# 10 Steps to a Pref-fab Module

IEA ECBCS Annex 50 – Prefabricated Systems for Low Energy Renovation of Residential Buildings

## Design Guideline

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# Preface

This design guidance is part of the work carried out in the IEA ECBCS ANNEX 50 project - Prefabricated Systems for Low Energy Renovation of Residential Buildings. The participation of the AEE – Institute for Sustainable Technologies is funded by the Austrian Federal Ministry of Transport, Innovation and Technology. The Annex 50 project aims to develope innovative pre-fabricated systems for retrofitting of residential buildings to energy-efficient buildings and forward implementation processes to stimulate feasible high performance renovations.

The partners of the IEA ECBCS Annex 50 project are:

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# Introduction

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]: In order 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 exceeded by Cyprus and Israel) – an increase up to 8$m^2$ per inhabitant is very ambitious and can not be reached without applications within the existing building stock. Within the frame of the aforementioned study the suitable area available on existing roof and façade surfaces was estimated – the limiting factors could be 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.

**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.

**Focus on typical residential building stock built in the time 1945-1980**
Which structure represents a typical building structure for a great number of social housing settlements in Austria? The building stock has 3-4 stores. The area is suburban (can be compared with the situation of small towns in Austria). Due to the fact that in most cases since the time of construction no improvement measures have been carried out since the time of construction the building stock shows a very poor and energy inefficient situation. The poor structural condition and energy performance causes high heating costs, less thermal comfort and less living quality.

**Focus on "lived-in" construction site**
But the most challenging circumstance is the fact that it is often impossible to resettle the tenants during constructions works. 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.

**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. This enables serial production of standardized modules, a much shorter construction period and less discomfort for tenants during the construction phase. The utilization for 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. 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. Advanced pre-fabricated module kits are

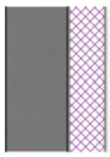
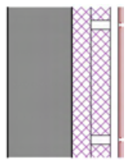
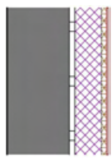
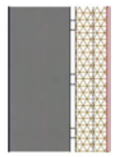
able to contribute to economic feasible and sustainable renovation, which offers further on advantages for builders and occupants.

**10 steps to a pre-fab multifunctional renovation module**

However, the challenge within renovation is the existing building stock. Pre-fabricated modules can be a good solution – but various requirements have to be considered. And – they are not always the appropriate solution. Building lines or bad access to the building site can block the implementation of pre-fabricated modules. But how is it possible to find an optimized solution, considering all possible conditions and requirements?

A guideline for the implementation of pre-fabricated multifunctional renovation modules should be provided to builders, planners and manufacturers in order to support their decision-making and during the planning and production process. Assistance is offered to different subject groups, splitted into 10 steps. Following the questions and objectives in each step, it is possible to get a comprehensive perspective on key points, which should be considered.

The **first 6 steps** should support the decision about an appropriate renovation concept – wether it is a composite heat insulation system, a rear ventilated façade, a partly pre-fabricated system or a fully pre-fabricated module system.

| **Composite insulation system** | **Rear ventilated façade system** | **Façade system – partly pre-fab** | **Pre-fab module system** |
|---|---|---|---|
| Common insulation measure – manually brought up insulation panels, covered with reinforced priming material and a plaster coating, which is coloured. | Insulation brought up between laths or other substructure, fixed with mounting system, covered by various claddings. Entire assembling procedure carried out manually. | Assembly of pre-fabricated substructure, filled with blown-in insulation. Cladding whether integrated in pre-fabricted system or manually brought up afterwards. | Fully pre-fabricated modules, assembled in fabrication hall, transported on-site and mounted on prepared sub-structure onto façade. Serial production possible. |
| F1 | F2 | F3 | F4 |

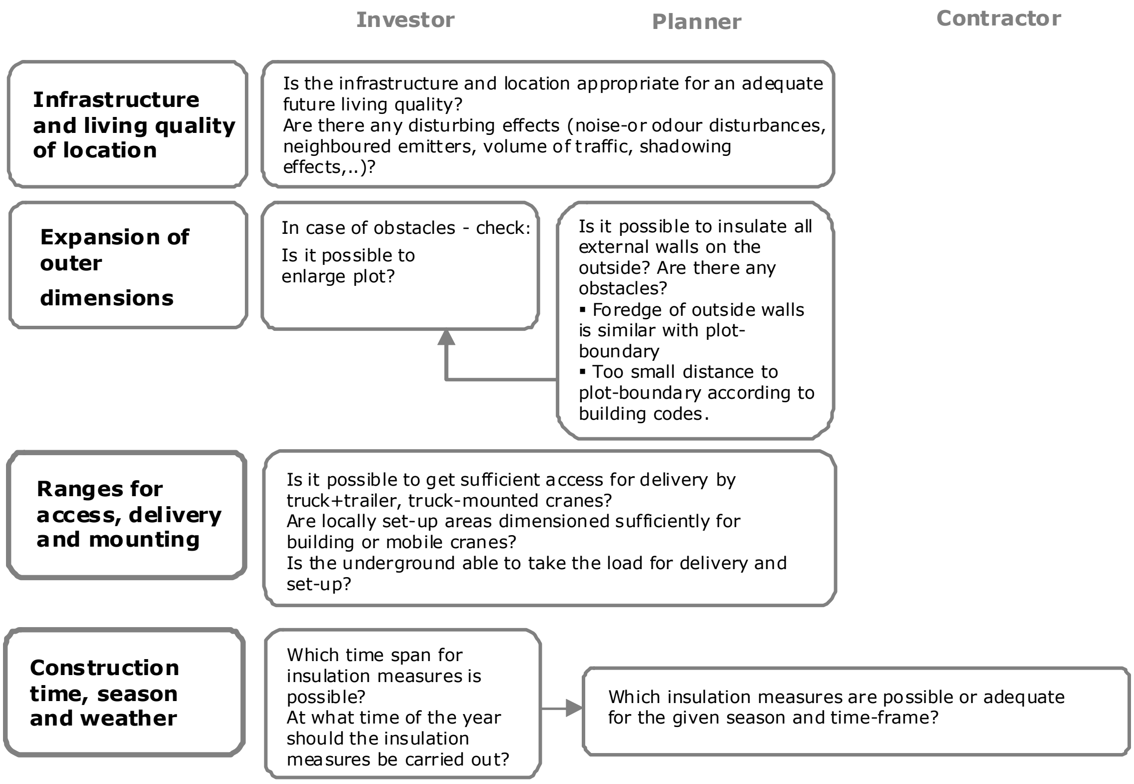
There at the end of each step a **SWOT-analysis** should offer assistance to choose the right system and show the advantages and disadvantages. If each of these steps show a majority of advantages for pre-fabricated module system it might be a good solution. But the path to a pre-fabricated module system is not completed until the steps 7-10 – which guide on the further path to a renovation module

Advanced renovation needs multi-functional pre-fabricated modules – in the right place at the right time. The practical supply of the key parties involved in the renovation process helps to make today's pilot projects a tomorrow's standard.

Enjoy your way to a pre-fabricated renovation module!

Gleisdorf, September 2010

# 1 Initial situation




## 1.1 Infrastructure and living quality of location

Housing and settlement policy should focus on an optimized development of existing and new buildings. Sometimes it could be better to demolish and build new housing estates on locations of better infrastructural equipment and higher living quality. Particularly big housing owners, housing associations or public entities operating buildings do have a broader portfolio of buildings with different base levels. Looking on a building park it is on a long term more sustainable and economic to select buildings of higher infrastructural and living quality for further improvement or renovation.

Important benchmarks are:

- Connection with technical infrastructure (supply of water, effluent disposal, power,…)
- Distances to commercial, educational, administrative and social infrastructure
- Access and distances to mobility infrastructure (public transport system)

But furthermore it is essential to identify possible disturbing effects, which may influence the living quality like:

- Noise- or odour-disturbances
- Neighboured emitters, which exceed customary in a place emerging emissions
- Volume of traffic like highways, streets, railway lines the frequency and distance of which imply disturbing noise
- Power lines or magnetic alternating fields (mobile phone antennas) which are within 100 m far from plot-boundaries

➡ Main issue is to evaluate if the quality of the surrounding is appropriate for a future sustainable and high-quality living environment.

## 1.2 Expansion of outer dimensions

Common renovation strategies focus on insulation measures on the outside of the existing building shell. Many building physics aspects can be fulfilled more easily - than by insulation of the internal wall surface. But bringing up insulation on the outside leads to thicker walls, an expansion of the outer dimensions, the gross floor area is increased and distances to plot-boundaries or frontage lines are shortened. Depending on building codes or local master plans barriers to bring up an exterior insulation may occur.

Therefore two essential issues have to be clarified:

- Does the existing distance to the plot-boundary or frontage line allow an exterior insulation?
- Which scale of increase of the outer dimension is possible according to legal regulations?

Regarding possible restrictions several possible alternatives can be considered. Sometimes the building code defines a possible exceeding of plot-boundaries to a certain scale if an insulation measure is implemented. Otherwise it could be possible to enlarge the plot and find an agreement with the neighboured owner (trade-off,…).

➡ Main issue is to check if it is possible to bring up an exterior insulation system.

## 1.3 Ranges for access, delivery and mounting

Every improvement of the thermal envelope on the outside has a certain space requirement depending on the chosen measures. Composite heat insulation measures or small-scaled façade systems, which are brought up and installed manually, need only the space for scaffolding. Façade systems depending on heavy and large-scaled components require more space for delivery and sufficient access with trucks, truck and trailers or low-loaders close to the façade makes the installation works easier and quicker. As well additional lifting gears enable smart proceedings. There is a broad variety of possible auxiliaries even for hard-to-reach area, but in urban areas of high density or interior courtyards constrictions might occur. Hence an on-site inspection or a site plan shows the options.

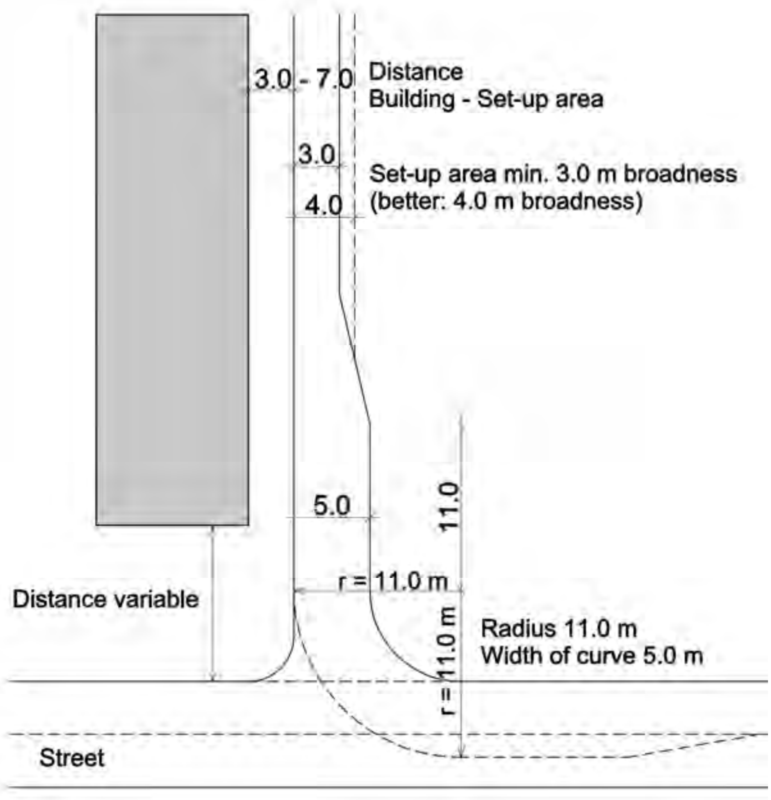
Practice-and security-oriented assistance for planning scaffolding work can be found within the website of the Austrian accident insurance group under following link:
http://www.auva.at/mediaDB/MMDB130137_M262.pdf

International product ranges for lifting, loading and handling tools
http://www.vertikal.net/en/access-lifting-directory/

Software-tool for crane-operation:
http://www.cranimax.com

Product-ranges for small cranes:
http://www.minikran-
mieten.de/Mietgerate_Minikran_Vermietung/mietgerate_minikran_vermietung.html

Heavy and large-scaled components need accessibility for trucks, trucks and trailers or low-loaders. To get a general idea of a common delivery the dimensions of a so-called "Euro-truck" may help:
The "Euro-truck" is defined within the EU and is valid in most of the European member states. The maximum width (without exterior mirrors) is 2.55 m and the maximum height is 4.0 m. Basically the length is restricted to 18.75 m (articulated lorries 16.50 m).
To check whether an existing access (street, place,…) is sufficient an approach of 3.0 m wide and every turn 5.0 m and offer 11.0 m curve radius can be estimated




**Picture 1-1: Range for access by truck - basic estimation (Source: AEE INTEC)**

For detailed considerations on sufficient access tractrix curves for specific vehicles can be used as templates or by means of various software-tools:

Tractrix curves for articulated lorries can be found under the following link:
http://www.vif.lu.ch/index/download/schleppkurven.htm

Tractrix curves or busses and trucks can be found under the link:
http://faiweb09.bl.ch/~web906/uploads/media/RL_Schleppk-Bus_01.pdf

Various software tools, which can be adopted for several CAD-tools:
http://schleppkurven.com/index.php?showme=Schleppkurven&vonmenu=

During the renovation of the residential area "Dieselweg" in Graz large-scaled pre-fabricated modules were brought on-site. The sequence shown in Picture 1-2 presents an overview on this kind of assembling procedure.

➡ Main issue is to check whether it is possible to deliver and mount large-scaled modules or not.

**Picture 1-2: Assembling procedure of pre-fabricated façade modules within the renovation "Dieselweg", Graz-Liebenau (Source: gap-solution)**

## 1.4 Construction time, season and weather

Currently common renovation concepts are based on composite heat insulation systems. The main work is to bring up small-scaled components and several layers of priming materials and surfacers, so it is a manual work and the performance quality is mainly dominated by the crew working on-site. Additionally a technically correct workmanship has to fulfil a series of standards and processing guidelines.

**Table 1-1: Selection of relevant standards for composite heat insulations systems processing in Austria and Germany**

| | |
|---|---|
| ÖNorm B 6410:2004 | External insulation composite systems - processing |
| DIN 55699:2005 02 | Processing of external insulation composite systems |

**Table 1-2: Processing guidelines available in Austria**

| | |
|---|---|
| http://www.waermeschutz.at/publikationen.php | Qualitätsgruppe Wärmedämmverbundsysteme: "Verarbeitungsrichtlinie für Außenwand-Wärmedämm-Verbundsysteme", Edition 08/2007 |

These guidelines define restrictions - beside others – for the realisation of composite heat insulation system concerning:

- Rain without additional protection measures
- Temperatures (Ambient, subsurface, component) below +5°C (for silicate plaster sometimes min. +7°C)
- Temperatures above +30°C
- Direct sunlight (without protecting measures)
- Wind
- Surface irregularities out of allowable deviation

Furthermore the procedure of bringing up composite heat insulation systems requires –after gluing and priming - necessary drying and cure time. During the entire time span the scaffolding remains in front of the façade and windows and doors are sealed with plastic foil. Therefore it is essential to decide – if it is

not tolerable for tenants to be surrounded with scaffolding or not to be able to open the windows for a long time – the renovation concept has to be adopted.
Furthermore it has to be considered if weather conditions may effect the renovation works (construction time in late autumn or winter or during summer) – maybe the executing phase is longer because of longer drying times or additional protection measures have to be considered.

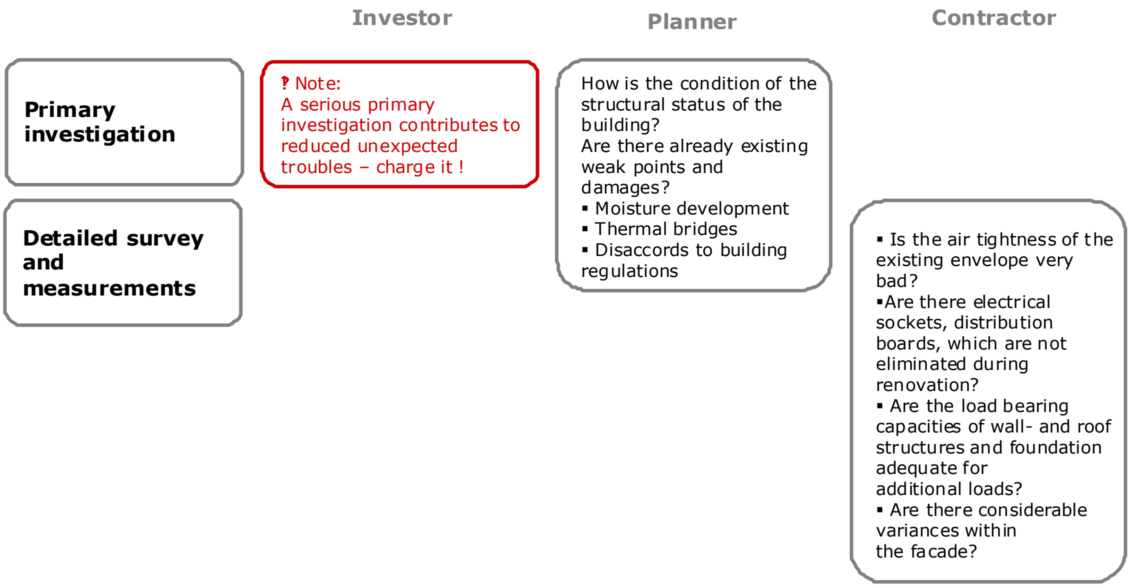
Basically every partial or complete pre-fabrication needs a more detailed and precise planning and preparation phase. It is necessary to go into greater detail and if the existing structure the complexity is rising. But in the end if it is necessary to reduce the realisation time span on-site and to reduce discomfort and disturbance on occupants, who remain in their flats, the integration of pre-fabricated components contribute to smart and shorter proceedings.

Main issue is to check which renovation concepts is possible to meet planned time-span and season of scheduled renovation works.

## 1.5 SWOT- analysis

| | Composite insulation system | Rear ventilated façade system | Façade system – partly pre-fab | Pre-fab module system |
|---|---|---|---|---|
| **Delivery** | Truck - Standard | Truck - Standard | Lorry or truck - dependent on module size. | Lorry or truck - dependent on module size. |
| **Areas for set-up and mounting** | Area for scaffolding necessary | Area for scaffolding necessary | Building, mobile or truck-mounted crane. | Building, mobile or truck-mounted crane. |
| **Weather** | Works depend on dry weather, moderate sun-shine and temperatures over 5°C. | Works only partly dependent on weather. | Works only partly dependent on weather. | Works nearly independent of weather. |

# 2 Existing building stock



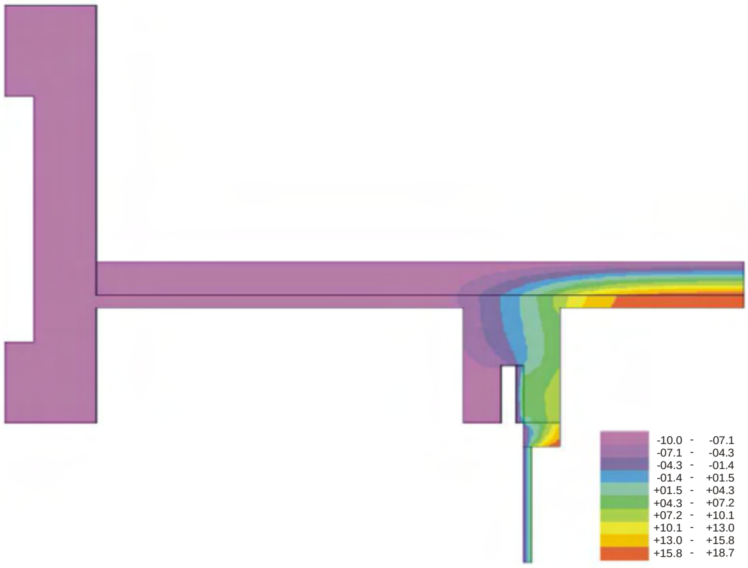

## 2.1 Primary investigation

Renovation means to grapple and deal with existing building structures. Every conception of a renovation concept are based on a thorough primary investigation of this existing substance of building structures. Critical or adverse incidents during the further work can be avoided if the renovation concept reacts on existing conditions.

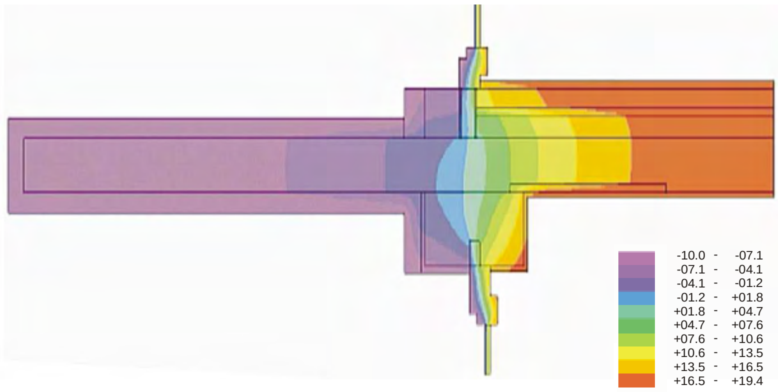
Generally the building stock built between 1945-1980 (post-war period and time of economic boom) is characterized by a great demand on immediately available and cheap living space. Therefore in many cases the building typology has similar structures. A lot of basic set-ups, the way of construction and selection of materials are typical for this period. But the challenge to succeed in realizing new and affordable living space was bigger than the concernment on the future energy demand of these buildings.

Note!
It is essential to investigate the material and physical structure of building components. Therefore accessibility to all parts of the component is necessary but not often possible (e.g.: The opening of structural units like floor covering or roof structures inside occupied apartments). A very useful guideline is the Austrian "Handbook for energy consultants – Fact sheets for constructions in old buildings" *(„Handbuch für Energieberater"– „Datenblätter für Altbaukonstruktionen und Rechenwerte"* [1])

Due to the characteristic way of construction in between 1945-1980 a series of typical thermal weak points was created, which can be found as a common thread for this epoch and are now a big challenge for every renovation.




**Picture 2-1: Typical thermal bridge of a projecting roof with an concrete attic (Source: Arch. Erwin Kaltenegger)**




**Picture 2-2: Typical thermal bridge of an concrete slab reaching out without thermal separation (Source: Arch. Erwin Kaltenegger)**

Some classic thermal bridges come up with reaching out concrete components without thermal separation, e.g.: balcony slabs or projecting roofs. The hype to build flat roofs created further thermal weak points – the attics were sparsely insulated if insulated at all.

→ Main issue is to identify the requirements for renovation works.

## 2.2 Detailed survey and measurement

### 2.2.1 Airtight envelope of existing building stock

The approval of the airtight envelope is now a well-known quality assurance measure after completion of construction works. The advantages of air tightness range from the avoidance of moisture-related building damages to reduced infiltration heat losses and a basic requirement for optimized ventilation systems.

The influence of air tight envelopes on reduced heat losses is essential: The Austrian "*klima:aktiv*" – criteria catalogue points out that an improvement of the air tightness from 3,0 $h^{-1}$ down to 1,5 $h^{-1}$ leads to a reduction of the heat demand to about 5,5 $kWh/m^2.y$. [2]
Comparative studies [3] within the renovation of large-volume buildings show large divergences between predicted data and monitored data of the calculated heating demand and consumption afterwards. Further inquiries in this showed that not approved default-values of air tightness and not eliminated leakages cause these deviations.

Hence a so-called "Blower Door"-test should be part of a detailed investigation of the existing building structure as well as the following identification of existing leakages. Weak points may be electric wiring, existing breakthroughs (chimneys, pipe network,) or wiring boxes and distribution panels.

This detailed survey is an essential basis for planning the position of the air tight envelope after the renovation. Mostly it is difficult, because not every building component or network is renewed – so some leakages may remain and cause infiltration against expectation.

Main issue is to identify possible weak points within airtight envelope.

### 2.2.2 Load bearing capacity of roof construction, exterior walls and foundations

The structural strength of the existing building structure (load bearing capacity of exterior walls and foundation, roof construction, ..) has further influence on the renovation concept of the thermal envelope.

Basically the building structure is a massive or a skeleton construction system. A very common way of construction for the buildings between 1950-1980 was to use reinforced concrete construction. Either the reinforced concrete was used for the skeleton and afterwards filled with masonry or the entire construction was made of haunching concrete. A third possibility – in the later periods – was the plate construction type, which was also dominated by reinforced concrete.
As already mentioned before – nearly all slabs were made of reinforced concrete and reached out without thermal separation on balconies and projecting roofs.

| **Concrete** | |
|---|---|
| Classification | Strength classification according to Eurocode 2 (exemplary): […], C16/20, C20/25, C30/37, […]<br>Due to ingredients or additional reinforcement |
| Types | Cast-in-place concrete / precast concrete units/ haunching concrete<br>Reinforced / on-reinforced concrete<br>Light-weight concrete / standard concrete / heavy weight concrete |
| Characteristics | High compressive strength, low tensile strength<br>Tensile strength reached by reinforcement |
| Important | Any exiting concrete construction must be evaluated as “cracked” without static approval. Gravel nets, hollows and cracks influence load bearing capacity. |
| Recommendation | Stress test and test drilling to approve actual bearing capacity. |

| **Masonry** | |
|---|---|
| Classification | Classification due to used the brick, the construction (single-shell, to-with) strength calls and cross-density of bricks. |
| Types of bricks | Solid brick, vertical coring brick, hollow blocks made of concrete or light-weight concrete,….. |
| Characteristics | High compressive strength, no tensile strength |
| Important | Masonry of unknown material without static approval has to be treated as not bearable. |
| Recommendation | Load tests and boreholes on-site |

It is a common characteristic of all massive constructions that they are good in carrying compressive loads, but worse in taking over tensile loads.
The compressive load capacity of walls depend both on the above mentioned characteristics and on the slenderness ratio (height: thickness) of the wall and on eventually stiffening partition walls.
Wall constructions made of reinforced concrete are – depending on the reinforcement) also able to take over tensile loads. But it is assumed to be difficult to prove the actual ratio and position of reinforcements.

**Picture 2-3: Building stock – solid construction (Source: AEE INTEC)**

**Picture 2-4: Building stock – plate construction type (Source: Ziv. Ing. Büro Boder)**

**Picture 2-5: Building stock – skeleton construction (Source: LIG Steiermark)**

Every additional load of a new thermal envelope has to be taken over by the existing bearing structure – down to the foundation. Therefore it is very essential to know the load bearing capacity of the foundation. The capability depends on the size of the existing foundations as well as on the soil pressure capability. Therefore a careful approval by a static engineer is decisive to avoid further subsiding and consequential effects like cracks or collapsing constructions.

Main issue is to prepare the fundamentals for a structural concept of a new façade system.

### 2.2.3 Evenness of underground (exterior walls, façade)

Another key aspect is to assess the evenness of the subsurface. Composite heat insulation systems are partly able to equate uneven facades, but there are allowable deviations defined by standards and workmanship-guidelines.

Table 2-1 shows permissible limits given by the ÖNorm DIN 18202; any unevenness above these limits can be compensated by several previal achievements (like manually brought up priming material) but it is affordable and needs additional time.

**Table 2-1: ÖNorm DIN 18202, Table 3 (Tolerances for surfaces of composite heat insulation systems)**

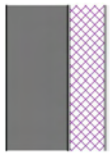
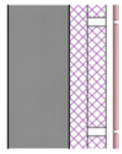
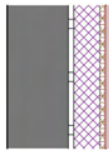
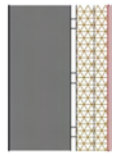
| | Limited height [mm] at reading points up to | | | | |
|---|---|---|---|---|---|
| | 0.1 | 1 | 4 | 10 | >10 |
| Walls with unfinished surfaces | 5 | 10 | 15 | 25 | 30 |
| Walls with finished surfaces | 2 | 3 | 8 | - | - |

Curtain walls or pre-fabricated façade elements need also even façade-surfaces. Large-scaled pre-fabricated components are even more sensitive due to uneven surfaces. But due to their way of construction they are mostly installed upon a substructure. This substructure can compensate uneven subsurface more easily and – it has to be mounted somehow. No additional effort is necessary.

The identification of the dimensions of the façade is important, but large-scaled and pre-fabricated components need very high quality data. Currently a common method is based on digital measurements, e.g.: 3D-laserscanning delivers 3-dimensional point clouds, which can be transferred to CAD-tools for further planning.

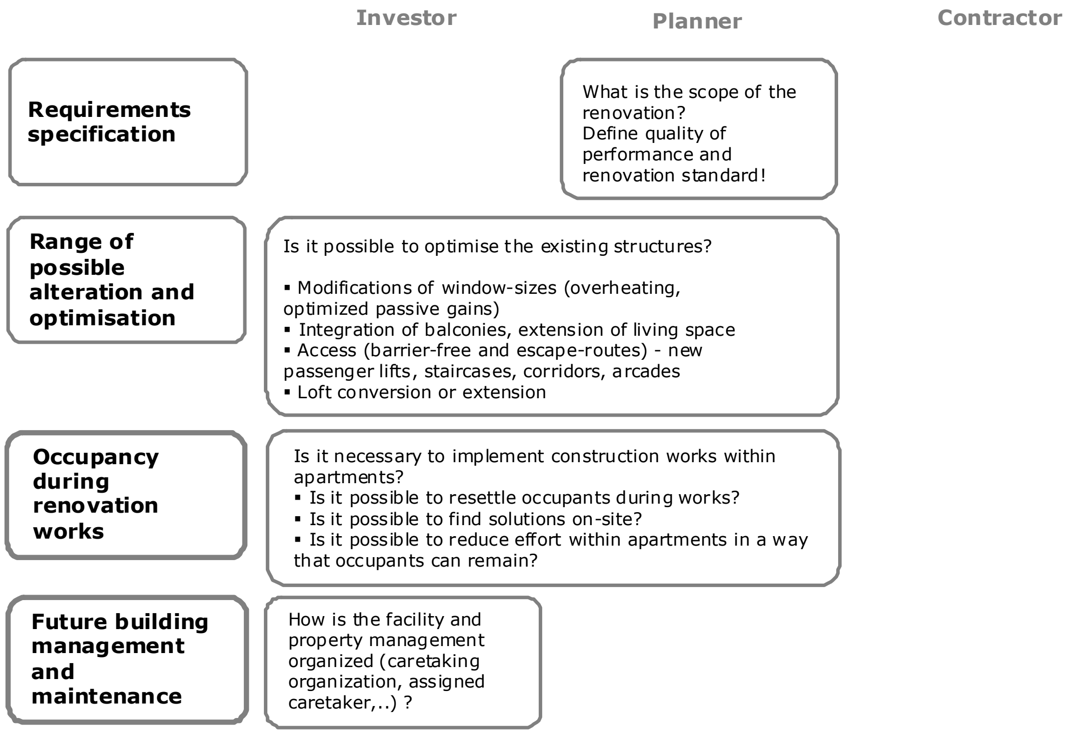
Main issue is to prepare the fundamentals for a fixing concept of a new façade system.

## 2.3 SWOT- analysis

| | Composite insulation system | Rear ventilated façade system | Façade system – partly pre-fab | Pre-fab module system |
|---|---|---|---|---|
| **Thermal characteristics** | Thickness of insulation layer is limited (freezing condensate). | Possibility of rear ventilation (useful considering moisture properties or to deal with soaked walls) | Possibility of rear ventilation (useful considering moisture properties or to deal with soaked walls) | Improved U-values possible (depending on layer composition) |
| **Constructive characteristics** | No substantial additional loads for existing walls. | Existing wall and foundation has to be proved due to their load bearing capacity. | Existing wall and foundation has to be proved due to their load bearing capacity. | Existing wall and foundation has to be proved due to their load bearing capacity. Possible to compensate by new system for load suspension. |
| **Surface conditions** | Surface has to be in the range of evenness-tolerance. In case of crumbling plastering additional fixings are needed. | Uneven facade surfaces can be compensated with substructures. | Uneven facade surfaces can be compensated with substructures. | Uneven facade surfaces can be compensated with substructures. |

# 3 New building envelope




## 3.1 Requirements

The main issue within renovation of buildings to energy-efficient buildings is to define the level of renovation standard. Furthermore it is necessary to agree on objectives for further planning. Comprehensiveness and thickness of the new thermal envelope, necessary energy efficiency measures as well as the entire energy concepts are influenced by the chosen level. For example: Renovations targeting about 60% percentage improvement of the heating demand can be done with current common "standard renovations". A "standard renovation" might include the bringing up a composite heat insulations system in combination with new passive house windows, the elimination of some significant thermal bridges and insulating cellar ceiling and top floor ceiling. But in order to reach high performance renovation it is necessary to change the renovation system, to integrate ventilation systems with heat recovery and to eliminate consequently all thermal bridges. [3]

High performance renovation levels can be defined individually. It depends on the energy policy of the investor or builder, as well as the possible necessity to fulfill requirements in order to get subsidies. In middle-European countries the "passive house" standard is well known, while in Austria a variety of criteria catalogues within the Austrian programme "klima:aktiv-haus" or "klima:aktiv-passiv haus" is wide spread. In Switzerland "Minergie" and "Minergie-P" is used.

**Table 3-1: Further information on voluntary standards for renovation**

| | |
|---|---|
| **Passive house standard** | http://www.passiv.de/07_eng/index_e.html |
| **Austrian criteria catalogues within "*klima:aktiv*"** | http://www.klimaaktiv.at/article/archive/27218/ |
| **Swiss "Minergie" and "Minergie-P ®"** | http://www.minergie.ch/home_en.html |
| **German EnEV** | http://www.enev-online.de |

Due to the fact that the passive house standard is very well known for new buildings, Table 3-2 shows relevant key indicators, which are often used as well for renovations.

**Table 3-2: Overview relevant indicators required to reach passive house standard according to "*PHPP 2007*" [4] ***

| | |
|---|---|
| **Heating demand** | $HWB_{WNF} \leq 15$ kWh/m$^2$y |
| **Primary energy-indicator (incl. household electricity, appliances,….)** | $\leq 120$ kWh/m$^2$y |
| **Primary energy-indicator (Heating, DHW, auxiliary)** | $\leq 40$ kWh/m$^2$y |
| **Heating load** | $\leq 10$ W/m$^2$ |
| **Air tightness of building envelope** | $n_{50} \leq 1.5h^{-1}$ |

* "*PHPP 2007*" is the 7$^{th}$ revised edition of the "Passive House Planning Package". The PHPP 2007 is a design tool, which can be used by architects and designers to calculate the energs balance of buildings with very low energy consumption. [4]

➡ The definition of specific targets and key indicators allow a better quality assurance during construction works and after completion.

## 3.2 Range of possible alteration and optimisation

Existing buildings are restricted within their possibilities for substantial alterations especially if they are occupied. During a thorough investigation some weak points may arise and it should be researched if there are possibilities to eliminate them by renovation or not:

- Decrease of window or glazing size (in case of overheating problems)
- Increase of window or glazing size (in case of too less natural lighting inside rooms)
- Thermal bridges caused by balcony slabs
- New (barrier-free) access infrastructure (Lift, staircase, corridors,..)
- Loft conversion or extension

**?** Note:
The flexibility of adaption of a renovation concept may differ depending on the chosen system for the new thermal envelope. Within composite heat insulation systems it is possible to make alterations anyway - increase or decrease opening sizes by brick-laying, or breaking through parapets), to enlarge small rooms by building up new floors and walls – but you need additional manual workmanship for brick-laying and concrete works or you have to introduce a second system – maybe semi-or pre-fabricated. The same arguments are true, when talking about rear-ventilated facades. But by using pre-fabricated systems it is possible to find a solution with the same system used for the entire envelope.

➡ Main issue is to check whether weak points can be eliminated by a renovation. If not it is possible to arrange compensation measures to avoid further negative implications.

### 3.2.1 Modifications of window-sizes

To find the balance between optimized daylight within rooms and prevent overheating caused by too large glazing is very difficult. Asking occupants of existing buildings if there is a current overheating situation in summer will result in a variety of individual perceptions. To get objectively correct statements detailed measurements of room and surface temperatures are necessary – but very rarely possible before renovation.
Generally north-oriented windows and glazings north-oriented should be smaller to reduce losses during winter and all south-/ south-west-orientedwindows and glazings should be larger to optimize solar gains.

Empirical values are collected in Table 3-3, they are not scientific proven and should only be used for first estimations.

**Table 3-3: Empirical values for windows and glazed areas due to different orientation (without shadow-appliances)**

| | |
|---|---|
| Windows and glazed areas oriented to the south | 15-40 % |
| Windows and glazed areas oriented to the east or the west | 10% |
| Windows and glazed areas oriented to the north | 5% |
| $h_f * U_f < 2$ | Additional heating devices below the windows or glazing prevent discomfortable airflows in the room. (Source: *Wiener Eigenheimförderung – Passivhausförderung*) |

By using additional shading systems especially south-oriented glazed areas can be enlarged (depending on the kind of appliance) up to nearly 80 %.

**Picture 3-1: South-west oriented windows – shadowed with exterior blinds (Source: Ziv.Ing. Büro Boder)**

**Picture 3-2: South-east oriented class-room windows – shadowed with exterior blinds (Source: AEE INTEC)**

### 3.2.2 Integration of balconies and living space extension

Balconies within buildings from the post-war period or the time of economic boom are typical thermal weak points due to their construction (slabs, made of reinforced concrete, reaching out without thermal separation).

Basically there are three possibilities to eliminate them or avoid negative implications:

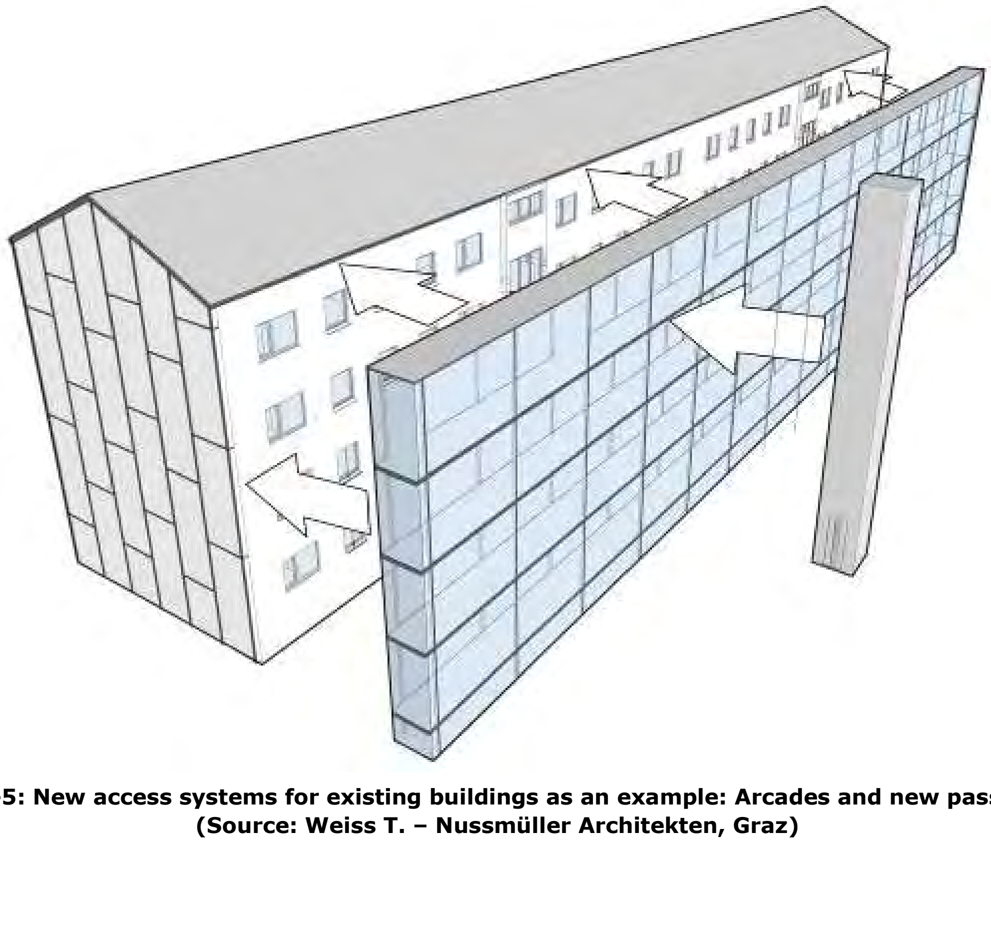
- Cutting off the slab and erecting a new construction in front of the new envelope (steel or timber construction)
- Insulation of the upper side and lower side of the slab – but a problem may arise concerning the height difference between upper edge of floor and balcony
- Integration of the balcony into the new thermal envelope – to reach enhanced living space

**Picture 3-3: Balconies before renovation within residential area Dieselweg, Graz (Source: AEE INTEC)**

**Picture 3-4: Integrated balconies after renovation within residential area Dieselweg, Graz (Source: AEE INTEC)**

### 3.2.3 Access (barrier-free and escape-routes)

A barrier-free access is obligatory (even in most of the building codes) and should be an integrative part of every renovation concept. The integration of a passenger lift is easy, but experiences so far show that many residential buildings of the building period 1945-80 have a mezzanine, that is a ground floor which can only be reached by at least one flight of stairs. So the intermediate landing of the staircase is oriented to the outside and any passenger lift positioned on the outside is only able to serve the intermediate landing and not the actual floor level. If there is no place left on one side of the staircase a possible alternative is to redevelop the entire access system and build a new arcade in front of the existing façade.



**Picture 3-5: New access systems for existing buildings as an example: Arcades and new passenger lift (Source: Weiss T. – Nussmüller Architekten, Graz)**

Substantial measures can also be requested by inadequate escape-routes. The development of requirements within building codes or standards in the past years shows a need for wider corridors or larger staircases and door openings. It is a crucial and challenging demand – sometimes it can only be solved in a way like mentioned above, namely to redevelop the entire system of access.
Renovation concepts based on pre-fabricated systems are more flexible to meet requirements concerning extension-buildings – it can be solved in the same way with pr-fabricated modules brought on-site and assembled.

### 3.2.4 Loft conversion or extension

Unoccupied lofts bear a great potential to contribute to the enlargement of high-quality living-space on locations with optimized infrastructure and living quality. Especially locations near city-centres often need more space as offered. Beside economic reasons post-compaction is a very good instrument to contribute to ecological aspects of city-development. Better exploitation of existing infrastructure, no additional use of building land and reduced lines of communication are some of the advantages.
But unimpeded loft extension is restricted by the introduction of the "Eurocode 8" – a European standard which has an influence on security measures within buildings due to earth-quake risks. With reference to this Eurocode it is necessary that even old buildings have to fulfill requirements like new buildings. Every country has the possibility within national annexes to define regions due to their earthquake-risk, but as an example: Buildings in Vienna have to resist an earthquake up to 6.2 according to the Richter-scale. [5]

## 3.3 Occupancy during construction works

Relocation of occupants is a very sensitive issue. Social conflicts may arise, especially if the age structure of the inhabitants is dominated by elderly people who have been living for a very long time in the same apartment. Not only the interference within their familiar surrounding, but also the uncertainty of coming back or getting new neighbours could be a problem. So a very important question is whether the renovation concept will make it necessary to implement construction works within apartments or not. If there are substantial alterations – like a complete new layout of the apartment – the first choice should be to consider a solution on-site. Maybe there are unoccupied apartments left and can be used to relocated tenants for a while but within the building. Only if there is no alternative a resettlement to a different location should be considered.

If the layout of the apartments is not to be modified and there are only renewals of sanitary equipment or building services it is often possible to install an intermediate bath or toilet, which can be used in the meantime.
The key issue is a transparent and comprehensive communication policy with the tenants and a smart and tough reaction on claims concerning trouble.

The chosen renovation concept contributes to this policy. Every concept that depends mainly on on-site and manual workmanship like composite heat insulation systems and every small-scaled façade system needs more and longer effort on-site and the surrounding is mostly filled up with priming material, clippings of insulation boards, foils, claddings. Moreover the procedure of sealing windows and doors with plastic foil to protect them during work has a great influence on occupied apartments behind.

Additionally a lot of safety regulations should be considered to secure the safety and health of occupants during construction works. For example: in Austria it is forbidden for unauthorized persons to enter a construction-site. So it needs a careful planning of the construction procedure to separate occupied areas from zones with construction works.
The longer the renovation lasts, the more challenging is the task to guarantee safety for both – workers and occupants. Assembling large-scaled pre-fabricated elements may afford extended safety regulations during assembling – but is for a shorter time-span. It should be considered whether a scaffold for a longer time span in front of the façade which influences the safety of tenants (accessibility to every window) is better than a transport of large-scaled elements with low-loaders and additional mobile-cranes.

Furthermore the formation of dust and noise may influence the health of tenants. Some works will cause more dust and noise than others. Works causing a lot of dust should be observed by a hygienic monitoring, which can be done by hygienists. Contaminations by dust or harmful particles can be stated or documented – subsequent claims can be prevented.

Main issue is to identify possible critical overlaps in a very early stage to enable a comprehensive information policy towards occupants.

## 3.4 Cleaning and maintenance

Routinely cleaning and maintenance of facades has necessarily established during operation of buildings and causes expenditure and therefore costs – depending on location, accessibility and type of the façade system. Whereas the surface needs mainly cleaning, all moveable parts (fittings and shadow-appliances) have to be inspected periodically (depending on the intensity of utilization it may vary from 2 years to twice a year). The inspection of silicone sealings is often forgotten – but they are important for durable waterproofing.

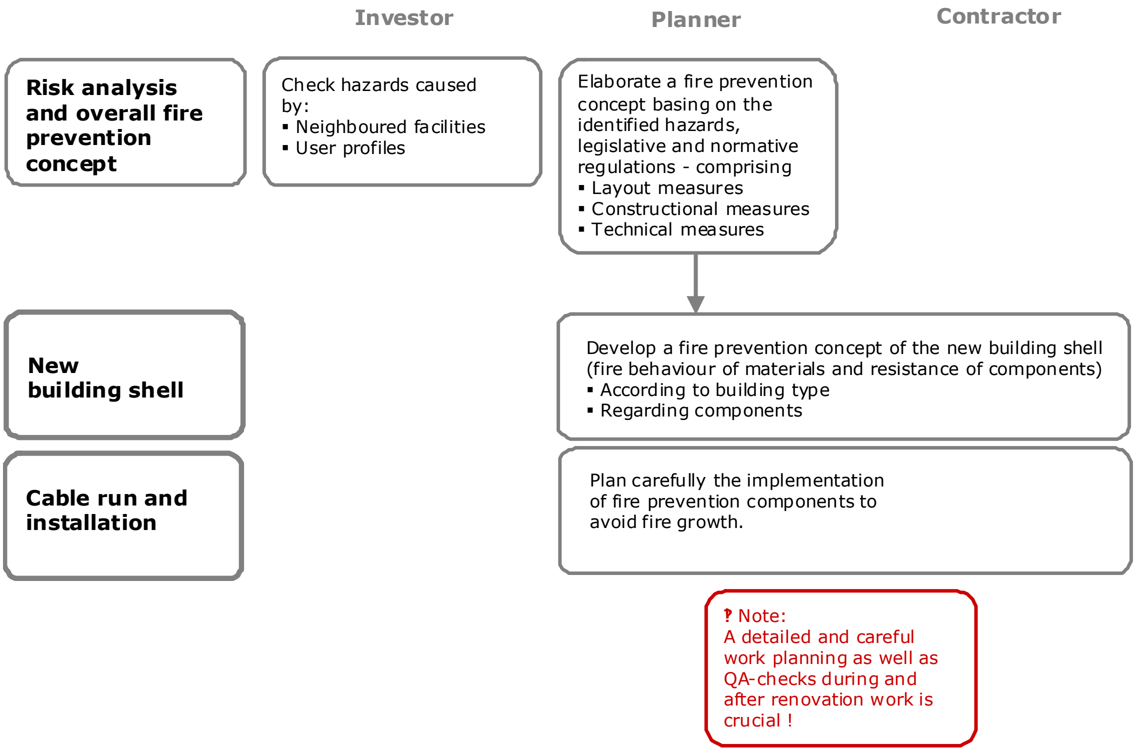
The decision of the final surface material of the façade shapes the building's appearance and the following effort of maintenance and cleaning. Several different materials require more or less cleaning to keep a façade visually clean. For example: the surface of walls covered with composite heat insulation systems have lower maintenance costs, but if they are polluted it is more difficult to clean them. Every plastering is sensitive to pressure cleaning if it is applied very often. Plain surfaces – especially glass – cause higher maintenance costs to keep them visually clean. But the surface is more resistant against periodical regular clean. Therefore plain and less structured façade-surfaces are more suitable for locations higher affected by pollution or dust.

Main issue is to identify the implications for subsequent facility management caused by design and definition of a new façade system.

## 3.5 SWOT-analysis

| | Composite insulation system | Rear ventilated façade system | Façade system – partly pre-fab | Pre-fab module system |
|---|---|---|---|---|
| **Construction time** | Long construction time-span and time for desiccation | Long construction time-span. | Shorter construction time-span, note manual bringing of insulation. | Very short construction time-span on-site. |
| **Application within high-performance renovations** | Limited thickness concerning freezing condensate on surface | Possible | Possible | Possible |
| **Potential of alteration and optimisation** | Yes, but not system-integrated | Yes, but not system-integrated | Realization system-integrated | Realization system-integrated |
| **Occupancy during renovation works** | Vast restrictions and discomfort for occupancy | Restrictions concerning long time span | Shorter construction works with minimized influences for occupancy | Very short construction works and minimized restrictions and discomfort for occupancy |
| **Cleaning and maintenance** | Long cleaning intervals, but not resistant due frequent cleaning | Plane surfaces can and have to be cleaned. | Plane surfaces can and have to be cleaned. | Plane surfaces can and have to be cleaned. |

# 4 Fire prevention




## 4.1 Risk analysis and overall fire prevention concept

Based on a risk-analysis, which comprises risks caused by neighboured buildings or utilizations and risks caused from own usages, an overall concept for fire prevention has to be developed, which should include all necessary fire prevention measures as well as their interactions and their contribution to reach the protective goals. For example in Austria the technical guideline of fire prevention "*TRVB A107*" defines the evaluation of risks "*considering the usage, the risk of fire and the expected extend of damages*". [6]

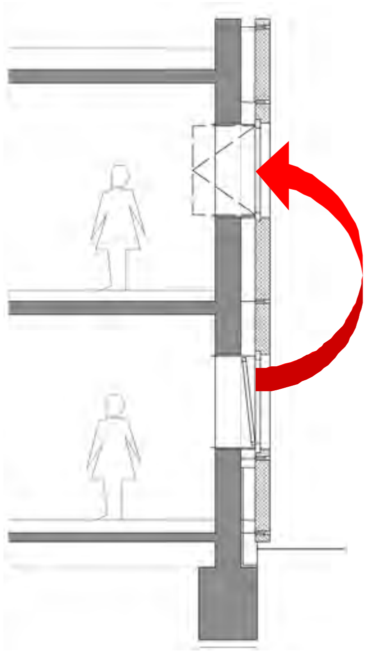
With reference to the complexity of fire prevention only aspects for façade-systems should be presented hereby:

- Hazard of fire-growth and smoke spreading along facade modules
- Hazard of fire-growth and smoke spreading caused by installations, ducts and resulting penetrations of fire-sections

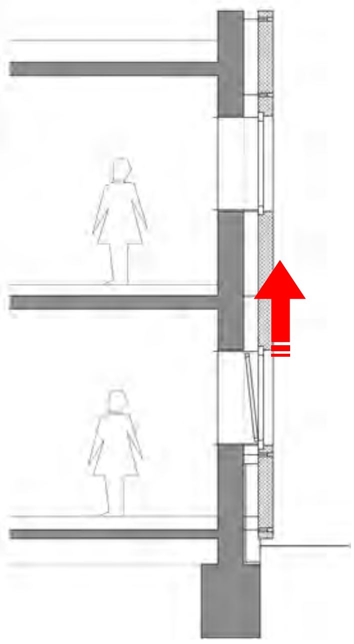
A fire may arise inside an apartment or in the space between existing old and new façade or within integrated installation shafts. (

Measures within the overall concept can be

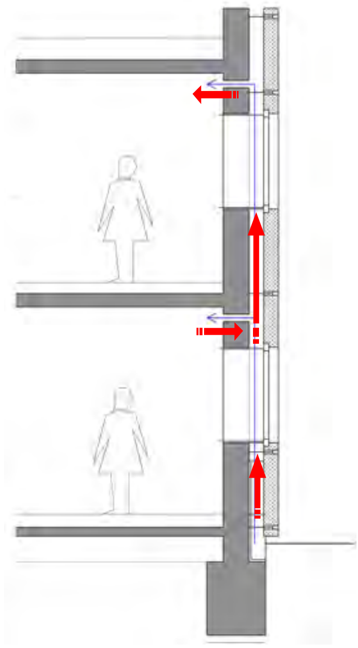
- Measures concerning the layout of building
- Constructional measures (physical structure, materials,..)
- Technical measures (fire detection systems, sprinkler systems, fire dampers, claps,…)



**Picture 4-1: Fire spreading from apartment to the upper one over windows.**



**Picture 4-2: Fire growth along façade module**



**Picture 4-3: Fire spreading within installation shafts or space between old and new façade.**

Due to the fact that fire prevention is only partly regulated comprehensively in European standards and depends largely on national legal regulations and technical guidelines it seems useful to give an overview on potential risks and possible measures, but the measures required in detail have to be adapted according to national and regional regulations and standards.

Main issue is to identify potential risks.

## 4.2 Fire prevention of the new building shell

Key issue is to evaluate risks which can be caused by facade systems due to fire growth or smoke spreading within the façade system and air-spaces (ventilated or not ventilated). Fire prevention measures concerning the new building shell will be influenced by the

- Fire behaviour of the chosen materials
- Fire resistance of the applied components
- Way of construction of the new façade system
-

### 4.2.1 Fire behaviour of implemented material

A façade covers the outside of building and connects apartments vertically which are mostly divided into different fire-sections. Furthermore in case of fire the growth proceeds along facades vertically – from bottom to top. Therefore it is essential that this proceeding is not enhanced by the materials and the structure of the new façade system. Requirements on fire behaviour properties of different materials are stated in European standards and have to be executed by national building codes and regulations.
In Austria the legal document of the *OIB*-guideline no.2* relegates to the ÖNorm B 3806.

* *OIB*-guidelines are published by the Austria Institute of Construction Engineering (*OIB*) www.oib.or.at – They are representing the technical part of the Austrian building codes and are valid for all 9 federal provinces.

**Table 4-1: Relevant standards concerning fire behaviour in Austria**

| | |
|---|---|
| ÖNorm EN 13501-1 | Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests |
| ÖNorm B 3806:2005 | Requirements for fire behaviour of building products |

The ÖNorm B 3806 regulates systems and products, classified according to the ÖNorm EN 13501-1, due to their application. The classification of building classes is now co-ordinated and segmented into 5 classes (GK 1-5) depending on the extension of gross floor area, number of floors and units. Following all requirements adapted building class are listed in tables.

Concerning composite heat insulations systems the fire behaviour and additional measures like positioning of fire-breaks or insulation of soffits can be found within this standard as well as in processing guidelines of the manufacturers. (→ www.wärmeschutz.at)

Within curtain walls or rear ventilated systems all structural components have to be considered:

- Sub-structures
- Joint and fixing elements
- Insulation layers
- Ventilated or non-ventilated airspaces
- Claddings

Therefore the fire behaviour of every material has to fulfil the requirements caused by the component and influenced by the building classification.
Every new façade in front of the existing wall will support fire growth if it is made of combustible components. Therefore materials – which are ecologically recommendable like wood – have reduced application possibilities. But many of national codes and standards imply exceptions for the use of timber constructions. Some detailed information on the fire behaviour of wood and wood-based materials can be found within the report published by M. Teibinger (*Holzforschung Austria*) [7]: http://www.holzforschung.at/fileadmin/Content-Pool/PDFs/Brandverhalten.pdf

### 4.2.2 Fire resistance of components

The fire resistance is a property of components concerning stability against collapse of walls or potential stiffening components – most of the requirements are regulated by different national building codes. The classification of products is regulated by a European standard. Ten years (beginning 2000) were foreseen as coexisting period of national and European standards. Since May 03, 2010 only products certified according to European standards are allowed to be used.

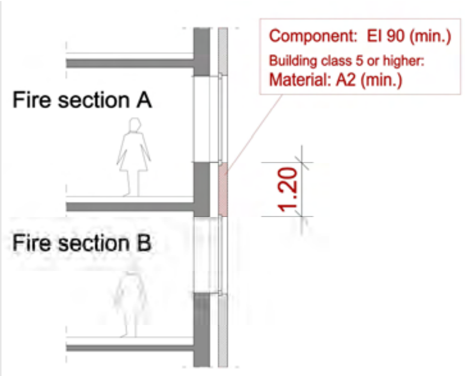
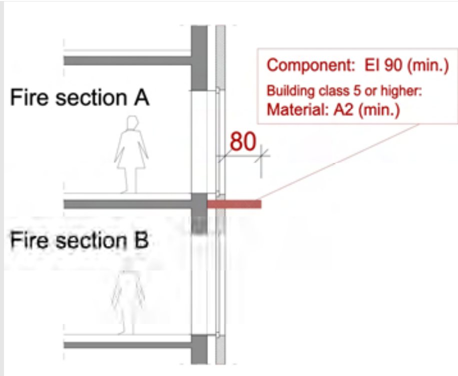
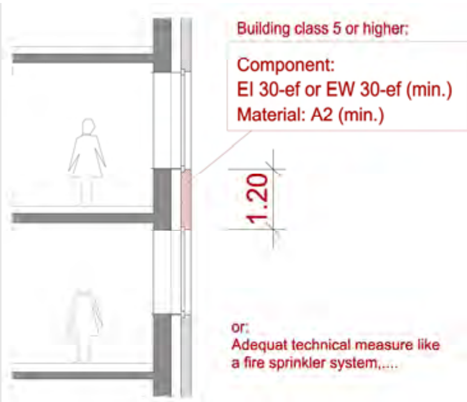
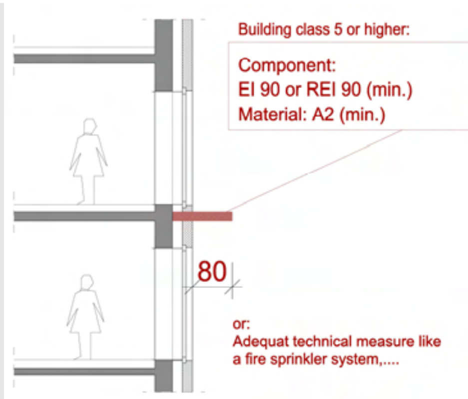
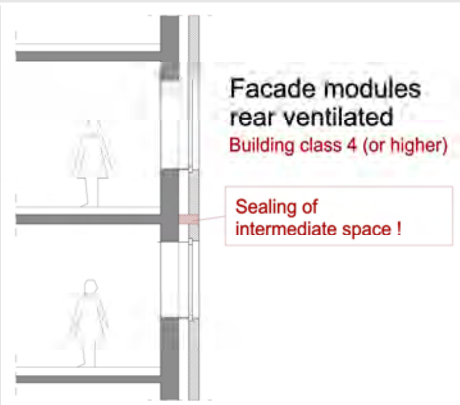
**Table 4-2: Relevant standards for fire classification**

| | |
|---|---|
| EN 13501-2 | Fire classification of construction products and building elements - Part 2: Classification using data from fire resistance tests, excluding ventilation services |

### 4.2.3 Spreading of fire and fume between existing walls and new facade systems

A series of measures can avoid spreading of fire and fume – the detailed requirements have to be adapted according to national regulations and standards. The following overview shows different hazards that have to be considered.

**Table 4-3: Overview on different hazards of fire spreading and possible measures**

| Hazard of flash-over within different fire-sections | |
|---|---|
| <br> | <br> |
| **Possibility to avoid flash over (Source: *OIB*-guideline no.6, 3.1.5)** | **Possibility to avoid flash over (Source: *OIB*-guideline no.6, 3.1.5)** |
| Hazard of flash-over for all buildings of building class 5 and more than 6 levels | |
| <br> | <br> |
| **Possibility to avoid flash over (Source: *OIB*-guideline no.6, 3.3)** | **Possibility to avoid flash over (Source: *OIB*-guideline no.6, 3.3)** |
| Hazard of fire growth within intermediate space | |
| <br> | Possibility to avoid fire growth within intermediate space (Source: *OIB*-guideline no.6, 3.5.1) |

➡ Main issue is to identify critical points and show a path to prevention measures.

## 4.3 Cable run and installation

A new and innovative possibility within renovation uses the new facades system to integrate vertically oriented installation ducts and horizontally oriented installation conduits. Old piping and installation lines cane be renewed or new units can be installed without substantial works within the apartments. The main supply line runs in front of the old facade, but any supplied apartment needs a breakthrough to get junction to the main supply lines. Typically each apartment is one separate fire-section (depending on national regulations) but the space between old and new facade is not separated according to the apartments behind. Therefore two main fire risks have to be noted:

- Risk of fire originating within a duct or conduit and infiltration into apartment
- Risk of fire emerging in an apartment, infiltration into duct and transferred to further apartments

A fire originating in a duct or conduit may be caused by power supplied wiring or units or hot works within piping or installation network. From experience – a fire once emerged will spread rapidly within the ducts causing further hot smoke.
Fire emerging in apartments can spread via the installation lines into the ducts – the proceeding is the same as mentioned before. In both cases ventilation systems bear a great risk of a very quick transfer through all over the building within different sections – if there is no separation.
Not only conduction along the piping but also the penetration of walls and slabs has to be considered. Basically at every penetration of a component separating different fire-sections adequate compartment measures (fire-bulkheads) have to be implemented. But only systems with a classification due to European standards and tested by accredited testing instates may be used.

Depending on the manufacturer there are a lot of possibilities to separate piping, wiring or ducts when passing different fire-sections. The necessary measure depends on

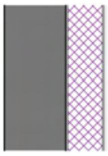
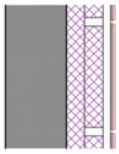
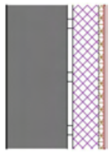
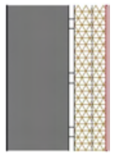
- Type of installation (water-/air conducting pipes and ducts, electric wiring, gas conducting pipes)
- Diameter or cross-section of pipe or duct
- Number of pipes and ducts (cable trays, different installations running together)
- Component which is penetrated

There is a great selection of products, detailed information on different products and measures can be found in product catalogues and guidelines from different manufacturers (exemplary):

www.hilti.at; www.wuerth.at;
www.geberit.de/web/appl/de/CMSKatalogde.nsf/pages/DerGeberit-Brandschutzloesungen-1

➡ Main issue is to identify critical points and show a path to prevention measures.

## 4.4 SWOT- analysis

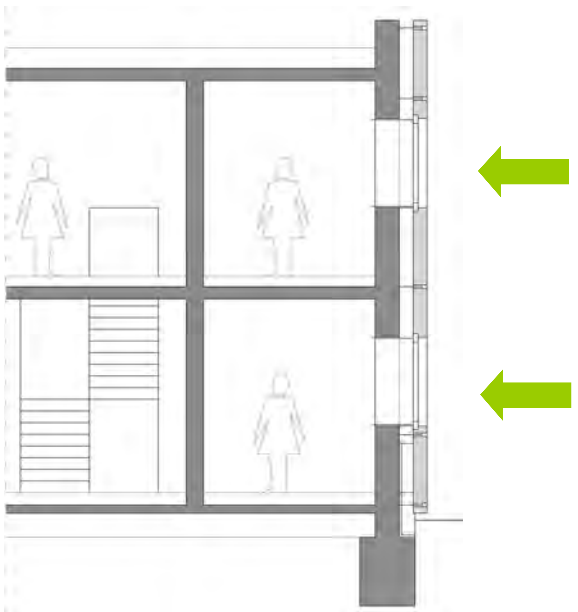
   

| | Composite insulation system | Rear ventilated façade system | Façade system – partly pre-fab | Pre-fab module system |
|---|---|---|---|---|
| **Fire behaviour** | Utilization of classified systems | Fire behaviour of each component has to be considered. | Fire behaviour of each component has to be considered. | Fire behaviour of each component has to be considered. |
| **Fire resistance** | Stability has to be ensured by underground (existing wall). | Stability has to be ensured by underground (existing wall). | Fire resistance of load bearing structural components have to be considered. | Fire resistance of load bearing structural components have to be considered. |
| **Fire growth within façade area** | Fire breaks within window-lintel; distance between window lintel and parapet to avoid flash-over; | Measures preventing growth within intermediate spaces; distance between window lintel and parapet to avoid flash-over; | Measures preventing growth within intermediate spaces; distance between window lintel and parapet to avoid flash-over; | Measures preventing growth within intermediate spaces; distance between window lintel and parapet to avoid flash-over; |
| **Fire growth along pipe-/ cable running within facade integrated installation ducts** | No risk if there are no installations | No risk if there are no installations | No risk if there are no installations | In case of integrated shafts provide measures to prevent fire growth. |

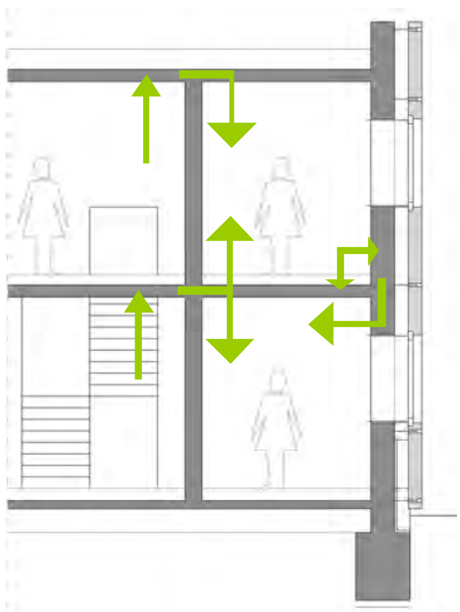
# 5 Sound insulation

| Step 1 → | Investor | Planner | Contractor |
|---|---|---|---|
| **Requirements** | Check disturbing effects caused by neighboured facilities and user profiles | Is there existing noise pollution exceeding limits given by standards / legal regulations? | |
| **Sound insulation against outdoor sound** | | Check reductions which could be achieved by the renovation module and compare achieved results with required standard - Are further measures necessary? | |
| **Sound insulation within building** | | Revaluate the air-borne and structure-borne sound inside the buildings? | |
| **Sound insulation for housing technologies and installations** | | Decouple sound producing pipework from building components! Plan and use flexible fixings! | |
| | | ? Note: A detailed and careful work planning is crucial ! | ? Note: QA during construction works helps to ensure good sound insulation! |

## 5.1 Requirements



**Picture 5-1: Air-borne sound from outdoor**



**Picture 5-2: Air-borne or structure-borme sound between different apartments or public spaces and apartments**

Sound insulation supports the prevention of living and adjoining rooms of sound emissions, which may perform as:

- Air-borne sound from outdoor (emerging from traffic or surrounding facilities)
- Air-borne sound between different apartments or public spaces (corridors, staircases) and the apartment
- Structure-borne sound between different apartments or public spaces (corridors, staircases) and the apartment

Following standards provide definitions and requirements concerning sound insulation:

**Table 5-1: Extract of relevant standards concerning sound insulation**

| | |
|---|---|
| **ÖNorm B 8115**<br>Part 1, Part 2, Part 4 | Sound insulation and room acoustics in building construction<br>Part 1 – Concepts and units<br>Part 2: Requirements for sound insulation<br>Part 4: Measures to fulfil the requirements on sound insulation |
| ÖNorm EN 12354<br>Part 3 | Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 3: Airborne sound insulation against outdoor sound |
| DIN 4109 | Sound insulation in buildings |
| SIA 181 | Sound insulation in buildings |

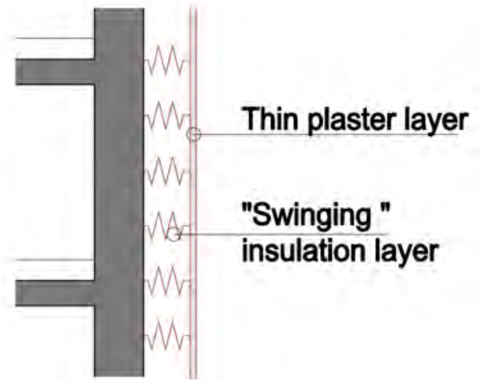
➡ Main issue is to identify appropriate requirements defined by standards to ensure sufficient prevention.

## 5.2 Sound insulation against outdoor sound

First all potential disturbing noises have to be identified within the investigation of the surroundings (see 1.1). Depending on the surrounding infrastructure and neighboured facilities a lower or higher continuous sound level has to be expected. With reference to possible neighboured nuisance emissions, which exceed customary in place emissions, it might be necessary to assess the actual continuous sound level on-site. Afterwards a comparison of the existing situation with legal requirements or recommendations of standards will show the range of necessary sound insulation measures.

Sound is spreading by the variation of air pressure, which are detected by the human ear and transferred to the brain. The reduction of the sound (sound-level difference) is called sound reduction index. The lower you hear the sound inside an apartment the better the sound reduction index from outdoor or the neighbouring room. Therefore this index states the amount of sound which passes a component due to the original sound. For example: a sound reduction index of 10 dB states that 1/10 of the original sound may pass. So the higher the index - the better the sound reduction potential of a component.

A very common but false conclusion is to assume, that improved heat insulation leads to improved sound insulation. The sound reduction index of monolithic walls or single shells is determined by the area weight of a component. How does the transmission of sound within monolithic walls happen? Stimulated by the variations of air pressure the wall gets into vibration and acts like a sound box – the air behind it is put into oscillation as well. Therefore the sound reduction is getting better if the component has a high area weight. Within old buildings most of the walls are built of monolithic walls – made of brick or concrete and are therefore very heavy.
High area weight is contra dictionary to insulation layers. A very common method within renovation is to bring up a composite heat insulation system. But in early stages of development of these insulation systems, these measures degraded the sound reduction. The reason was the very thin, but stiff layer of insulation (mostly polystyrene) together with priming and thin plaster lead to a very high dynamic stiffness.




**Picture 5-3: Composite heat insulation system acting as a swinging layer and influencing sound transmission (Source: AEE INTEC)**

But the use of mineral wool, thicker layers of insulation and mineral plasters it is possible to improve the sound reduction index.

Referring to the way of transmission it is obvious that leakiness and cracks contribute to sound transmission between different parts – the oscillating air spreads within every gap.

Following measures contribute to improved sound insulation against air-borne sound:
- Massive and heavy components – the higher the area weight the better the reduction potential
- Improvement of air tightness – between different units and to the outside

Requirements for sound reduction of different components are given by the above mentioned standards, by legal regulations (depending on the country) and due to the actual outdoor sound level.

➡ Main issue is to evaluate the sound reduction index achieved by the new façade and identify whether it is sufficient enough or further measures are necessary.

## 5.3 Sound insulation within the building

Sound insulation within the building concerns

- Air-borne sound
- Structure-borne sound

Basic information on air-borne sound transmission is given in the chapter before. But within renovation a new aspect has to be considered for sound insulation inside buildings (between apartments or apartments neighboured to public rooms, corridors and staircases).

Structure-borne sound is transmitted within the building by transmission within flanking components (“flank transmission”). The vibration (for example from impact sound) is transmitted along the component and stimulates oscillation of adjacent air layers. A very efficient sound insulation measure is to reduce or eliminate transmission paths by flexible bearing or decoupling of components.

New systems mounted on the outside of the façade may generate new transmission paths (flank transmission). It is essential to avoid this by careful planning of fixing and assembling.

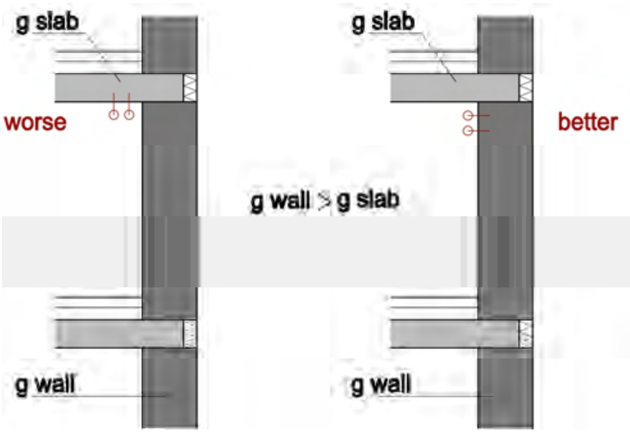
While covering the building with a new envelope on the outside the existing sound reduction against outside is improved. Less disturbing sound intrudes from outside into the living space. But now every sound coming from neighbouring units is dominating – even if the level is the same as before.

Note!
If the building gets a new shell, which improves significantly the sound reduction index it is recommended to revaluate the sound reduction index inside the building – among different apartments as well as between apartment and public spaces.

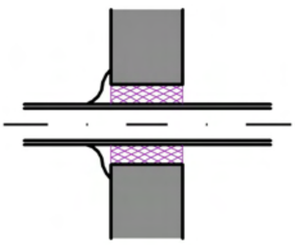
➡ Main issue is to revaluate the existing sound insulation inside the building and find appropriate measures.

## 5.4 Sound insulation for housing technologies and installations

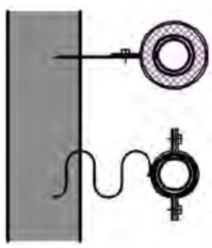
Until now it was a common practice to have installations within the building shell. It was more difficult to reduce sound emerging from water-conducting pipes, sewage pipes or toilet flushing – but careful planning and implementation was and is state of the art.
By having new shafts on the outside – the sound is now coming from a different side. Every water-conducting pipe or sewage pipe is separated by the (mostly) massive exterior wall from the living space inside. So the heavy area weight of these walls will contribute to sound reduction. Some of the sources of noise will remain inside – a lot of common sound insulation measures can be applied to avoid disturbances. But it is new to have the option to install ventilation devices within the new façade system. It is new to have installations and pipes on the outside. So there is a new sound disturbance coming from the outside. The crucial issue is to take care of flexible fixing and decoupling of pipe work or devices which may cause vibrations or sound.
Furthermore it is crucial how ventilation ducts or water-conducting pipes are passing the wall to the inside.




**Picture 5-4: Piping inside apartments – mounted on the component with heavier area weight (Source: AEE INTEC)**



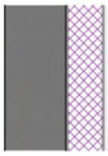
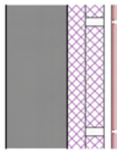
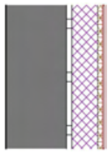
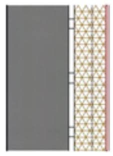
**Picture 5-5: Pipe passing from installation duct into apartment (Source: AEE INTEC)**



**Picture 5-6: Fixing pipes to avoid sound transmission (Source: AEE INTEC)**

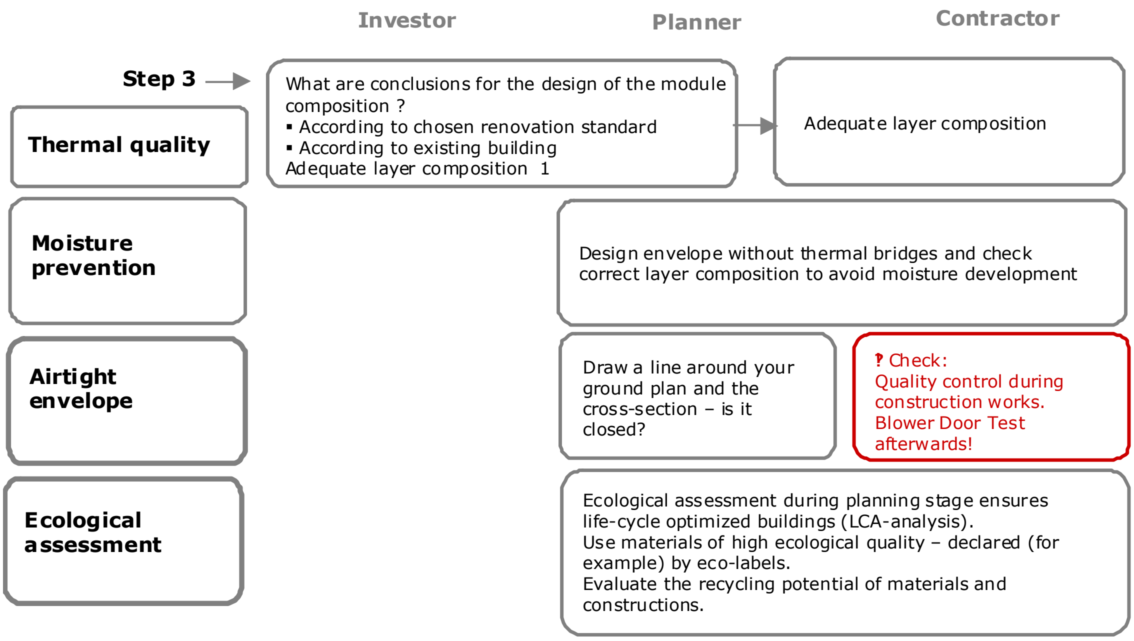
➡ Main issue is to identify critical points within building services and set measures for prevention.

## 5.5 SWOT- analysis

| | Composite insulation system | Rear ventilated façade system | Façade system – partly pre-fab | Pre-fab module system |
|---|---|---|---|---|
| **Sound insulation against outdoor sound** | Usage of correct insulation material, adequate thickness of insulation layer and priming / plastering | Systems with large area-weight may improve sound insulation significantly. | Systems with large area-weight may improve sound insulation significantly. | Systems with large area-weight may improve sound insulation significantly. |
| **Sound insulation within the building** | No implications | If significant reduction against outdoor sound – revaluation of sound insulation inside necessary. | If significant reduction against outdoor sound – revaluation of sound insulation inside necessary. | If significant reduction against outdoor sound – revaluation of sound insulation inside necessary. |
| **Transmission of structure-borne sound** | No implications | Flexible bearing and fixing, consequently decoupling. | Flexible bearing and fixing, consequently decoupling. | Flexible bearing and fixing, consequently decoupling. |
| **Sound insulation against sound emerging from installations.** | Common measures within existing or new installations inside the building. | Common measures within existing or new installations inside the building. | Common measures within existing or new installations inside the building. | New installation shafts or units on the outside contribute to reduced disturbing sound. |

# 6 Building physics and ecology




One aspect within chapter 3 was to define the level of renovation standard – a key aspect for further planning - influencing among others the new thermal envelope. The chosen insulation material, layer composition and thickness of each layer determine the thermal performance (U-value), moisture properties and impact on environment.
Concerning the new envelope high performance renovation requires some key aspects like good thermal behaviour (U-value), consequent elimination of all thermal bridges to avoid condensate, prevention of moisture within structural units, shape of air tight envelope and usage of materials of high ecological quality.
High performance renovation is also more demanding in terms of construction quality – therefore a more careful and detailed (working) planning is necessary. Finally every system (manually, pre-fabricated,….) has to be evaluated referring to the framework given by the existing building. Technically correct systems may be not suitable in any case.

## 6.1 Thermal quality

Thermal quality contributes to reduced heat transmission losses to higher inner surface temperatures and therefore to improved user comfort. Generally thicker layers of insulation result in improved U-values. Sometimes during renovation it may be difficult or impossible to enlarge outer dimension of a building (see 1.2), insulation materials of higher quality may contribute to thinner layers, but the resulting difference is rarely essential.

**Table 6-1: Overview thermal conductivity of different insulation materials**

| Insulation material | Thermal conductivity index |
|---|---|
| | [W/mK] |
| **Cork** | 0.045 |
| **Mineral wool** | (0.035-) 0.04 |
| **Foam glass** | 0.045 |
| **Polystyrol extruded** | 0.035 |

A possible alternative are vacuum insulation panels (VIC) but they are more expensive and demanding inr planning and within completion. So they are suitable for very specific fields of application (if the thickness is a key issue like on doors to flat-roofs, ….)
As mentioned before the renovation standard determines the thermal quality of the envelope. Table 6-2 shows exemplary values required by different standards. The Austrian building code depicted in the "OIB guideline no. 6" is not very ambitious – every "standard renovation" should meet these requirements. Even if there is no common understanding on the specific key figures for low-energy houses the values are more demanding, while passive house standard within renovation is – depending on the initial situation – an ambitious goal.

**Table 6-2: Overview different U-values of relevant building components**

| **Construction unit** | ***OIB*-guideline no.6*** | **Low-energy houses** | **Passive houses** [4] |
|---|---|---|---|
| | [W/(m²K)] | [W/(m²K)] | [W/(m²K)] |
| **Roofs** | 0.20 | 0,15 – 0,25 | ≤ 0.15 |
| **Windows** | 1.40 | 1.20 | ≤ 0.80 |
| **Outside walls** | 0.35 | 0.20 – 0.30 | ≤ 0.15 |
| **Basement ceiling slab** | 0.40 | 0.30 – 0.35 | ≤ 0.15 |

* *OIB*-guidelines are published by the Austria Institute of Construction Engineering (*OIB*) www.oib.or.at – They represent the technical part of the Austrian building codes and are valid for all 9 federal provinces.

Methods for calculation of thermal quality as well as on user's comfort can be found in various European and national standards (see Table 6-3 )

**Table 6-3: Extract national and European standards for thermal insulation requirements**

| | |
|---|---|
| **EN ISO 6946** | "Building components and building elements- Thermal resistance and thermal transmittance- Calculation method" |
| **ÖNorm EN 15251** | "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics" |
| **EN ISO 7730** | "Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria" |
| **DIN 4108-1 to 4, 6, 8, 10 (some even pre-standard or draft)** | "Thermal insulation and energy economy in buildings" |
| **VDI 4701 Sheet 1** | "Planning and dimensioning of the indoor climate (VDI ventilation code of practice)" |

## 6.2 Moisture prevention

The content of water vapour of inside air is considerably higher than the amount in the air outside. If the warm air from inside containing water vapour penetrates into the component and passes several layers to the outside – it will cool down during this process (outside the component the temperature – during cold season – may be at -13°C). Somewhere the air will pass the condensation point – and water will drip out. This leads to moisture development within the component and causes sustainable and mostly for a long time undiscovered building damages.

Measures to avoid this are careful planning and completion, especially concerning:

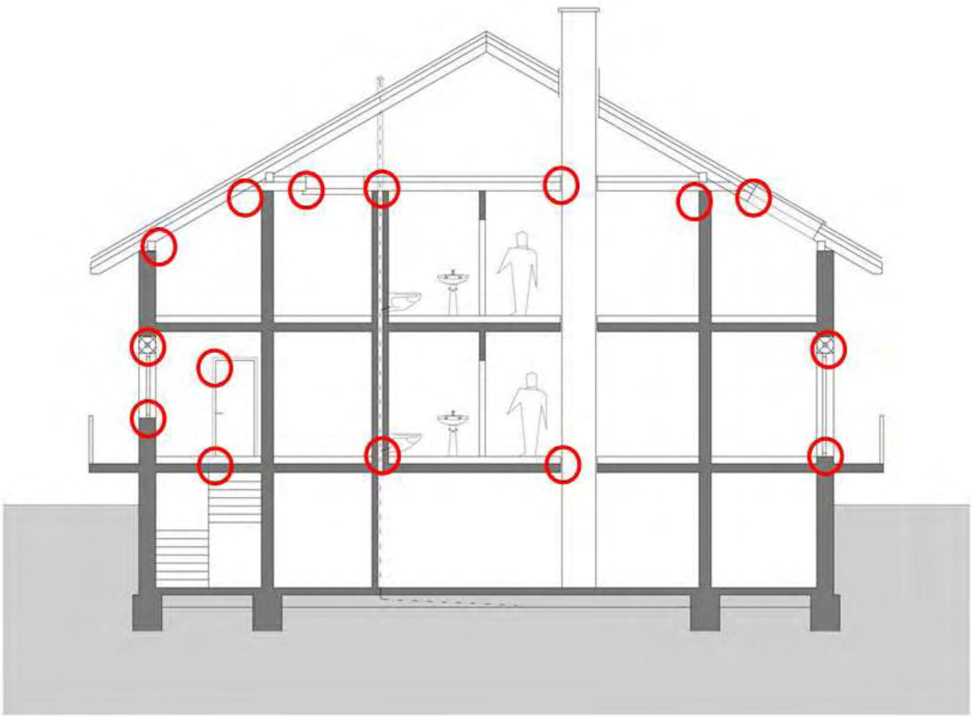
- The correct position of vapour barriers or retarders within the layer composition
- An air tight envelope to prevent exfiltration
-
-

**Table 6-4: Overview legal and normative regulations for moisture prevention requirements**

| | |
|---|---|
| ÖNorm B 8110-2 | "Thermal insulation in building construction – Part 2: Water vapour diffusion and protection against condensation" |
| DIN 4108-3 | "Thermal protection and energy economy in buildings – Part 3: Protection against moisture subject to climate conditions; Requirements and directions for design and construction" |
| SIA 180; SN 520180 | "Heat and moisture protection in building construction" |
| EN ISO 13788 | "Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods" |

## 6.3 Airtight envelope

Leakiness within the thermal envelope contributes to thermal losses, caused by infiltration as well as condensate development, caused by exfiltration. Condensate within a component reduces the performance of insulation layers, which often remains undiscovered and leads to building damages (see 6.2). But furthermore air tightness leads to draughts (by component joints) and decreased sound insulation.
A careful planning considers the air tightness of the entire envelope comprising all joints and critical points. Area sealing as well as linear sealing is by the way a common practice. But especially renovation longs for more: in many cases opened internal plaster or unplastered areas causes leakages. Furthermore existing and remaining installations and fittings (like sockets, distribution boxes and panels) or invisible joints like the connection between floating floor screed and the wall or missing links to the stair-flights are weak points in the air tight envelope.



**Picture 6-1: The airtight envelope – critical points**

The validation of the air tightness is done by means of the so-called "Blower Door Test" – a procedure according to ÖNorm EN 13829, respectively ISO 9972.

**Table 6-5: Overview leakage rate $n_{50}$ – Difference of test pressure 50 Pa**

| | |
|---|---|
| ***OIB*-guideline no. 6** * | $n_{50} \leq 3.0\ h^{-1}$ – without mechanical ventilation<br>$n_{50} \leq 1.5\ h^{-1}$ – with mechanical ventilation |
| ***„klima:aktiv-passivhaus" -*** Renovation of residential buildings [2] | $n_{50} \leq 1.5\ h^{-1}$ , additional points if the value $n_{50}$ is $\leq 0.6\ h^{-1}$ |

* *OIB* guidelines are published by the Austria Institute of Construction Engineering (*OIB*) www.oib.or.at – They represent the technical part of the Austrian building codes and are valid for all 9 federal provinces.

Examples and further detailed information can be found within:
*IBO* – Austrian Institute for Healthy and Ecological Building (Ed.): "Details for Passive Houses - A catalogue of ecologically rated constructions". Wien 2009 [8]

## 6.4 Ecological assessment

Ecological assessment can be done within two point of views: product-related and object-related. Object-related assessments are furthermore life cycle analysis of buildings (LCA) and are based on declarations of single buildings products.
The initial point therefore is the ecological evaluation of building products and building components. The assessment identifies and assesses criteria, which influence the environment, buildings and occupants. The increasing number of products on the market and more complex constructions make the orientation more difficult.

The assessment is based on: [9]

- Life cycle assessment
- Qualitative criteria
- Eco-labelling
- Environmental declaration

The life cycle assessment is based on quantitative valuation methods. Indicators are (for example) the non-renewable part of primary energy (PEI), the global warming potential (GWP), the acidification potential (AP), and some more. [10]
But quantative criteria do not comprise implications on health during completion or usage or dangerous substances. Therefore qualitative criteria are very important, but it is even more complex to find scientific methods of evaluation. [9]

Eco-labelling is used to qualify products. Basic requirements are given by the ISO standard 14024 "Environmental labels and declarations - Type I environmental labelling - Principles and procedures". But each label comprises very specific qualitative requirements, but they depend on aims and objectives of each label. Within the German-speaking countries the following labels are well known: [9]

http://www.natureplus.org/natureplus/
http://www.ibo.at/de/produktpruefung/index.htm
http://www.umweltzeichen.at/
http://www.blauer-engel.de/
http://www.eco-label.com/

The aim of environmental declarations is not to qualify single products, but serve as information for end-users. The manufacturer may choose between declarations according to the ISO standard 14021 „Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling)" or according to ISO 14025 "Environmental Product Declaration–EPD". But for future practice-oriented implementation of the EPD the EN 15942 "*Nachhaltigkeit von Bauwerken - Umweltproduktdeklarationen - Kommunikationsformate zwischen Unternehmen*" will be essential. Object-related life-cycle assessment incorporates the life cycle of a building – the construction phase, use, but also demolition and disposal. Key issue is the comparability of data sets, therefore international harmonization of definition and methodology is necessary. [9]

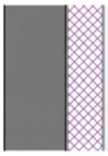
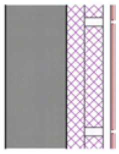
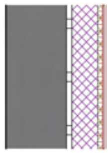
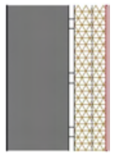
Within the Austrian research project „ ABC – Disposal. Assessment of Buildings and Construction", coordinated by the *IBO* - Austrian Institute for Healthy and Ecological Building an ecological assessment of building materials at the end of a building's life cycle was carried out. The performance evaluation was done by means of qualitative and quantitative methodologies. Table 6-6 shows the out comings of the performance assessment of different materials which are used within façade construction systems. Further, more detailed information can be found in the final report of the project: http://www.ibo.at/de/forschung/index.htm [11]

**Table 6-6: ABC – Disposal Evaluation matrix – Performance assessment of different facade materials (Source: *IBO* – Mötzl [12], Translation: AEE INTEC)**

<table>
<tr><th></th><th>1<br>Excellent</th><th colspan="2">2<br>Very good</th><th colspan="2">3<br>Weak points</th><th colspan="2">4<br>Problematic</th></tr>
<tr><td rowspan="3">1 Recycling</td><td>Aluminium, steel</td><td colspan="2" rowspan="3"></td><td colspan="2">Glass</td><td colspan="2" rowspan="3"></td></tr>
<tr><td>Timber post</td><td colspan="2" rowspan="2">Concrete + composite heat insulation systems</td></tr>
<tr><td>Concrete + hilü facade</td></tr>
<tr><td rowspan="2">2 Combustion</td><td></td><td colspan="2">Composite heat insulations system -<br>corc, wood fibre</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Wood, small untreated</td><td></td><td colspan="2">Wood coated</td><td colspan="2">Wood treated</td><td></td></tr>
<tr><td rowspan="2">3 Disposal</td><td>Glass</td><td colspan="2"></td><td></td><td colspan="2">Mineral wool</td><td></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2">Fibre cement</td><td colspan="2"></td></tr>
</table>

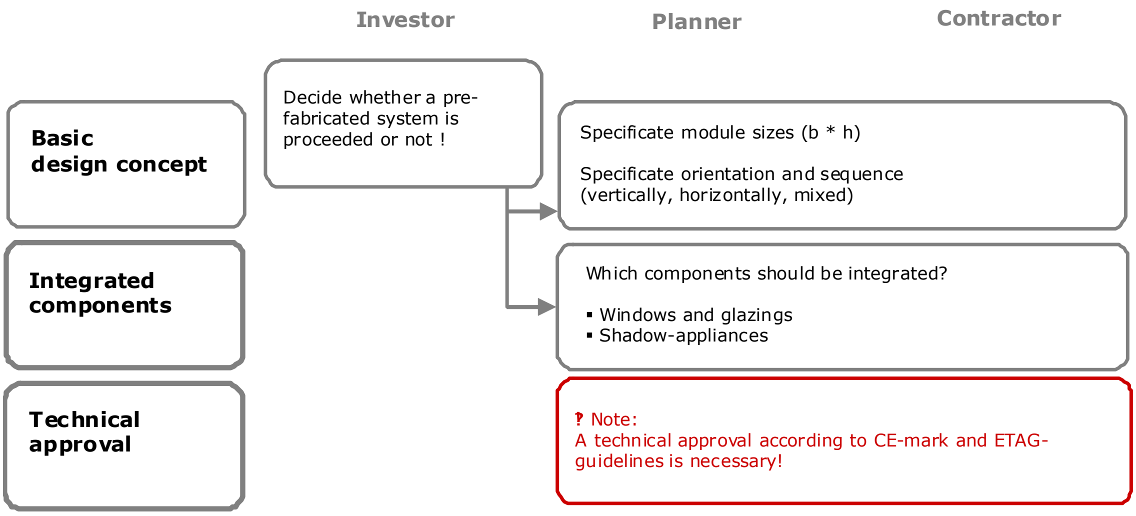
06/2010 Mötzl (IBO)
07/2010 Translation Geier (AEE)

## 6.5 SWOT- analysis

| | **Composite insulation system** | **Rear ventilated façade system** | **Façade system – partly pre-fab** | **Pre-fab module system** |
|---|---|---|---|---|
| **Thermal quality** | Depending on thickness. Too thick layers may cause freezing condensate. | Note! Careful planning to avoid thermal bridges emerging from fixing. | Uneven spaces can be insulated easily by blow insulation into space between old and new façade. | Uneven spaces can be insulated easily by blow insulation into space between old and new façade. |
| **Moisture properties** | No significant implications. | Air ventilation relieves moisture prevention. | Air ventilation relieves moisture prevention. | Note! Careful planning and completion necessary. |
| **Air tightness** | Note! Careful planning and completion necessary. | Note! Careful planning and completion necessary. | Note! Careful planning and completion necessary. | Note! Careful planning and completion necessary. |
| **Ecological assessment** | Depending on chosen materials. Recycling due to the way of making not really possible at the moment. | Depending on chosen materials. Decomposition potential facilitates recycling. | Depending on chosen materials. Decomposition potential facilitates recycling. | Depending on chosen materials. Decomposition potential facilitates recycling. |

# 7 Basic module kit




The conception of the basic module-kit determines the future visual identity of the façade – surface, structure, segmentation. But on the way to find the optimized solution a series of technical, logistical and economic parameters have to be considered.

## 7.1 Basic design concept

### 7.1.1 Specification of module sizes

The specification of maximal and minimum possible and sufficient sizes of the basic module is determined by criteria of transport and sizes of available material:

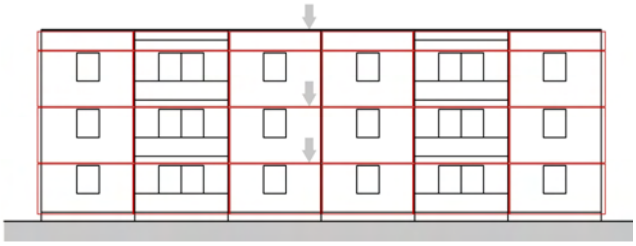
- What are available standardized sizes of necessary boards, sheets or plate material?
- How is it possible to minimize clippings?
- What is the maximum size of a module for transportation?
- What is the maximum size for delivering on-site and lifting to the façade due to the ranges for set-up area and possible lifting auxiliaries?

### 7.1.2 Specification of module orientation and sequence

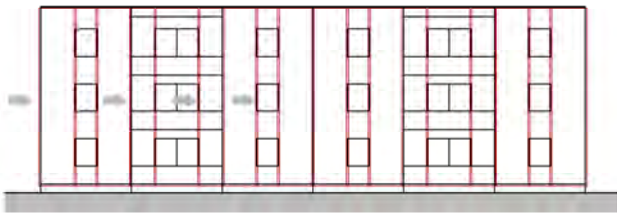
The orientation – vertically or horizontally will be determined by the static system (see 8.1), the load bearing capacity and structure of the existing old wall. Massive wall systems are very flexible as both vertically and horizontally oriented modules are possible. Skeleton or plate type constructions affect a raster – load bearing points are fixed and determine the module size.

The orientation will influence further aspects:

- Visual appearance (façade structure dominated by horizontally or vertically lines)
- Assembling procedure
- Integration of installation within new façade system (vertical shafts)



**Picture 7-1: Modules oriented horizontally**



**Picture 7-2: Modules oriented vertically**

Main issue is to adjust design and visual appearance with technical and constructive aspects.

## 7.2 Integrated components

Pre-fabricated modules bear the potential of easy integration of additional components. The basic assembly is done in the fabrication hall under guaranteed conditions. There are a lot of joints and junctions, which have to be completed carefully. Further any expansion or extension (balconies, new arcades, winter gardens,..) can be pre-fabricated in a system-integrated way. The additional effort is easier to calculate and is not necessarily carried out on-site – as a consequence the construction time on-site is reduced.

### 7.2.1 Windows and glazings

Windows are substantial components within any facade – visually and technically demanding, due their complexity: The junction between window-frame and wall is decisive for air tightness, subject to thermal bridges and major issue for the design.

Their scope comprises:

- Optimized supply with natural daylight
- Outlook for occupants
- Insight from outside
- Optimisation of solar gaining

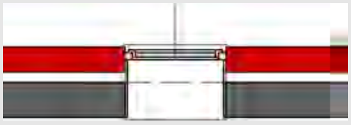
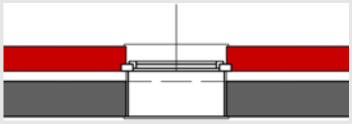
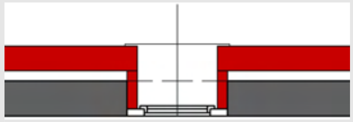
But the balance between optimization of glazings between solar gaining and hazard of overheating during summer is difficult. (see 3.2.1 and 7.2.2).

Visual appearance is partly shaped by the position of the window within the reveal. A series of pros and cons result from different window-positions.

**Picture 7-3: Windows exterior flush-mounted (Source: AEE INTEC)**

**Picture 7-4: Windows mounted centered within reveal (Source: Obereder H., A+ ZT GmbH)**

**Table 7-1: Different positions of a window within the reveal**

| | **Exterior flush-mounted** | **Centred in the reveal** | **Interior flush-mounted** |
|---|---|---|---|
| |  |  |  |
| **Advantages** | Simple manufacturing and assembling | Window integrated within insulation level | Optimized position of heat dissipation device (below window)<br>Exterior shadow appliance integrated in lintel |
| **Risks** | Potential weak points:<br>Window frame as thermal bridge causing condensate<br>Driving-rain-proof of superior window joint | Air tight connection between window and old facade is hard to implement – potential leakiness | In case of to less thick reveal insulation – thermal bridges + heat losses |
| **Precaution** | Window position adapted to insulation level – relocation of sufficient distance into reveal to enable insulation-cover of window frame. | More carefulness and inspections within completion | Sufficient insulation of reveal at least 3-5 cm. |
| **Dis-advantages** | Exterior shadow appliance is difficult to integrate. | Increased effort for working steps and completion | Sufficient insulation of reveal diminishes glazed area for incide of natural daylight |

Note!
Module-integrated windows provide the advantage of completing the joint between window and new facade under controlled conditions within fabrication hall. Even so the connection between module and reveal has to be completed carefully on-site as well.

Main issue is to adjust overall appearance of the façade with building physical aspects.

### 7.2.2 Shadow appliances

Not only heating, but also cooling is getting more and more important for our energy demand. A lot of building regulations and standards in various countries define that within residential buildings mechanical cooling has to be avoided by the careful and intelligent planning of passive measures.

**Table 7-2: Abstract legal regulations and standards referring to the prevention of overheating**

| | |
|---|---|
| ***OIB*-guideline no. 6** * | 7.3 The overheating of buildings during summer has to be avoided. Due to new buildings and comprehensive renovation of residential buildings the Austrian standard „ÖNorm B8110 part 3"has to be obeyed. |
| **ÖNorm B 8110-3**<br>Thermal protection in building construction - Heat storage and solar impact | 6.1 Overheating in summer is regarded as avoided, if the felt room temperature in the specific room during hot seasons does not exceed the limit temperature. The limit temperature is set during operation within daytime at 27°C and 25°C during nighttimes. |

| | |
|---|---|
| DIN 4108-2 Thermal insulation and energy economy in buildings | 8.1 …. within building construction unacceptable temperature conditions have to be avoided by means of structural measures …… and not by elaborative, complex energy-intensive cooling measures…. |

* *OIB*-guidelines are published by the Austria Institute of Construction Engineering (*OIB*) www.oib.or.at – They represent the technical part of the Austrian building codes and are valid for all 9 federal provinces.

De facto even within housing construction overheating occurs, not only in summer but also on days with high irradiation during transitional season.

Key indicators for building's behaviours during summer are:
- Glazing (solar energy transmittance G-value, percentage within façade, orientation, incline)
- Ventilation situation of the room/apartment/building (1-/ 2-/ 3- sided, intensity)
- Location (global radiation)
- Building structure (heat storage capacity, thermal mass, room geometry)
- Sun protection (kind, position, rear ventilated, control)

Most of the indicators can hardly be changed within renovations. Two possible alterations can be mentioned: During construction works inside the building, especially in case of loft conversion the implementation of coverings with heavy area weight or the completion with cement screed instead of dry screed. But the best precaution of overheating is the application of exterior shadow appliances, especially automatically controlled.

**Picture 7-5: External venetian blinds, upper part adjustable for optimized daylight transport. (Source: AEE INTEC)**

**Picture 7-6: External venetian blinds - "all-metal". Very common used within object-range (robustness in case of wind-loads). (Source: Ziv. Ing. Büro Boder)**

**Picture 7-7: Blinds mounted "intermediate" (in-between the glass-panels) – to be used for plane façades. (Source: AEE INTEC)**

Overheating precaution measures should be an integrated part of the entire renovation concept and can not be treated separately. The implementation of exterior shadow-appliances is a simple and sustainable measure. Shadow-appliances inside the lazing or in the intermediate space are not as sufficient as outside shadowing. Highly reflective surfaces of the slats or other measures like intelligent control-systems may contribute to lower cooling demand but the real cause the transmission of sunlight into thermal energy is only avoided by external appliances.

Note!
Manual control of external adjustable shadow-appliances is mostly done by crank drives. But the penetration of the crank-drive is on the one hand a thermal bridge and on the other hand a penetration of the air tight envelope. For remedy use an integrated electric motor.

Detailed information for further planning, a lot of possibilities for sun-protection measures can be found within the toolkit of the IEE-project "Keep cool - From cooling to sustainable summer comfort". A lot user-specific information, guidelines and innovative solutions can be downloaded there.

www.keep-cool.eu/

➡ Main issue is to prevent overheating by passive measures.

## 7.3 Technical approval

In order to put building products on the European market it is necessary to fulfil the Construction Products Directive (89/106/EWG). Aiming on the essential requirements on building structures (security, common welfare, health and environmental protection) mandatory properties of buildings products are regulated. All components or products, which are permanently implemented within buildings have to meet European technical specifications and are identified by the CE-mark. But the CE-mark is only an indicator on the usability. The implementation of this directive is done on national basis – for example in Austria it is anchored in the several building codes of the 9 federal states. The Construction Products Directive shows acc. to Art. 4 Par.2 several kinds of harmonized European technical specifications, which may serve as a basis for CE-marking of building products. One of them is the European Technical Approval (ETA).

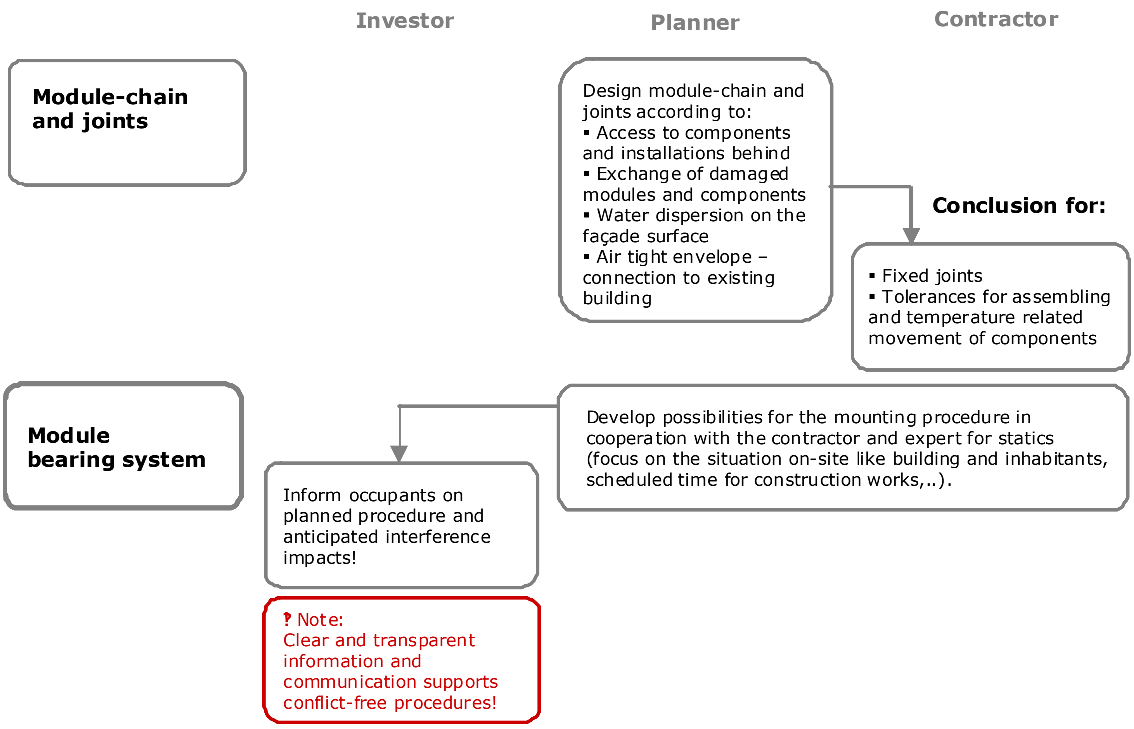
**Table 7-3: Abstract – European Technical Approval Guidelines (ETAG)**

| | |
|---|---|
| **ETAG 007** | European Technical Approval Guidelines for timber frame building kits (Edition 2001). Identification number of the Austrian version: OIB-467-020/02. |
| **ETAG 017** | European Technical Approval Guidelines for veture kits – prefabricated units for external wall insulation (Edition 2005). Identification number of the Austrian version: OIB-467-031/09. |

Further information is available within the website of the Austria Institute of Construction Engineering (*OIB*): www.oib.or.at

➡ Main issue is to meet European standards for product classification.

# 8 Joint and fixing techniques



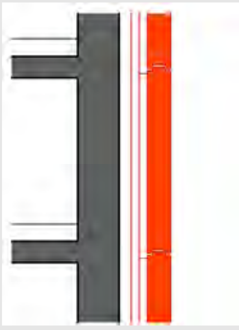
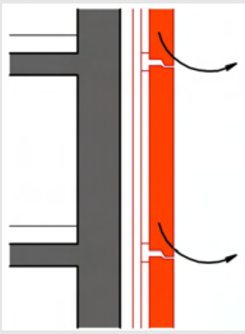

## 8.1 Module-chain and fixing

The design of the module-chain influences first assembly, fixing and joining techniques, but has further implications for maintenance and repair. Interactions are shown in Table 8-1.

The design of the joint formation is decisive for further work planning. On one hand the surface of faced has to be waterproof against driving rain and the entire new envelope should constitute an air tight envelope. But on the other hand – if there are damages or the necessity of access to the intermediate space the intermountability should be possible. Additionally tolerances between the single modules should allow an easy assembly and expansion and movements caused by temperature.

Main issue is to raise awareness – every detailed planning decision indicates implications for further operation and repair.

**Table 8-1: Overview joining techniques of (semi-) pre-fabricated modules**

| | | Advantages | Disadvantages | Implications on structural system and joint |
|---|---|---|---|---|
| Fixed module system |  | Simple and quick assembling | No access to intermediate space between old/ new facade | Standing or hanging construction system |
| | | Good sealing and waterproofing (driving rain, air tightness) | Limited intermountability if modules are damaged | Tongue and groove joints or rabbet |
| Single fixed modules |  | Intermountability of single damaged modules | More effort and carefulness during planning and assembling | Open joint formation with cover profiles or rabbet with slide-in technique |
| | | Access to installations and intermediate space | Sealing and waterproofing needs more detailed planning and careful assembling | Only hanging construction system possible |

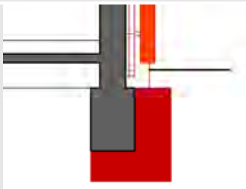
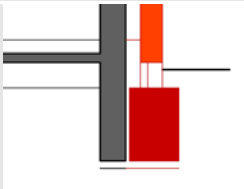
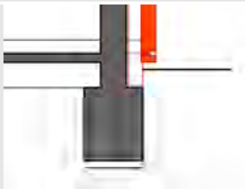
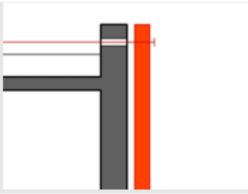
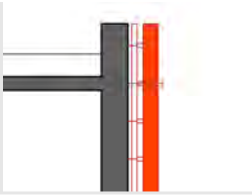
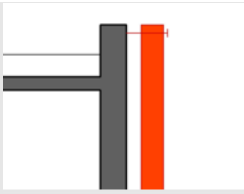
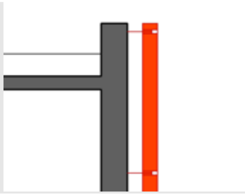
## 8.2 Structural design

There are two different scenarios:

- The existing structure is able to bear the loads of the new façade system
- The existing structure is not able to bear the load of the new façade system

If the load bearing capacity is too little either a load distributing substructure is possible or the new façade has to be implemented as self-standing construction. Very often the foundation – invisible from outside – is forgotten. To avoid future settings an examination of the bearing capacity of the existing foundation shows which further loads can be carried. If capacities are too little either a reinforcement of the existing foundation helps or a new foundation is necessary.

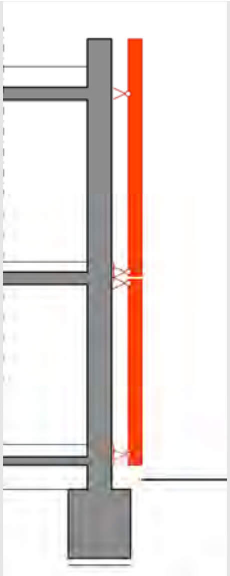
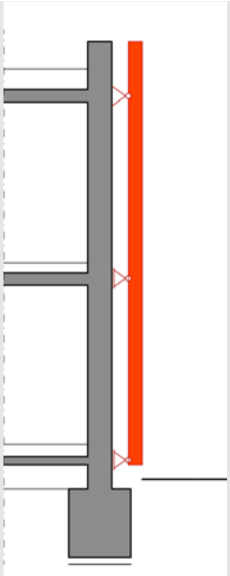
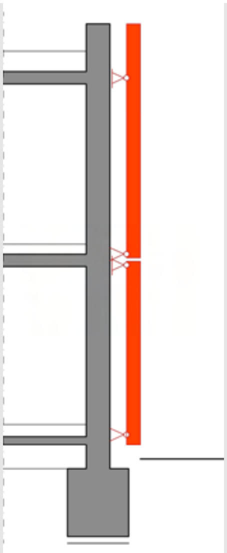
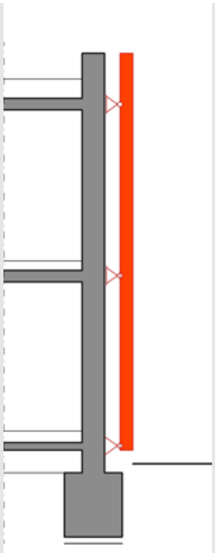
**Table 8-2: General overview on structural design of the new facade system**

| | Suspended construction | | Standing construction | |
|---|---|---|---|---|
| **Foundation** | Load transmission via existing construction → existing foundation is sufficient | Load transmission via existing construction → existing foundation has to be reinforced | New foundation | Load application upon the plinth via existing foundation |
| |  |  |  |  |
| **Substructure** | Load application „suspension" within eaves, attic or roof | Load distributing substructure upon existing subsurface | Area-covering structure element (module acts as plate), additional fixing on the top necessary | Area-covering structure element (module acts as plate), several fixing points all over the facade |
| |  |  |  |  |
| **Dimensioning** | Slimmer module sizes | Slimmer module sizes | Thicker module sizes necessary (Buckling stability) | Lower thickness of modules (shorter buckling length) |

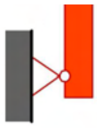
Depending on whether a standing or suspended construction system is chosen, it is either possible to fix the modules directly upon the old façade or to mount a substructure. Depending on the module-size it is possible to implement a single-span beam construction continuous beam construction.
Furthermore the fastening subsurface influences the bearing system - it is either a massive structure, a skeleton or plate type construction.
Massive constructions as subsurface offer the possibility of either of direct fixing or mounting a substructure. A substructure evens out uneven facades in preliminary stages. A faster proceeding of further module assembling is possible. Nevertheless mounting the substructure needs preparation on-site and therefore either scaffolding or mobile cranes are necessary.
Fixing at floor level has the advantage of potential better load bearing properties, because mostly intermediate floors are made as reinforced concrete slabs or there is an existing grid beam. Even if walls have low load bearing capacities (like porous concrete or gas concrete,..)
Skeleton- or plate-type construction systems offer limited possibilities of direct fixing – the raster has to be adapted to the possible subsurface fixing points.
The direct fixing extends the assembling procedure but no preliminary work is necessary.

Modules sizes spanning more than one level are difficult to implemented (transport and lifting). A possible size could be a sanding module spanning the entire height of the façade, but with limited width (about 3 meters). Every system that uses more fixing points with smaller distances in-between reduces bearing loads and improves capacity to resist wind loads. Additionally the buckling length is reduced – the entire construction can be designed slimmer.

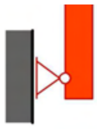
**Table 8-3: Overview on different bearing systems for module systems**

| | **Single-span beam construction** | **Continuous beam construction** |
|---|---|---|
| | Module system is mounted directly on subsurface or upon substructure | Continuous beam acts as substructure |
| **Suspended construction** |  |  |
| | Fixed support on top | Fixed support on top |
| **Standing construction** |  |  |
| | Fixed support at the bottom | Fixed support at the bottom |
| **Evaluation** | Modules have to be self-supporting. | Modules may be designed slimmer. |
| | Additional substructure not mandatory necessary. | Equalization of uneven subsurfaces by substructure. |
| | Without substructure every module has to be adjusted during assembling. | Assembling modules on substructures enables faster proceeding. |
| | Intermountability of each module is possible. | Single modules are exchangeable. |
| **Tolerances** | Tolerances to allow movements emerging from temperature of each module | Tolerances to allow movements emerging from temperature of each module. |

Legend:



Fixed support



Slide bearing

Fixed support on the top, slide bearing at the bottom

Fixed support at the bottom, slide bearing on the top

The challenge within old buildings is the uncertainness of load bearing properties and load capacities as well as uneven subsurfaces or already damaged soils.

There is a broad product range of manufacturers offering fixing and mounting systems.
The main difference is between the usages of dot-shaped or line supported fixings systems. Every dot-shaped fixing applicates loads selectively and concentrated into subsurface – a disadvantage is when there are weak points within the old walls. Line supported fixing system are more flexible due to inhomogeneous soils.

**Picture 8-1: Steel angles as support brackets at the bottom. Example: Dieselweg Graz (Source: AEE INTEC)**

**Picture 8-2: Levelling laths made of a timber substructure. Example: Dieselweg, Graz (Source: AEE INTEC)**

Individual support brackets are suitable support areas for standing construction systems at the bottom. But they can also be used for support of suspended or standing constructions at the top (Picture 8-1).

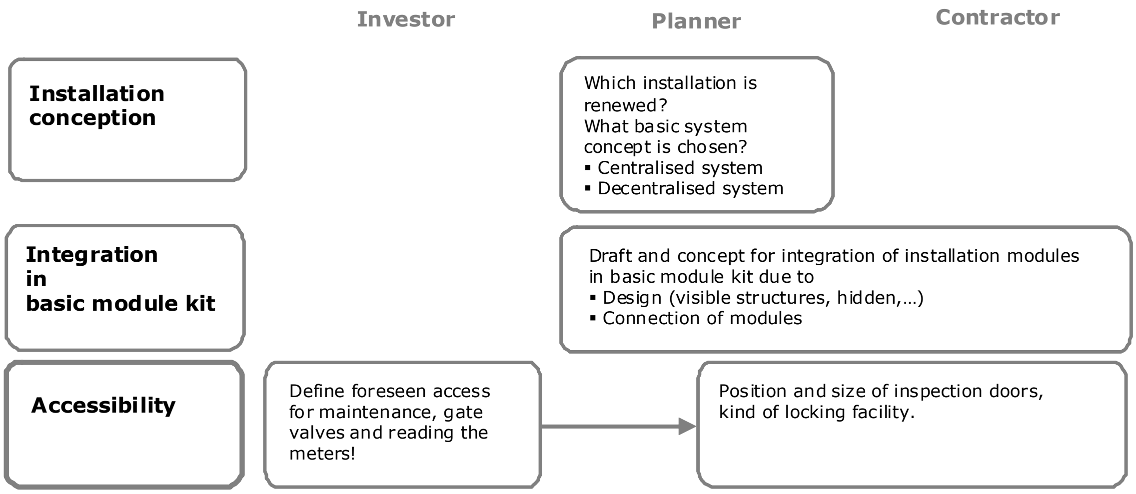
Furthermore every fixing system has to able to absorb movements and stresses caused by temperature-related expansions. The acceptance of these movements can be guaranteed by the arrangement of elongated holes between substructure and module.

Wooden substructures (Picture 8-2):
Referring to the application of timer framework or wood-based boards it makes sense subsequently to use the same material for the substructures. The advantage is an easy workability – the customization on-site is easy, it is light weight compared to steel and different profiles are congenial available. The disadvantage – compared to steel or aluminium substructures is the lower load bearing capacity, a less form-retentive property and the combustibility.
Due to fire-prevention requirements it has to be proved in each case if a planned timber substructure is sufficient.
In order to find adequate anchors or dowels or further fixing possibilities for different applications a lot of product catalogues or guidelines are available. Exemplary the following are mentioned (but there are more of them offering good advice):

www.wuerth.de/de/medien/zul/duebel/uebersicht-duebel.pdf
www.werkzeugforum.de/fileadmin/pdfs/know_how_duebel.pdf

Main issue is to raise awareness – early coordination with static engineer provides a target-oriented planning.

# 9 Service module kit




After a period of 20-25 years existing building services or housing technology can be stated as outdated. The renewal of DHW- or heating-dissipation leads to measures within existing installation shafts or new ones have to be installed. But in any case it is necessary to carry out measures within the apartments.

Due to binding legal regulations about the protection of tenants or condominiums it is often very difficult to implement comprehensive renewal of piping if only one occupant does not agree on planned measures. But the chance to complete renovation of building structure and buildings services should not be forgotten. A comprehensive renovation (thermal envelope and housing technologies) provides the possibility to optimize all systems and to complete renovation all at once.

The upgrading of piping or installation as a single measure at a later date is more expensive than carrying them out together with other works. And it will lead to further disturbance and discomfort for users.

## 9.1 Installation concept

As a result from the investigation of the building stock (see 2.1) the existing supply and position of installation shafts should be known. Following measures can be necessary:

- Renewal or adoption of energy generation for DHW and space heating
- Renewal or adoption of the distribution and/or dissipation system for DHW and space heating
- Renewal or adoption of heat storage for DHW and space heating
- Renewal or adoption of further piping or wiring (water, sewage, electric wiring, SAT, …)

First of all it should come to the decision which installation has to be renewed. Existing installation should be checked:

- On functionality - it is not necessarily demanding to demount fully functional installation.
- On their potential for optimisation –after renovation the entire system should be optimized from generation to distribution and dissipation.

The crucial point is the basic concept on energy generation of DHW and space heating. It is possible – for both – to install centralised or decentralised systems.

**Table 9-1: Overview on different concepts for DHW and space heating**

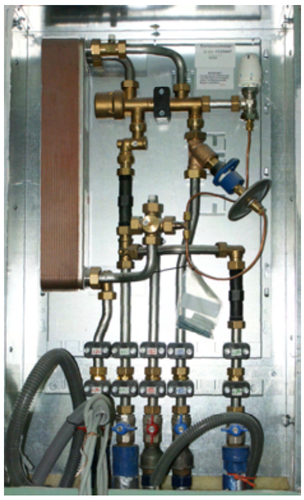
| | Decentralised system | Centralised system |
|---|---|---|
| **Description** | Supply of DHW or space heating is done separately in each unit or apartment. | Supply of DHW or space heating is arranged for all together in a centralised station. |
| **Advantages** | Less piping, independent systems | Centralised system causes less effort on commissioning and maintenance works. Optimisation potential easier to achieve. |
| **Disadvantages** | A lot of units with potential of error rate, more effort for commissioning, maintenance. Optimisation more or less in scope of responsibility of each occupant. | A lot of piping, which has to be installed and causing losses. |
| **Implications** | More attention on support for single units (for service, control and in case of errors) | Control, service and repair are done by skilled personal. |

Main issue is to develop a sufficient and adequate installation concept.

## 9.2 Integration in basic module kit

Shaping a new thermal envelope provides the possibility to integrate pre-fabricated installation modules on the outside of the existing wall but inside the new thermal envelope. Pre-fabricated installation inside the buildings is currently state-of-the-art. Not only shafts, even entire installation blocks or comprehensive sanitary blocks are pre-fabricated, transported on-site and fixed on the planned positions – only some connecting work is necessary. This technology can be adopted for external use.

**Picture 9-1: Installation module inside the building (Source: Ziv.Ing. Büro Boder)**

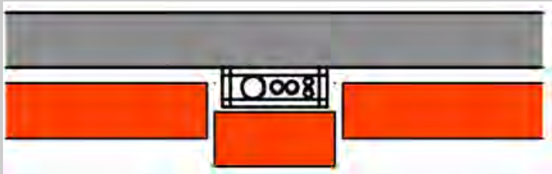


**Picture 9-2: Transfer station installed inside a building (Source: AEE INTEC)**

But so far it has not been implemented during renovation – maybe the problem of arranging water-conducted pipes on the cold outside has not been solved yet. But the advantage of installation on the outside within renovation is that installation works inside the apartments are reduced, occupants are less disturbed and it is possible to renew piping during occupancy. If one tenant refuses works within his flat it is possible to connect all other flats with the new installation system because it is not necessary to lead pipes through this specific unit.

How to overcome the hazard of freeze on the outside? Table 9-2 shows two possibilities.

**Table 9-2: Examples of integration of installation shafts in module system**

| **Installation shaft visible within building shape** | **Installation shaft integrated in plain façade surface** |
|---|---|
|  |  |
| Installation shaft is a covered with the same insulation layer as used for the basic modules. | Installation shaft is covered with high efficient insulation material (vacuum insulation panel) |

Main issue is to integrate the installation ducts technically correct into the design of the new façade.

## 9.3 Accessibility

In case of installation shafts within the building it is very difficult to get access in case of a burst pipe – mostly it remains undiscovered for a long time. Every upgrading is hard to implement and even metering is not always easy to solve. Installation shafts on the outside provide the possibility to arrange inspection doors – with access from a public space. It is no longer necessary to get access to single apartments – it is not necessary to bother tenants for upgrading, repair, maintenance or reading the meter.

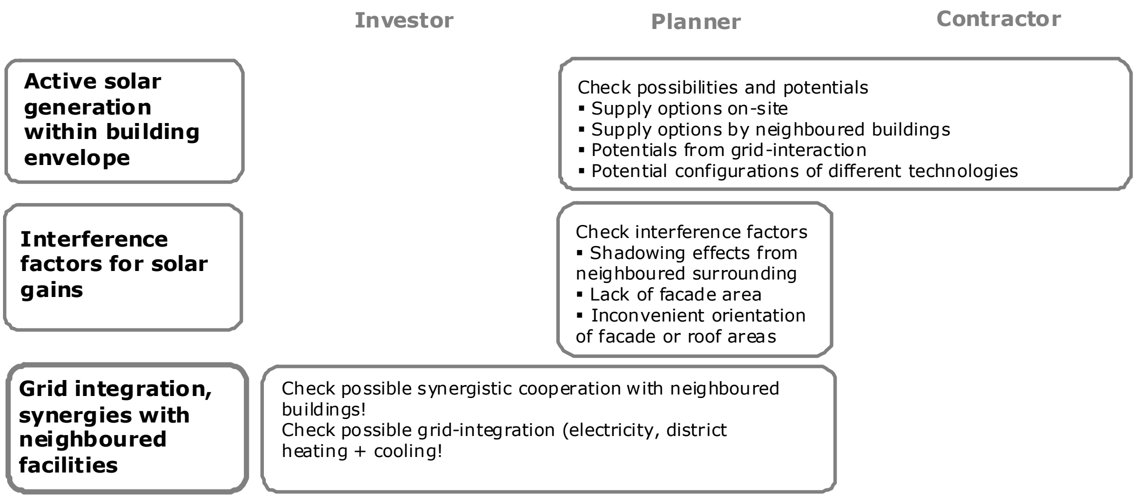
But following aspects due to the position of the inspection doors have to be decided:

- Locking facility – who is allowed to access? This an important issue if there are stop- or turn cocks for main supply lines or apartment supply lines, gate valves or meters for reading related to each apartment.
- Position and size of inspection door – preferable it is reachable without ladder.

Main issue is to raise awareness for further facility management necessities.

-

# 10 Active module kit




Future buildings will mutate from energy consumers to decentralised energy suppliers. Therefore it is necessary to produce energy on-site.

Different renewable energy sources are possible:

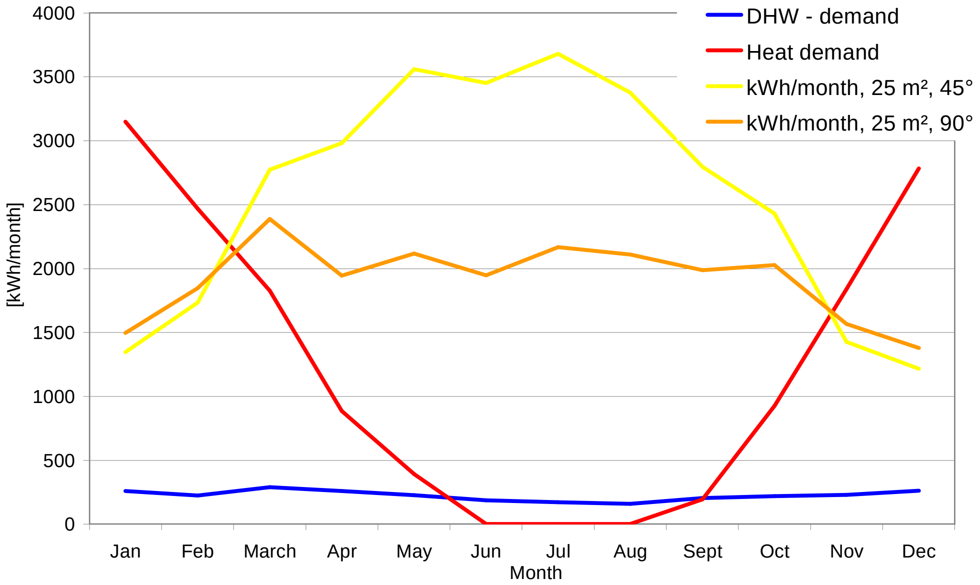
- Photovoltaic (PV)
- Solar thermal plants (ST)
- Wind mills or turbines
- Biomass – thermal heating system or CHP
-

Referring to the mentioned possibilities it is only a photovoltaic or solar thermal plant, which is integrable within façade areas. Wind mills or turbines are hardly system-integrable. Therefore this facility is not treated in this context.

## 10.1 Active energy generation within building envelope

Until now the main objective of a façade was the protection against weather or outdoor conditions and the maintenance of indoor climate conditions as well as the visual appearance of a building. Active energy generation within the facade enlarges this task area.
Due to the complexity architect and energy-engineer must co-operate in a very early planning stage. A lot of relevant preliminary decisions of the architect during the design phase have significant influence on the further operation of the active systems. Orientation, incline, position and size are given by the shape of the thermal envelope.

The irradiations at the façade or on the roof are composed by direct radiation from the sun, reflection from the surroundings and diffuse irradiation. Generally the irradiation on façade areas (90° areas) is about 30% less than on 45° areas (pitched roofs). Every façade oriented south shows a very steady radiation profile and the total radiation over the year shows a maximum solar yield. A deviation of collector area to south-west or south-east diminishes the annual yield of about 3 % compared to straight south-orientation. Bigger variances up to straight east or straight west-orientation lead to losses about 16% of the annual solar yield. [13]
In many regions in middle Europe like Austria, Switzerland or the south of Germany it is common to have a lot of snow during a long time of the year. Snow effectuates that the share of reflected irradiation is increasing. This percentage is even the bigger the higher incline from the horizontal area. During winter season the irradiation on a vertically oriented area (90° - façade) is higher than on 45° pitched areas (roof) – in case of snow.




**Picture 10-1: Seasonal course of the diurnal average irradiation upon south-oriented areas in case of 45° incline (roof-integration) or 90° incline(facade-integration) compared with the user profile for DHW generation and heating. (Source: Colourface, AEE INTEC [13])**

Basically solar thermal plants with vertically oriented collectors need more collector area, to gain the same solar coverage rate as plants with 45° incline. But due to more balanced radiation profile over the year – to meet permanent consistent user profiles for PV and solar combi systems it can be stated that the additionally necessary area is smaller – compared to pure DHW-solar thermal plants.

Note!
What are suitable and available areas within the existing building shell - are extensions or additions of the existing building possible?

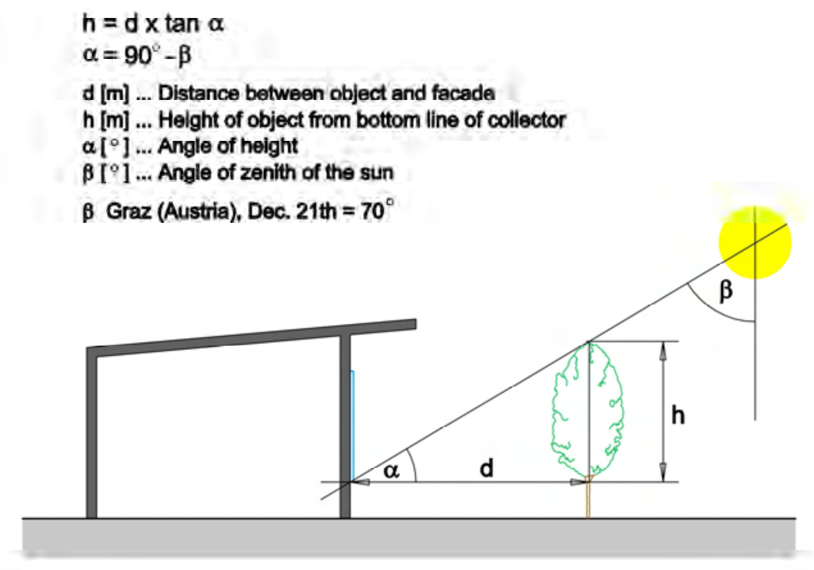
➡ Main issue is to optimise module integrated collector area.

## 10.2 Interference factors for solar gains

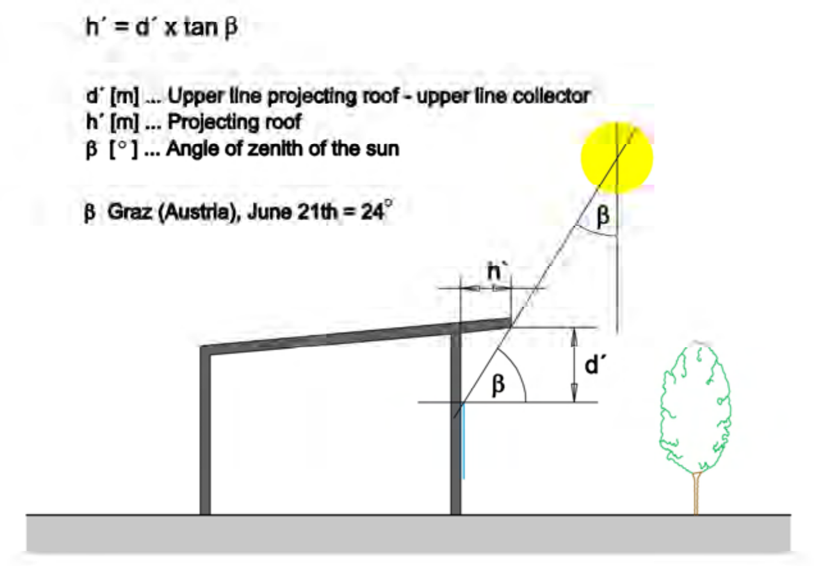
Every shadowed collector can not transfer sunlight into thermal energy, beyond that – he acts as cooler: if one part of the collector area is irradiated and therefore the heat transfer medium is heated, the thermal energy is given off within the shadowed part. Optimized gains are only possible if the entire area is free of shade.

Shadowing may arise from:
- Projecting roofs
- Neighboured buildings or facilities
- Trees or plantings

Especially in urban areas, which are mostly densely developed, it is a challenge to find enough area which is not shaded. Often it is easier to find unshadowed area on roofs, but due to larger buildings or larger demands the roof area is mostly too small. Within façade areas there is the interference from surrounding buildings, trees, plants or from projecting roofs, but more often residential buildings want to have a view and openings south-oriented. Additionally existing buildings have a more or less unalterable position, orientation and envelope. The scope to make alterations is very small.




**Picture 10-2: Shadow casted by a tree upon a south-oriented façade (Source: Colourface)**




**Picture 10-3: Shadow casted by a projecting roof upon a south-oriented façade (Source: Colourface)**

Picture 10-2 shows necessary distances and possible heights of plants or objects positioned in front of the existing façade. It is essential that even at the lowest altitude of sun in December the bottom of the collector is not shaded. Picture 10-3 depicts the possible overhang of projecting roofs considering the fact that even at time of the highest altitude of sun in June no shadow is falling upon the upper side of the collector.

As mentioned above it might be difficult to find enough suitable area for active energy generation on the buildings envelope. But maybe it is possible to find facilities on-site (carport, roofing of bicycle park,..) or synergies with neighbours. Just in urban areas a lot buildings do not have the necessity of a view and may provide large areas for active energy generation (shopping malls, supermarkets, parking decks, cinemas, function rooms,..)

Main issue is to optimise solar yield of building envelope.

## 10.3 Grid integration and synergies with neighbours

Any produced energy that is thermal energy or electricity needs customers or has to be stored for future usage. Following possibilities can be stated:

- Own consumption at the time of production
- Storage on-site (within the system- boundary of the building)
- Feeding into grids (heating grids, electricity grid)
-

At the time long-time storage is restricted due to current storage technologies restricted and not possible at an economic scale. It needs a large space (buffer storage tanks of multi-family houses need more than 5 $m^3$). Further the possibilities for storing electricity in battery packs are not possible at an economic scale as well. Some innovative pilot projects are on the way, ideas of using car batteries of electric cars are emerging – but until first successful implementation there is further need for research. Until the economic concepts are available it is necessary to integrate buildings into grids – the grids act as permanent customers – so that it is possible to uncouple energy generation and consuming.
The integration into electric power grids is not a technological challenge (from the user's point of view). But concerning the supplier side (grid-operators) there will come up challenges in future to handle permanent mismatches emerging from decentralised production of energy from renewable energy sources. Peak loads on diurnal or seasonal scale have to be co-ordinated somehow in order to guarantee supply at any time.
Peak loads emerge from identical user profiles, where the times of need are cumulated (morning/ evening or heating in winter). On the other hand the grid is "overloaded" by supply from PV during summer.

While feeding into electric grids is a not a demanding technology the integration of decentralised production into thermal (heating) grids is in its beginnings. The technology is available – but the complexity is even higher. Supply and return run temperatures as well as the hydraulic concept have to be considered. More and more innovative projects have been installed in the last years, where decentralised solar thermal plants are integrated into heating grids or shared within smaller districts and combined with biomass cogeneration stations. Some examples like the solar supply of the district heating of the city of Graz (Styria) or several solar supplied residential areas can be found under:
http://www.solid.at/index.php?option=com_content&task=view&id=89&Itemid=129&lang=en
-
A possible future solution is to consider user profiles at a very early stage. Finding synergies within the neighboured facilities – especially with demand which is different from the own consumption may lead to intelligent micro-grids. For example the user profiles from residential buildings are different from office and administrative buildings or retirement or nursing homes (DHW, heating, cooling).

! Note
Integration of active energy generation within buildings enables contributions to decentralised supply. Payback times of investments can be reduced significantly. But different supply options have to be checked – the better the supply on-site meets the user profile and enables feeding into a grid (unless heating or electric) the more advantages are gained.

Further concepts of active building envelopes will have implications on our energy supply system, tariff policy and security of supply.

Main issue is to enlarge the scope to surrounding facilities and prepare energy-efficient settlements.

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