(m²a) after the refurbishment (heating period with 84 kKh/a resp. 3500 Kd/a).
This accords to the real metered heat consumption, but it has to be regarded that the refurbishment was in autumn and the insulation wasn't finished until december.

4.2 Primary Energy Input and Environmental Impacts

Concerning the primary energy input and the CO_2 emissions, the reducing factor is even more than 10.

The energetic payback time for the measures is less than 2 years.

4.3 Costs

4.3.1 Refurbishment Costs

With 503 Euros per m² living area (accordingly to the german DIN 276 cost group 300/400 incl. tax) the refurbishment costs are lower than comparable projects without passive house components.
The additional costs, compared with the thermal protection of a conventional new building accordingly to the current energy-saving regulation, are less than 10% for the actual insulation; in contrast the passivehouse windows and higher insulated outer doors are more expensive for one third of a standard version.
Here detail works for optimisation of thermal bridges and airtightness carry more weight than a conventional building, but the additional 10 Euro/m² aren't considerably.
The ventilation system made ca. 50 Euro/m² more in the budget, in return the heating system is almost 20 Euro/m² cheaper thanks to the smaller dimensions and shorter piping.
It is to be considered that in principle refurbishment measures are more expensive than comparable works at a new building.

In counterpart of the higher refurbishment costs (ca. 90 Euro/m², without solarthermic system) the thermal heat demand is reduced further from 49 to 27 kWh/(m²a).

4.3.2 Rental Fees

The rent without heating costs at Jean-Paul-Platz was ca. 2.35 EUR/m² per month before the refurbishment – so these flats with nearly 150 m² living area belonged to the cheapest in whole Nuremberg.
The rent increase is 1.87 EUR/m² per month, whereas the rechargeable costs weren't fully bailed.
Setting off the reduced operation costs, the rent is increasing effectively for ca. 1.20 EUR/m².

5. Eco-Efficiency-Assessment

5.1 Introduction: Assessment Criteria

Energetic refurbishment measures are reducing the energy demand for habitation – but for the implementation itself energy is needed.
Eco-efficiency-assessment considers the objects and materials used at a refurbishment and finds out, how much primary energy was necessary for their production resp. which impacts were involved:

- ► Global Warming Potential (GWP), caused by carbon dioxide (CO_2) and similar substances (methane, laughing gas, hydrocarbons (with and without fluorine, chlorine etc.); expressed in kg CO_2-equivalents.
- ► Acidification Potential (AP), caused by sulphur dioxide (SO_2) and similar substances like nitrogen oxides (NOx); expressed in kg SO_2-equivalents.
- ► Summer Smog Potential (POCP), caused by lightly volatile hydrocarbons (VOC) and similar substances like nitrogen oxides (NO_x); expressed in kg Ethen (C_2H_4)-equivalents.
- ► Mass: the building sector is one with the highest turnover of masses. Though the declared net masses are only a little part of the real mass flows, which includes excavation for the basic materials and process water, too.

[see also Tools \ Life Cycle Assessment and Tools \ Sustainability Assessment]

5.2 Assessment of Refurbishment Measures

The following things were counted to the discrete measures:

- Insulation of the external walls: complete thermoskin with polystyrene insulation slabs, external plaster etc.
- Cellar Insulation: insulation slabs of polystyrene and mineral wool, glue, filling plaster
- Roof / Insulation: insulation slabs of polystyrene, cement screed, foils etc.; roofing with clay rooftiles, new battens and roof-foil
- Windows: 3-pane thermal-protection glazing, insulated plastic frame, fittings etc.
- Ventilation System: complete system (central unit, distribution pipes with silencers, valves, piping insulation etc.)
- Heating System: heating system (boiler, distribution pipes, piping insulation, rediators, fittings), without DHW-part (storage tank, circulation pipes etc.)
- Solarthermic System: flat collectors, buffer storage tank, piping, piping and storage insulation, fittings
- The useful lifetime was expected with 40 years; replacement due to wearing parts like boiler and fans was considered

The refurbishment of the 3-storey-building could be compared with the existing datas from the SOLANOVA-Project. First absolute values are shown in the diagrams, followed with a illustration of the percentage shares of the measures:

Nuremberg (Nü):

- ► Due to the big masses of cement screed and roofing the partial mass of the upper ceiling insulation is very high – this has an impact on the other factors, too.
- ► The insulation of the external walls is around 25 % of the entire impacts nearly at all factors.

- The share of the window area is relatively small, therefore the partial impacts are 10 to max. 20 %
- The building services (ventilation, heating, solar) amounts ca. 3 to max. 14 % of the entire impacts

SOLANOVA (Sol):

- Basically the input for the refurbishment of the 8-storey SOLANOVA building was higher, which caused higher mass flows and impacts.
- The SOLANOVA building has a flat roof; its insulation is covered with paving slabs. Hence the mass of this position is less than in the Nuremberg building.
- Due to the higher surface part of the exterior walls the impacts are around 35 %.

Specific Environmental Impacts

Basis 1 / Living Area: In relation to the living area the favourable ratio of (refurbished) envelope to inhabited volume at the SOLANOVA building is obvious: referring to Primary Energy Input (PEI) and Global Warming Potential (GWP) the impacts are less for a fourth resp. one third.

Basis 2 / Inhabitants: Because the specific living area in the Nuremberg building is 50 % higher than in the SOLANOVA building (30 vs. 20 m²/person), the effects shown before are insified. This chart shall point to the wide influence of a increasing specific living area.

[see also Case Studies \ SOLANOVA (HU)]

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