



Live comfortably – Save natural resources.

Built for the future:

The ISOVER Multi-Comfort House.



# Our comfort must be Nature's comfort.



**Dear house owners, planners and architects,** "My home is my castle" will be topped in the future by "My home is my ISOVER Multi-Comfort House". For this reason, we have created this brochure. Needless to say that you will find here all those many arguments which speak in favour of building according to the passive house standard: ecological, economical and quite comfortable reasons. For the ISOVER Multi-Comfort House compromises on nothing, least of all energy waste.

But our brochure offers much more than just arguments. It can be a source of information and help you with the planning and realization of any kind of building project. And should you need further support: we will be glad to help you – any time.

Good luck and have a good life!  
Your Saint-Gobain ISOVER Team

## The Kyoto Protocol is a climate protection initiative. The Passive House is active climate protection.

Everybody talks about increasingly extreme weather events, but only some take action. With their signature under the Kyoto Protocol, a Climate Protection Agreement, more than 140 industrial nations committed themselves to drastically reduce their CO<sub>2</sub> emissions. This means: highest priority for economizing on our natural resources and for using energy-saving technologies on a worldwide scale. Against this background it seems obvious that each and every one of us should contribute to more economical house-keeping – for example by building and living while making most efficient use of energy.

## Make your decision for the ISOVER Multi-Comfort House – Combine comfort & environmental protection under one roof.

Live comfortably. Make no sacrifices. But go easy on the environment all the same. A fantastic vision? Much more than that. The ISOVER Multi-Comfort House can make this vision come true. No matter what you have in mind: the passive house standard allows you to realize all your building dreams. Quite simple. Economical. Energy-efficient ... **and it pays off – cash!**

## State-of-the-art knowledge for an excellent energy balance.

It is the details in the ISOVER Multi-Comfort House that play such an important role. Because quality is the most essential precondition for an excellent energy balance. That's why we have created this brochure. It contains all you would and should like to know as a house owner, planner or architect. Clearly arranged in five chapters.

*Pettenbach, Upper Austria: Refurbishment of an old building acc. to passive house standard. G. Lang Consulting.*



*The planning CD with construction examples.*

## List of Contents

|  |                |
|--|----------------|
| <b>The Concept</b>   | <b>4-13</b>    |
| For a good life. For every one. For ever.<br>Snugly warm with 10 tea lights.<br>Well planned. Well insulated.<br>Well saved.   |                |
| <b>The Planning</b>  | <b>15-27</b>   |
| A heating energy demand of 15 kWh/m <sup>2</sup> a.<br>Always a holistic concept.<br>The planning steps: from idea to realization.<br>Energy efficiency is calculable – The Passive House Planning Package (PHPP)  |                |
| <b>The Realization</b>   | <b>29-97</b>   |
| A gain for every building style.<br>Airtightness from top to bottom: the building envelope.<br>Mistakes are avoidable.<br>The avoidance of thermal bridges is plannable.<br>Moisture protection and airtightness with ISOVER-VARIO.<br>Optimum all-round thermal insulation.<br>The windows: triple glazing does a better job – Saint-Gobain Glass.<br>Making good use of the sun: solar power.<br>Good air, pleasant warmth: the Comfort Ventilation System.<br>Realization of balconies and conservatories |                |
| <b>The Possibilities</b>   | <b>99-117</b>  |
| Model examples can be found anywhere.<br>New buildings for private or commercial use.<br>Old house with modern comfort.<br>A passive house that sets a precedent.  |                |
| <b>The Ecological Import</b>   | <b>119-129</b> |
| Isover – From nature, for nature<br>Rigips – Flexible and sustainable construction<br>Weber – Mineral-based thermal insulation composite systems   |                |
| <b>The Service</b>   | <b>131-135</b> |
| Addresses and contacts<br>Selected literature  |                |

# For a good life. For every one. For ever.

## Simply move in and feel at home.

Life in an ISOVER Multi-Comfort House does not need time for settling in. For the simple reason that you won't miss anything. Except maybe a couple of annoyances. But honestly: who will seriously long for cold feet, draughty corners and musty or overheated rooms? In the passive house, however, everyone can enjoy their own patch of paradise.

### No freezing and no sweating.

You will enjoy agreeable room temperatures between 20 and 23 °C – all year round. Scientifically this has been proven to be the ideal temperature range for relaxed living and

efficient working. And most of the year without any heating at all.

### Draw a deep breath – day and night.

Even allergy sufferers never run out of good air in an ISOVER Multi-Comfort House. Thanks to the Comfort Ventilation System which is part of a passive house's basic equipment. It works similar to the human lung. A permanent flow of filtered fresh air constantly ensures best air quality, free of dust, pollen and aerosols, while at the same time removing stale air. And in the same breath, heat distribution and heat recovery take place in the entire house.

## Build with all comfort.

### And gain energy at the same time.

The most inexpensive energy is the one that is not consumed in the first place. It does not need to be generated, imported, or paid for. Naturally, this also doesn't have any harmful effects, neither on human beings nor the environment. This is the basic concept of the passive house. Since a sufficient amount of warmth remains in the house, any active heat supplied by traditional

space heating is usually superfluous. This saves energy and costs. The more so in view of further increasing world market prices for limited resources such as oil and gas. Thanks to its uncomplicated technical equipment, the ISOVER Multi-Comfort House requires very little maintenance.

### Built-in safety to ensure long life.

Last but not least, this also applies to the building fabric. Thanks to its ideal humidity, the good air in the ISOVER Multi-Comfort House prevents the formation of mould and thus structural damage into the distant future. And this ensures the building's high resale value – just in case.

## The passive house standard gives you all the freedom you want.

A passive house does not define itself by outer appearance but by its inner values. Therefore any type and size of building can be realized. Every year, a growing number of examples testify to that. Whether one-family house or industrial estate. Whether school or church or

mountain shelter. And it is no longer only the new buildings which comply with this future-oriented building standard. There is an increasing number of existing, old and even historical buildings where the refurbishment is based on passive

house principles. By using well-selected passive house components it is possible to achieve ecologically and economically sensible results.



Office and residential building in Mosnang. Insulated with Flora natural hemp by ISOVER. Architect: Monika Mutti-Schaltegger.



# Snugly warm with 10 tea lights.

Count on energy savings of up to 75 %.



College of Physical Education Albstadt, Architect Prof. Schempp, Tübingen, Germany

Compared to conventionally built new houses, the space heating requirement of a passive house is lower by about 75 %. And in contrast to old buildings, savings amount to as much as 90 %. In cold winters, a room of 20 m<sup>2</sup> can be heated with just 10 tea lights or two bulbs of 100 watts each to keep it snugly warm. In terms of fuel consumption, a passive house needs less than 1.5 l heating oil or 1.5 m<sup>3</sup> natural gas per square meter and year.

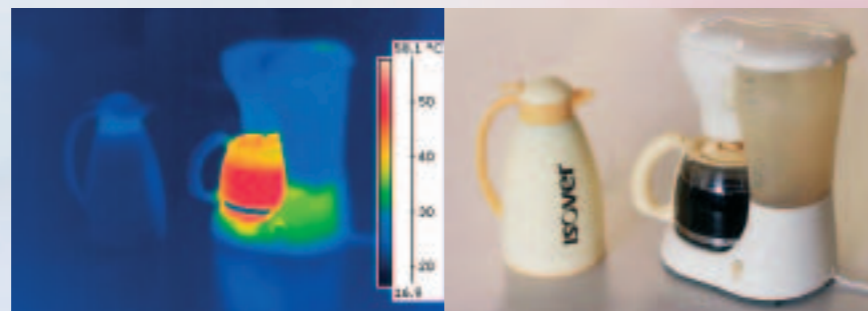


WeberHaus, Rheinau-Linx

## The motto for all rooms: Keep the warmth inside!

Based on the thermos flask principle, the ISOVER Multi-Comfort House retains its comfortable temperature. As in the thermos flask, the interior is well protected against loss of heat. Active heat from outside is supplied in a controlled way. The passive house really lives up to its name by making extensive use of "passive" components. These include heat-insulating windows,

heat distribution systems in the heated space and, above all, efficient thermal insulation to ensure that the warmth is kept inside.



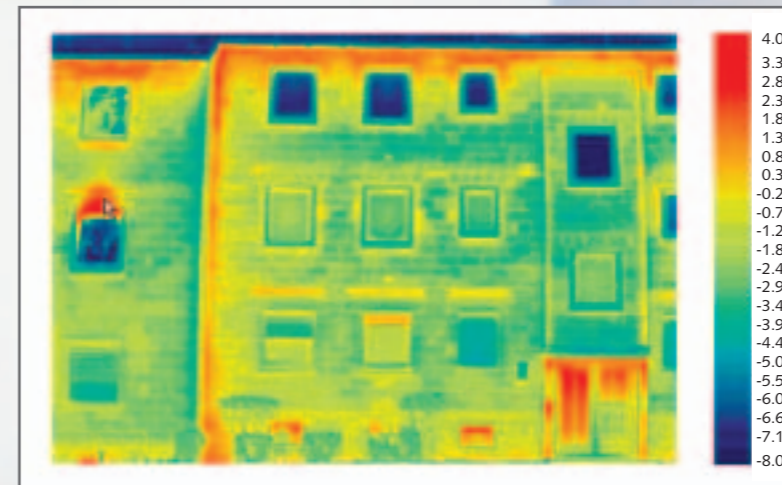
Modern comfort: keeping warm without consuming energy.

## Every occupant is a heat source.

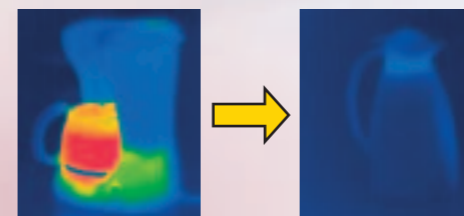
Unlike conventional buildings that suffer high losses of heat to the outside, the thermal discharge of humans, animals and household appliances is quite important for covering the required amount of heating energy. Every person con-

tributes by a calorific value of approx. 80 watts to heating up the interior. Considerable heat gains are realized through the windows which in winter allow higher amounts of sun energy to enter the house than those lost to the out-

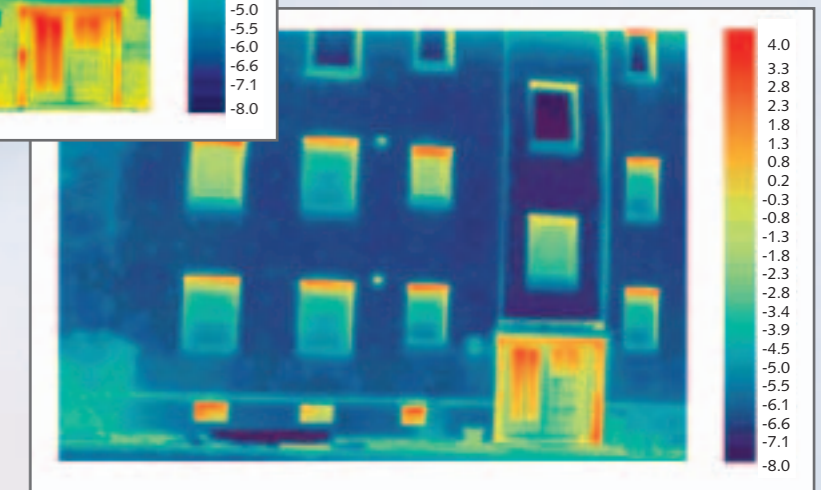
side. Add to this the heating energy recovered from the exit air and you can normally save yourself the expense incurred by a conventional heating system.



Thermographic picture – before refurbishment: The entire house is a thermal bridge.



From active to passive!



Thermographic picture – after refurbishment: The external wall is thermally insulated, but heat still leaks through windows and doors.



Multi-family house after energetic refurbishment

## Everything well-insulated and airtight.

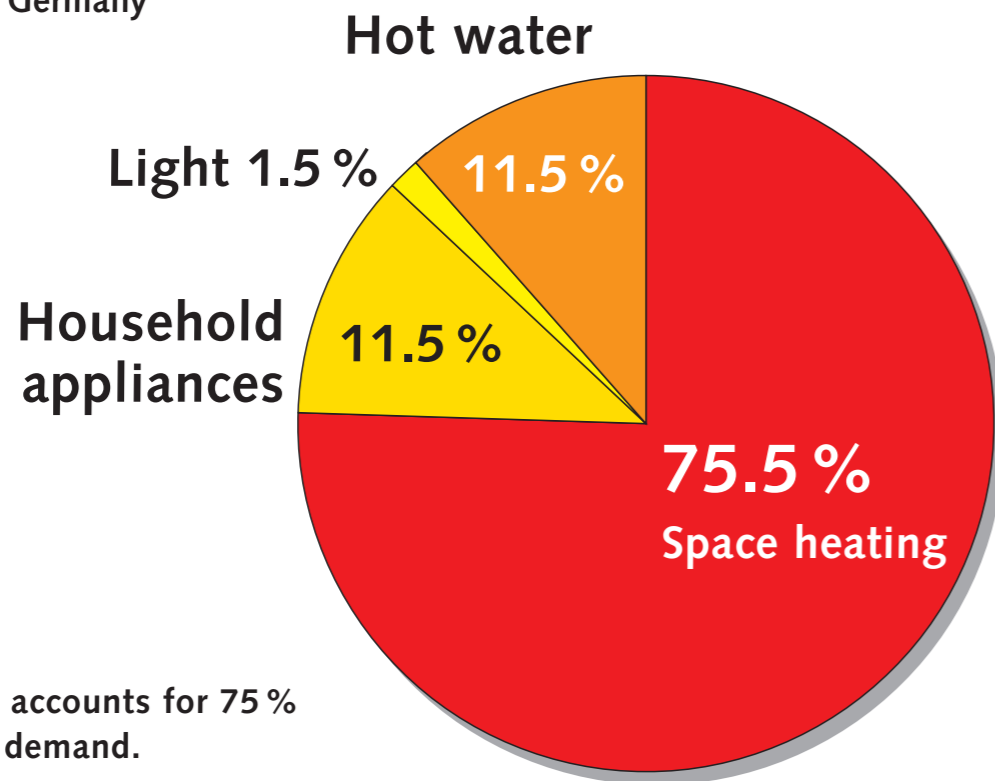
From the roof down to the foundation slab: a jointlessly sealed and airtight building envelope ensures thermal and acoustic insulation. And the ventilation system – complete with heat recovery – takes care of fresh air supply and heat distribution.

# Always ahead – simply unrivalled.

Indicators: A car's fuel consumption is a house's U-value.

The energy coefficient or U-value of the ISOVER Multi-Comfort House is the best indicator of its economy. Houses with ideal southern exposure can even remain under the maximum annual heating demand of 15 kWh per square meter and year. This value makes other newly built houses look like veritable energy wasters.

Final energy consumption\* of private households in Germany



Space heating accounts for 75 % of our energy demand.

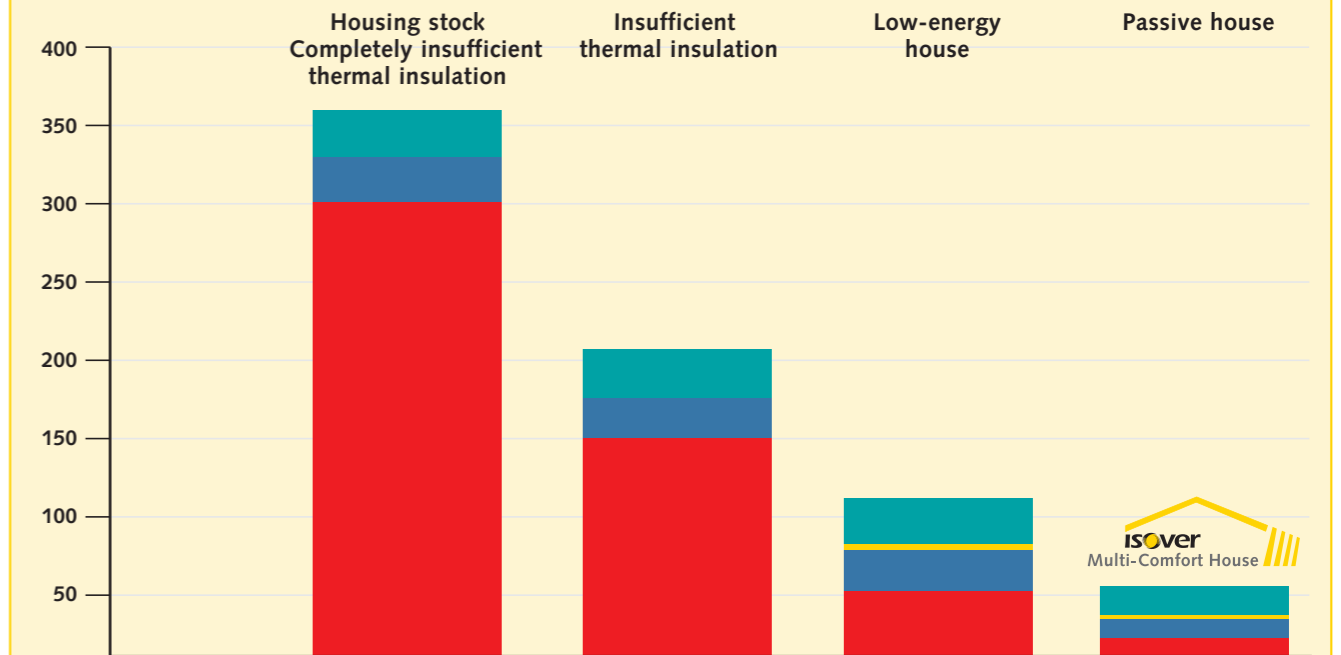
Building and living is regarded to be that sector of life which is most harmful to our climate. For instance, an approximate 3000 kg oil equivalents per capita still vanish into thin air every year for providing hot water and space heating (example: Western Europe). However, 90 % of this energy can be saved today. Without high investment cost. Even state-sponsored in many cases. Always comfortable in the ISOVER Multi-Comfort House.

\* Electricity, gas, oil, petrol etc. Source: VDEW, issued in 2002

## Energy demand in kWh per m<sup>2</sup> useful living space and year

Household electricity  
Ventilator electricity  
Hot water  
Space heating

Final energy demand



| Heating energy demand of a typical one-family house                                     | kWh/m <sup>2</sup> a<br>300-250  | kWh/m <sup>2</sup> a<br>150-100  | kWh/m <sup>2</sup> a<br>50-40   | kWh/m <sup>2</sup> a<br>≤ 15   |
|---|--|--|---|--|
| <b>BUILDING STANDARD</b>  | <b>Completely insufficient thermal insulation</b><br>Structurally questionable, cost of heating no longer economical (typical of rural buildings, non-modernized old buildings). | <b>Insufficient thermal insulation</b><br>Thermal renovation is clearly worth the trouble (typical of residential houses built in the 50s to 70s of the last century). | <b>Low-energy houses</b>  | <b>Very low energy houses</b><br>(passive houses need to meet this parameter as part of the requirement profile) |
| <b>BUILDING ELEMENT</b>   | <b>Typical U-values and insulation thicknesses</b>   |  |   |  |
| <b>External walls</b><br>(massive wall of 25 cm)<br>Insulation thickness                | 1.30 W/(m <sup>2</sup> K)<br>0 cm  | 0.40 W/(m <sup>2</sup> K)<br>6 cm  | 0.20 W/(m <sup>2</sup> K)<br>16 cm                                      | 0.13 W/(m <sup>2</sup> K)<br>approx. 30 cm   |
| <b>Roof</b><br>Insulation thickness   | 0.90 W/(m <sup>2</sup> K)<br>4 cm  | 0.22 W/(m <sup>2</sup> K)<br>22 cm   | 0.15 W/(m <sup>2</sup> K)<br>30 cm                                      | 0.10 W/(m <sup>2</sup> K)<br>40 cm   |
| <b>Floors to ground</b><br>Insulation thickness   | 1.0 W/(m <sup>2</sup> K)<br>0 cm   | 0.40 W/(m <sup>2</sup> K)<br>6 cm  | 0.25 W/(m <sup>2</sup> K)<br>10 cm                                      | 0.15 W/(m <sup>2</sup> K)<br>26 cm   |
| <b>Windows</b>  | 5.10 W/(m <sup>2</sup> K)<br>Single glazing  | 2.80 W/(m <sup>2</sup> K)<br>Double glazing, insulation glass (air-filled)   | 1.10 W/(m <sup>2</sup> K)<br>Double glazing, thermal insulation glazing | 0.80 W/(m <sup>2</sup> K)<br>Triple glazing, thermal insulation glass, special frame                             |
| <b>Ventilation</b>  | Leaky joints   | Open the windows   | Exhaust air unit  | Comfort ventilation with heat recovery   |
| <b>CO<sub>2</sub> emission</b>  | 60 kg/m <sup>2</sup> a   | 30 kg/m <sup>2</sup> a   | 10 kg/m <sup>2</sup> a  | 2 kg/m <sup>2</sup> a  |
| <b>Energy consumption in liters heating oil per m<sup>2</sup> living space and year</b> | 30-25 liters   | 15-10 liters   | 4-5 liters  | 1.5 liters   |

# Live comfortably – and make high savings.

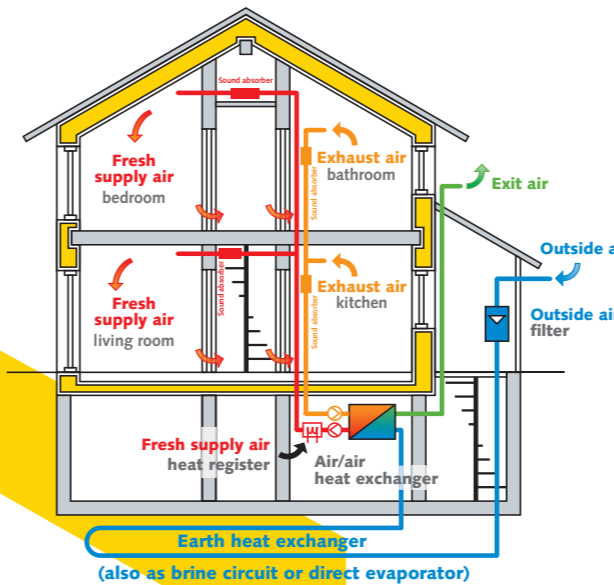
**Air temperature 20-23 °C, relative air humidity 30-50 %.**

In order to enjoy such agreeable living conditions, you have to dig deep into your pockets with conventionally built houses. Not with the ISOVER Multi-Comfort House where highest living comfort in all rooms helps you save a lot of cash. Even if the construction of such a house may incur extra cost, the total financial burden will be significantly lower compared to a conventionally built new house – thanks to extremely low energy costs over its useful life.

U-value 0.1 W/m²K



Airtightness



**Heating energy demand:  
< 15 kWh/m²a**

|   |                  |   |
|---|------------------|---|
| Max. 10   | W/m²             | Heating load calculated according to the Passive House Planning Package |
| <b>Max. 15</b>  | <b>kWh/(m²a)</b> | <b>Specific heating energy demand</b>                                   |
| 40-60   | kWh/(m²a)        | Specific total <sup>1</sup> final energy demand                         |
| 100-120   | kWh/(m²a)        | Specific total <sup>1</sup> primary energy demand                       |
| Reference area (m²) is the heated useful living space.  |                  |   |
| <sup>1</sup> total = including all of the household's energy consumers (heating, hot water, ventilation, pumps, lighting, cooking and household appliances) |                  |   |



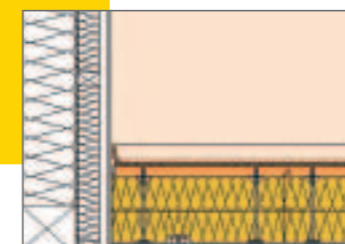
U-value 0.1 W/m²K



Largely reduced thermal bridges



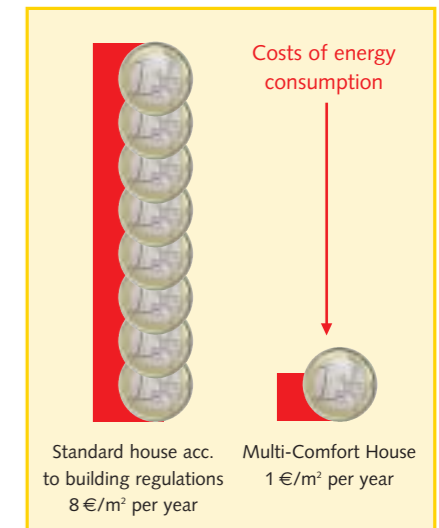
U-value 0.7 W/m²K



U-value 0.12 W/m²K

**Improvement by 8:1 compared to building regulations. That's life in an ISOVER Multi-Comfort House.**

Compared to the passive house standard, not only conventionally built new houses but even more progressive types such as the low-energy house are comparatively expensive. Whenever possible, choose the passive house standard right from the start. After all, how often do you build a house? Just once in a lifetime.



**Planning with maximum precision and responsibility.**

Optimum house location, correct positioning of windows and doors, proper dimensioning of the ventilation system, very high insulation standard, tight building envelope – all these factors are considered before building an ISOVER Multi-Comfort House. Special attention must be paid to avoiding thermal bridges. Thermal bridges and leaks have serious consequences for every type of building. Technically as well as energetically.

**Cosiness.**

When living in a passive house, the enclosing areas such as walls, floors and windows have very pleasant inner surface temperatures, even at very low outdoor temperatures. External walls as well as floors above the cellar are only by 0.5 to 1 degree cooler than the room air temperature. Passive house windows are by 2 to 3 degrees cooler than the room air temperature. In houses that do not comply with the energy standard of a passive house, such a high degree of cosiness can only be reached with considerably higher heating costs.

# A lifetime investment which pays off daily.

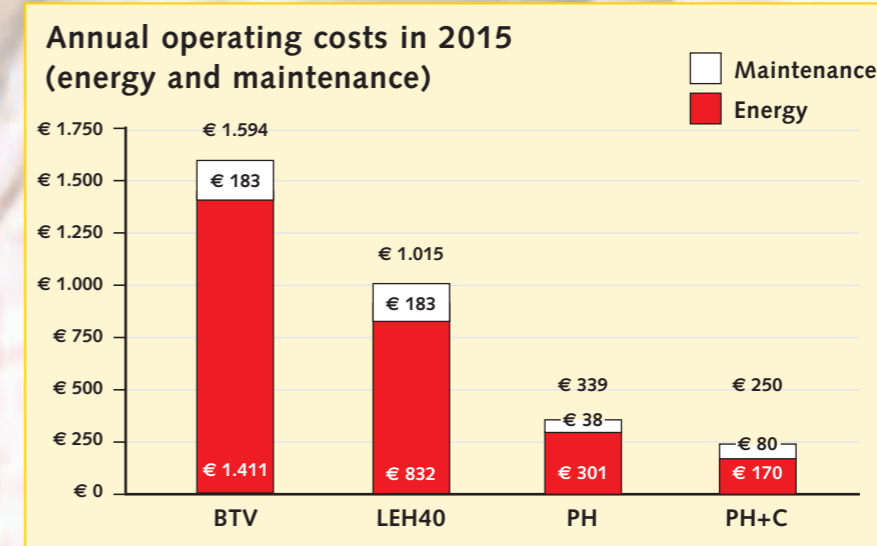
## Profitable also under financial aspects. An example of subsidized housing in Lower Austria.

True, if you want to enjoy the benefits of a Multi-Comfort House, you'll first have to dig a bit deeper into your pockets. Due to the high quality of the single components, construction costs are currently around 5-8 % higher than for standard houses. But there are signs that the cost difference will gradually diminish in the course of realization. Some passive houses have already been built at prices typical of conventional housing. The reason? Well, increasing demand, of course. The higher the number of passive houses built, the cheaper the production of high-quality building components and

the lower the total price of the building. A look at total profitability will finally convince you. As soon as you include the current expenses for operation, maintenance and repair, the ISOVER Multi-Comfort House shows itself at its best. Thanks to the minimum annual demand for heating and water of currently 100 to 160 EUR, the extra costs pay off after only a few years. One example for illustration: In a standard house built according to the latest Austrian Building Regulations, energy costs account for 4.23 % of the monthly total burden – compared to a mere 0.35 % in a passive house. Should

energy prices continue to rise or even double over the next few years, their share of total costs will inevitably rise to 8 % and more in conventionally built homes – making cost savings for passive house owners grow even further. If you also consider that household net incomes in Europe decrease by an average 1-2 % p.a., the passive house is the low-cost alternative of the future.

## Cost benefits in 2015



Source: E. M. Jordan, "Wirtschaftlichkeit des Passivhauses – Architektur zum Wohlfühlen als Preisschlagler unter besonderer Berücksichtigung der Bedingungen in Niederösterreich." (Profitability of the passive house – "Feel-good" architecture at bargain prices under special consideration of the conditions in Lower Austria)

With a current price increase of 6 % per year, heating costs will have doubled in ten years!

- BTV** A house complying with the NÖ Bauordnung (Lower Austrian building regulations) resp. the NÖ Bautechnikverordnung (Lower Austrian building code).
- NEH40** A house achieving an annual heating demand of requirements of 40 kWh/m<sup>2</sup>a (according to EN 832).
- PH** A passive house – this example house was actually built!
- PH-K** A passive house with a solar collector for domestic hot water preparation.

## Cost benefits today

| Energy costs                     | Standard | LEH  | PH   | PH+C |
|----------------------------------|----------|------|------|------|
| per year in EUR                  | 788      | 465  | 169  | 95   |
|                                  | 100 %    | 59 % | 21 % | 12 % |
| Operating costs sum total in EUR | 934      | 611  | 199  | 159  |
|                                  | 100 %    | 65 % | 21 % | 17 % |

Source: E. M. Jordan, "Über die Wirtschaftlichkeit von Niedrigenergie- und Passivhäusern unter besonderer Berücksichtigung der Bedingungen in Niederösterreich." (About the profitability of low-energy and passive houses with special consideration of the conditions in Lower Austria)

Standard: house acc. to the Building Regulations of 1985  
 LEH: low-energy house  
 PH: passive house  
 PH+C: passive house with collector

## Go easy on energy – get high subsidies.

The higher construction costs incurred by passive houses are offset right from the start if you can benefit from state subsidies. Building a Multi-Comfort House entitles you to maximum financial support, thus making it a profitable project for all parties involved. And rightly so! If people actively sup-

port better building quality, this does not merely reflect an idealistic concern for our environment, but a turn towards sustainable profitability – both for the individual and society as a whole.

- Point by point:**  
**The ISOVER Multi-Comfort House can score many points in a cost/benefit analysis:**
- Energy-saving construction pays off from the very first day
  - Safe investment into the future
  - Added value every year through decreasing operation costs
  - Comfortable living in all seasons
  - Longer useful life thanks to highest quality standard
  - Valuable contribution to sustainable climate protection

# The Planning.

**Circumspect & meticulous.**



- A heating energy demand of 15 kWh/m<sup>2</sup>a.
- Always based on a holistic concept.
- The planning steps: from idea to realization.

# A heating energy demand of 15 kWh/m<sup>2</sup>a: that's the benchmark.

Where a heating energy demand of 15 kWh per square meter and year is achieved, economy, building physics and design are in perfect harmony.

Judging from its outer appearance alone, an ISOVER Multi-Comfort House may resemble conventional design patterns. But when it comes to interior design, meticulous planning is indispensable. This is more demanding and more cost-intensive – at least at the start. Eventually, however, the new concept will facilitate realization and help achieve the decisive energy balance: low heat losses on the one, solar and internal heat gains on the other hand. The occupants benefit from low heating costs while enjoying high living comfort and the long-term appreciation of their homes.

### These are the values you can expect from your ISOVER Multi-Comfort House:

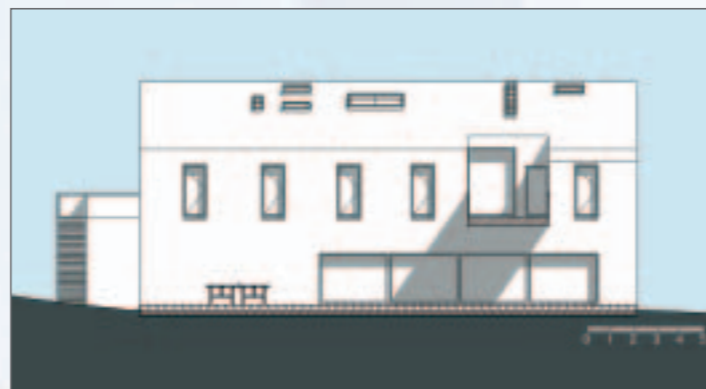
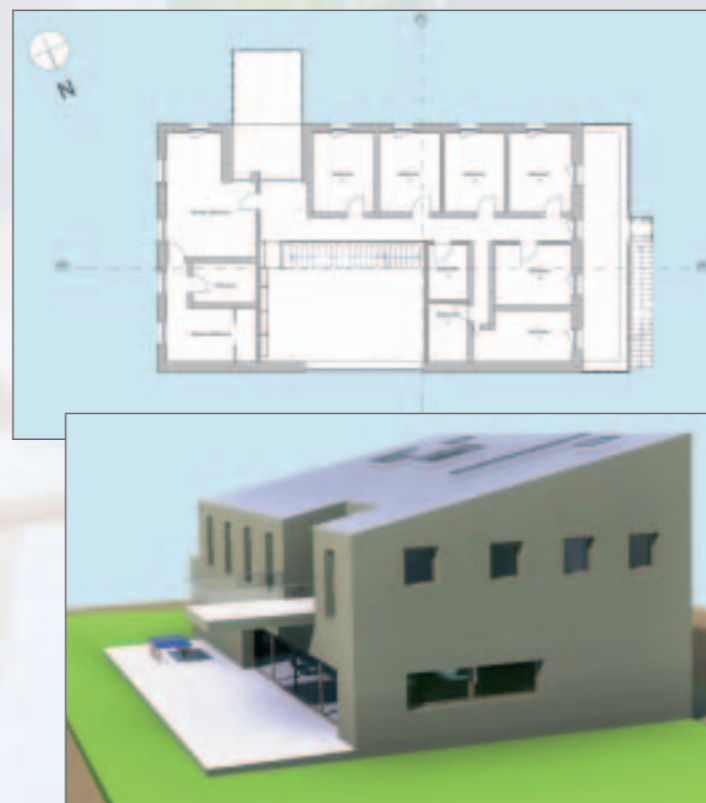
|                                     |  |
|-------------------------------------|--|
| Max. 10 W/m <sup>2</sup>            | Heating load calculated according to the Passive House Planning Package (PHPP) |
| <b>Max. 15 kWh/(m<sup>2</sup>a)</b> | <b>Specific heating energy demand acc. to the PHPP</b>                         |
| 40-60 kWh/(m <sup>2</sup> a)        | Specific total* final energy demand  |
| 100-120 kWh/(m <sup>2</sup> a)      | Specific total* primary energy demand  |

Reference area (m<sup>2</sup>) is the heated useful living space.

\* total = including all of the household's energy consumers (heating, hot water, ventilation, pumps, lighting, cooking and household appliances)

### One team. One plan. One house.

Careful planning is one thing, excellent workmanship another. Why? Because a passive house has only a limited "energy budget". Its energy performance must therefore be guaranteed for many decades. In the long run, the quality of workmanship is even more important for the building's energy efficiency than the U-values calculated for the individual structural components. By the way: in an ISOVER Multi-Comfort House you will never find the structural damage frequently caused by condensation and moisture.



Draft of an ISOVER Multi-Comfort House in Bougival near Paris. Architect: Vincent Benhamou.

### Quality assurance right from the start.

Specialist companies normally guarantee that the predefined values are achieved. Nevertheless, it is highly advisable to incorporate quality assurance measures in the invitation to tender. These include above all:

- Energy demand calculation which is made independently of the client
- Measurement of airtightness (the so-called "Blower Door Test")

### Meticulous planning facilitates the craftsmen's work.

While the planning of passive houses is a highly demanding job that requires both elaborate design and the consideration of high efficiency standards plus controlling, the craftsman's job is comparatively easy. One example: Roofs are planned to be free of penetrations as far as possible. Easier to build, faster to realize.

### Point by point: Success factors for the passive house standard.

#### Primary factors

- *Maximum thermal insulation, structural compactness and freedom of thermal bridges: All components of the building envelope are insulated at a U-value below 0.15 W/(m<sup>2</sup>K), achieved by insulating thicknesses between 25 and 40 cm.*
- *The windows must have triple glazing and insulated frames. Aim: a U-value of < 0.80 W/(m<sup>2</sup>K), including the frame, and a g-value of 0.5 (total solar energy transmittance) for the glazing.*
- *Airtightness of the building: The result of the Blower Door Test must be < 0.6 air changes per hour.*
- *Heat recovery from the exhaust air: Over a counterflow heat exchanger, the major part of the warmth from the exhaust air is fed again to the fresh air supply – heat recovery rate above 80 %.*

#### Secondary factors

- *Pretreatment of fresh air: Fresh air can be pre-heated in winter and pre-cooled in summer via a geothermal heat exchanger (energy well).*
- *South orientation and freedom from shadows in winter: Passive use of solar energy saves heating energy.*
- *Domestic hot water generation: The required energy can be produced with solar collectors (energy demand for the circulating pump 40/90 watts per liter) or by air-to-water heat pumps (average coefficient of performance 4). In summer, the heat pump can also be used for energy-efficient cooling. Dishwashers and washing machines should be hot-water connected to save the energy needed for the heating process.*
- *Energy-saving household appliances: Fridge, oven, deep-freezer, lamps, washing machine etc. as efficient power savers are yet another useful constituent of the passive house concept. But this is something the occupants must take care of themselves.*

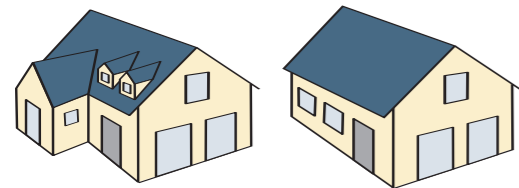
# A concept that allows no gaps.

## Compact design is most favourable.

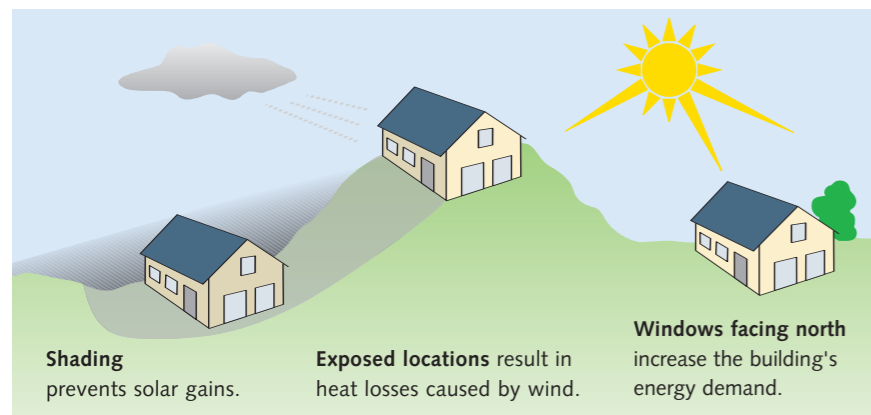
In order to keep the costs of building an ISOVER Multi-Comfort House as low as possible, it is recommendable to choose a simple, compact design. Every exposed or projecting part of the building increases the energy demand. As far as the building's geometry is concerned, a favourable relation between envelope and volume definitely helps (minimization of the envelope enclosing the heated volume). Less building envelope area reduces the heat loss and the cost of construction.



House in Skaerbaek, Denmark, with favourable north/south orientation.



Complicated designs increase the energy demand compared to plain, compact building styles.



## Plan with the sun.

In addition to the shape of a building, also location-related factors have a positive impact on the building's energy balance. If there is a choice, the ISOVER Multi-Comfort House should ideally face south. Without shade provided by mountains, surrounding trees or other buildings so that maximum solar gains can be achieved, especially in the cold winter months. It is therefore recommended that the window areas face south.

## Thermal bridge free construction down to the very last corner.

Thermal bridges are weak points of the building envelope and cause unwanted loss of energy. To build a thermal bridge free envelope therefore takes top priority in energy-efficient construction. In fact, the building envelope must be planned in such a way that every blueprint – whether floor plan or sectional

drawing – can be circled with a pen "in a single breath".

The critical areas for potential thermal bridges are where the pen needs to stop. Here, it is necessary to work out detailed solutions – preferably in close cooperation with the craftsmen.

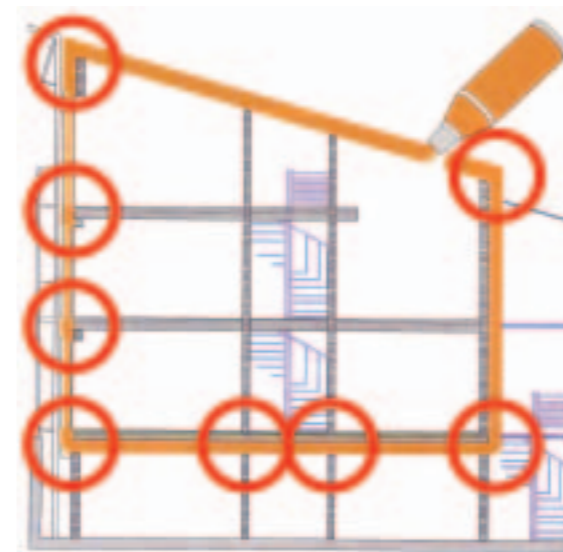


Fig. Passivhaus Institut Dr. Wolfgang Feist

## Control is a must.

Just as essential as meticulous planning down to the very last detail is the execution of the Blower Door Test in the construction phase. This test checks the building's airtightness and is able to pinpoint secret energy wasters such as joints, cracks, thermal bridges or other leaky spots. This type of quality control assures long-term security – for the building as well as for all parties involved. The best time for carrying out the Blower Door Test is definitely after completion of the building envelope and airtight barrier and before installation of the interior insulation. This makes the detection of leaks and their sealing easier.

## Point by point: These are the criteria to be fulfilled by a passive house.

- High airtightness of the building envelope. The recommended value of 0.6 air changes at a 50 Pascal pressure difference should be observed and checked before completion.
- 0.8 W/(m²K) is the benchmark for windows including frame, above all in rooms with large glass areas and little extraneous heat, produced e.g. by human beings or electrical appliances. To reach this aim it is absolutely necessary to install specially insulated windows and frames: even at glazing values below 0.6 W/(m²K).
- Continuous insulation and avoidance of thermal bridges/penetrations of the insulating envelope caused by cellar stairs, attic stairs, emergency chimneys.
- Ideally south orientation of the windows.
- Shading of east, south and west windows in summer.
- Compactness of the building envelope: V/A (volume to surface area ratio) should be between 1-4, A/V (surface area to volume ratio) should be between 1-0.2.

# Peace and quiet don't come easy – even in passive houses.

## Location is crucial.

How loud or quiet a building is depends first and foremost on the proper dimensioning of sound insulation with respect to the authoritative outdoor noise level. In the approach corridors of airports, along main roads and next to schools or swimming baths, a high level of external noise is inevitable. Here, more extensive soundproofing measures are necessary to ensure that the residents can live quietly. In these extreme conditions, the passive house shows itself off to best advantage: the windows need not be opened as fresh air is supplied via a ventilation system.



## Meticulous planning.

If the building site is affected by excessive noise, the passive house can be located as far as possible away from the noise source. The windows of living and sleeping rooms should then be installed on the front facing away from the noise source. Depending on the dimensions of the house and its surrounding buildings, the sound level can be expected to be 5-10 dB lower. But since it is necessary to make passive use of

solar radiation for heating, this might be feasible only to a limited extent.

## Indoor and outdoor sound insulation.

Sound is a phenomenon that occurs both outside and inside the building, caused by talking, walking, music, sanitary installations, and outside. It is therefore requisite to provide adequate sound insulation – from the roof all the way down to the cellar. When planning the build-

ing's facade, window areas play an important role: they determine the acoustic insulation of the external wall. As they are transparent, their sound absorption capacity is much lower. To offset this shortcoming, the acoustic insulation of the light-proof components must be increased. Usually, a construction sound reduction index  $R'_{w}$  of approx. 53 dB is required by law. When designing quietness into the interior, structural engineers differ between airborne and structure-

borne (resp. impact) sound. The sound reduction index indoors is determined by walls, doors and flanking components. In Europe, the recommended values are 40 to 48 dB. Impact acoustic insulation refers to the acoustic insulation of floors and stairs. If possible, an impact acoustic insulation  $L'_{nT,w+CI,50-2500}$  of 40 dB should be achieved for neighbouring flats and of 45 dB within a flat or one-family house. The recommended value for comfortable airborne sound insulation between individual flats is in the range of 58 to 63 dB ( $D'_{nT,w+C}$ ). On the whole, all building styles used in the construction of passive houses are able to ensure excellent acoustic quality.

## Good acoustics, good marks.

Good acoustics also help in non-residential buildings such as offices, hospitals and schools. The things that children learn or don't learn at school often determine their future path of life. Since pupils spend most of their lesson time listening, good classroom acoustics are an important criterion. A low noise level and a short reverberation time in the

classroom improve concentration, promote communication and make learning easier. Today, we have the necessary knowhow and technologies for designing perfect acoustic environments. The surface condition of ceilings and walls plays an essential role in this process. Soundproof wall and ceiling panels are able to reduce disturbing background noise. By absorbing sound, they prevent undesired reflections of sound. Thus, disturbing echoes and reverberant noise are suppressed and the background noise level is decreased. As a result,

pupils can better hear and grasp what is being said: with less effort – also for the teaching staff – better learning results are achieved. The same applies to offices, event locations and factory halls. By providing optimum acoustic conditions, it is possible to improve people's performance and well-being. We should take advantage of these positive effects: by making use of high-quality mineral fibre boards with fleece backing. They guarantee optimum sound absorption and excellent acoustic quality in all rooms.



# Live and let live in peace and quiet.



Only "enhanced" or even higher sound insulation is able to guarantee the residents' satisfaction. Hence, "comfort class" insulation should generally be installed. And, with musicians around, even a class higher.

## Whether from inside or outside: noise is always disturbing.

Where more and more people live together on less and less space, noise becomes an increasingly disturbing factor. In their own four walls, residents often have to suffer from outdoor noise. As if that wasn't enough, indoor noise sources are also becoming increasingly important. Studies carried out in different European countries clearly

show: the most important source of noise – besides road traffic – is your own neighbours! And it is the European sound insulation regulations that must be blamed for this negative trend in the first place. Fact is that in virtually all European countries the legally required sound insulation is not sufficient to allow comfortable living.

## Every human being has a need for quietness.

We need quiet phases in our daily lives like we need food and drink. They allow us to refuel body and soul. And they maintain our health. On the other hand, every human being does also produce noise. By talking, walking, showering, cooking, playing, listening to music etc, we often cause a level of noise that is perceived as a nuisance by others.

Of course, this affects first and foremost our neighbours. But also our own family members may feel disturbed.

### The troublemakers: airborne sound and impact sound.

Surveys carried out among tenants have shown that the minimum sound insulation stipulated by the European countries is sufficient only in rare living conditions. In particular the tenants of multi-family houses complain about noise nuisance caused by neighbours. But

they also complain when they need to restrict their own activities to ensure their fellow tenants' peace and quiet. Based on these experiences, ISOVER has worked out recommendations and guide values which guarantee acoustic comfort even under unfavourable living conditions. In order to produce a quiet indoor climate, a distinction is made between airborne resp. structure-borne sound and impact sound. The quality of airborne sound insulation depends on walls and flanking components such as floors, doors etc. The level of impact sound is determined by floors and stairs. In a nutshell: If

you want to ensure a satisfactory level of acoustic quality, better go for the ISOVER Comfort Class right from the start.

### Always favourable and worthwhile in new builds, costlier in old ones.

Provided good planning according to EN 12354 (valid in most European countries) and workmanship, a comfortable level of sound insulation can be achieved in new buildings at relatively low costs. You just need to budget for 2-3 % extra costs compared with "noisy" solutions. Often, the thermal insulation provided by the passive house standard at the same time ensures comfortable sound insulation. In these cases, next to no extra costs are incurred for either new or old buildings. Instead, the quality of living rises as does the value of the house. When letting or selling the house, a higher price can be achieved if the house is equipped with comfort class sound insulation. The acoustic comfort classes set up by ISOVER can serve as a valuation basis here.

### To the point: The acoustic comfort classes of ISOVER.

| Class  | "Music"                        | "Comfort" | "Enhanced" *) | "Standard"     |
|--|--------------------------------|-----------|---------------|----------------|
| Airborne sound insulation between flats<br>$D_{nT,w} + C$ (dB)   | $\geq 68$<br>( $C_{50-3150}$ ) | $\geq 63$ | $\geq 58$     | $\geq 53$      |
| Airborne sound insulation between the rooms of one flat (without doors), also incl. one-family houses<br>$D_{nT,w} + C$ (dB)           | $\geq 48$                      | $\geq 45$ | $\geq 40$     | $\geq 35^{**}$ |
| Impact sound insulation between flats<br>$L_{nT,w} + C_{1,50-2500}^{***}$ (dB)   | $\leq 40$                      | $\leq 40$ | $\leq 45$     | $\leq 50$      |
| Impact sound insulation within a flat, also incl. one-family houses<br>$L_{nT,w} + C_{1,50-2500}^{***}$ (dB)                           | $\leq 45$                      | $\leq 50$ | $\leq 55$     | $\leq 60$      |
| *) Minimum requirements for row houses<br>**) If requested<br>***) For a transitional period: $L_{nT,w} + C_I$ , values lower by 2 dB. |                                |           |               |                |

# So that everything runs smoothly.

## Point by point: The most important planning steps.

### 1. Site plan

- Freedom from shading in winter and structural shading in summer
- Best possible freedom from shading caused by buildings, mountains, coniferous forests
- Compact building styles are preferable

### 2. Concept development

- Minimize shade in winter. This means: if possible build without parapets, projections, non-transparent balcony enclosures, divider walls etc.
- Choose a compact building structure. Use opportunities to combine buildings. Glazed areas should face south and cover up to 40 % of the wall area. Keep east/west/north windows small and only as big as required for optimum ventilation.
- Use a simple shell form, without unnecessary recesses.
- Concentrate the utilities installation in one place, e.g. bathrooms above or adjacent to the kitchen.
- Leave space for the necessary ventilation ducts.
- Thermally separate the basement from the ground floor (including cellar staircase) – absolutely airtight and thermal bridge free.
- Get at first energy estimate based on a calculation of the expected energy demands.
- Check the possibility for state subsidies.
- Work out a cost estimate.
- First exploratory talk with the building authority.
- Contract agreement with architects, including a precise description of services to be rendered.

### 3. Construction plan and building permit planning

- Select the building style – light or solid. Work out a design concept, floor plan, energy concept for ventilation, heating and hot water.

- Plan the insulating thickness of the building envelope and avoid thermal bridges.
- Consider the space required for utilities (heating, ventilation etc.).
- Floor plan: short pipe runs for hot/cold water and sewage.
- Short ventilation ducts: cold air ducts outside, warm ducts inside the insulated building envelope.
- Calculate the energy demand, e.g. by means of the Passive House Planning Package (PHPP) available from the Passivhaus Institut, Darmstadt.
- Negotiate the building project (pre-construction meetings).
- Apply for a housing subsidy.

### 4. Final planning of the building structure (detailed design drawings)

- Insulation of the building envelope: ideally U-values should be around  $0.1\text{W}/(\text{m}^2\text{K})$ . Minimum requirement:  $0.15\text{W}/(\text{m}^2\text{K})$ .
- Design thermal bridge free and airtight connection details.
- Choose windows that comply with passive house standard: optimize type of glazing, thermally insulated frames, glass area and sun protection.

### 5. Final planning of ventilation and heating (detailed system drawings)

- General rule: hire a specialist planner.
- Ventilation ducts: short, smooth-walled ducts. Air flow velocities below 3 m/s.
- Include measuring and adjusting devices.
- Take sound insulation and fire protection measures into account.
- Air vents: avoid air current short-circuiting.

- Consider the air throws of the air vents.
- Provide for overflow openings.
- Install a central ventilation unit, including a back-up unit (heater coils) in the heated area of the building envelope.
- Additional insulation of central and back-up unit may be necessary. Make sure to soundproof the devices. Heat recovery rate should be above 80 %. Airtight construction with less than 3 % recirculated air. Current efficiency: max. 0.4 Wh energy required per  $\text{m}^3$  transported air.
- The ventilation system should be adjustable by the user.
- Provide for cooker hoods suitable for return air operation with grease filters made of metal.
- Optional: geothermal heat exchanger. Ensure airtightness. Observe the necessary clearance between cold parts of the piping and the cellar wall resp. water pipe. Provide a bypass for summer operation.

### 6. Final planning of the remaining utilities (detailed plumbing and electrical drawings)

- Plumbing: Install short and well-insulated pipes for hot water in the building envelope. For cold water install short pipes insulated against condensation water.
- Use water-saving fittings as well as hot-water connections on washing machine and dishwasher. Short sewer pipes with only one downpipe.
- Sub-roof vents for line breathing (vent pipes).
- Plumbing and electrical installations: avoid penetration of the airtight building envelope – if not feasible, install adequate insulation.
- Use energy-saving household appliances.

### 7. Call for tenders and awarding of contracts

- Plan for quality assurance measures in the contracts.
- Set up a construction schedule.

### 8. Assurance of quality by the construction supervision

- Thermal bridge free construction: schedule on-site quality control inspections.
- Check of airtightness: airtight penetration of all pipes and ducts by proper sealing, plastering or taping. Electrical cables penetrating the building envelope must be sealed also between cable and conduit. Flush mounting of sockets in plaster and mortar.
- Check of thermal insulation for ventilation ducts and hot water pipes.
- Seal window connections with special adhesive tapes or plaster rail. Apply interior plaster from the rough floor up to the rough ceiling.
- $n_{50}$  airtightness test: Have a Blower Door Test performed during the construction phase. Timing: as soon as the airtight envelope is complete but still accessible. This means: before finishing the interior work, but after completion of the electricians' work (in concert with the other trades), including identification of all leaks.
- Ventilation system: ensure easy accessibility for filter changes. Adjust the air flows in normal operation mode by measuring and balancing the supply and exhaust air volumes. Balance the supply and exhaust air distribution. Measure the system's electrical power consumption.
- Quality control check of all heating, plumbing and electrical systems.

### 9. Final inspection and auditing

# Energy efficiency is calculable.

Is it indeed possible to design extremely energy-efficient houses with simple planning tools? In the 1990s, it was still a widely held view that passive house planning could only be managed with the help of dynamic building simulation programs that were based on hourly performance and took the different uses of the rooms into account. Meanwhile, it has shown however that simplified calculation methods are sufficiently precise to dimension the heating system and predict the energy consumption of passive houses.

## Very helpful: the Passive House Planning Package (PHPP)

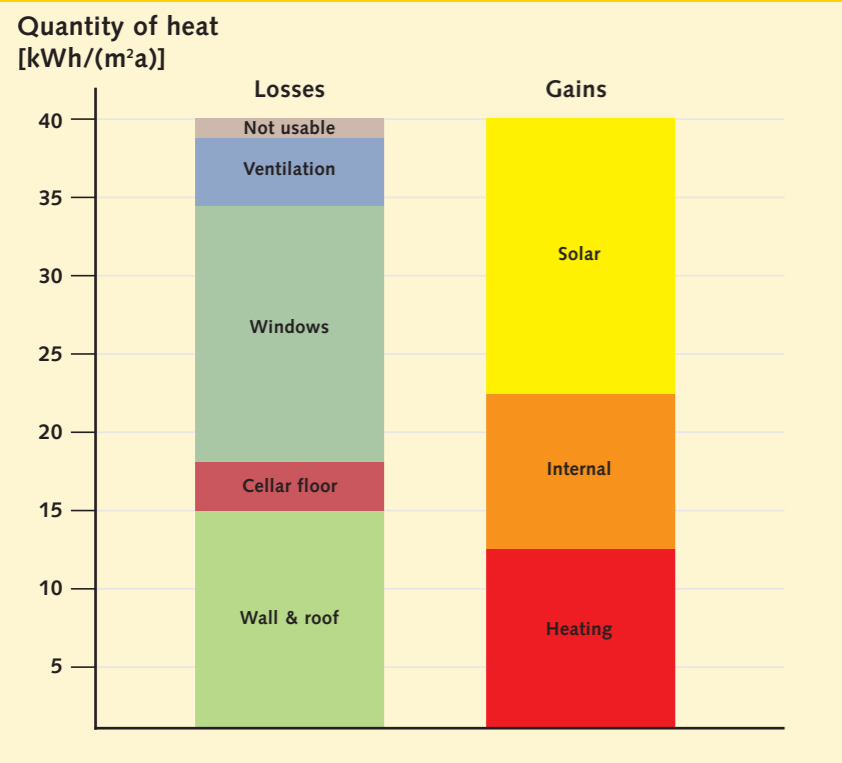
Practical use of such an energy balancing procedure is made, for instance, in the Passive House Planning Package (PHPP). This is a spreadsheet-based design tool which can be used to calculate the complete energy balance of a building. To do so, it is on the one hand necessary to determine the building's heat losses caused by transmission and ventilation. On the other side of

the balance, solar and internal heat gains need to be considered. The fact that these gains are not always achieved at times when they are needed is accounted for by setting them off against the losses. The difference between losses and useful gains eventually results in the building's demand for heating energy that must additionally be supplied. In order to obtain correct results, it is of vital importance for the calculation to distinguish between significant and insignificant factors and to choose the proper frame conditions. This includes, for example, the thermal output of inhabitants and household appliances or the solar radiation available inside a house. For this purpose, the PHPP contains standard values which have proved successful in comparison with other measurements. Apart from establishing the room heat balance, the PHPP also deals with other project-specific issues that come up in the course of planning. Among others, these include the heatability via supply air, the energy demand for auxiliary power and household electricity, the energy needed for preparing domestic hot water and the room climate in summer.

The PHPP is available from the Passivhaus Institut in Darmstadt, Germany

(www.passiv.de)

## Exemplary thermal balance of a passive house (based on one heating period)



## Passive House Planning • ANNUAL SPACE HEATING REQUIREMENT

Climate: Frankfurt (region 12) Interior Temperature: 20.0 °C  
 Building: End-of-Terrace Passive House Kranichstein Building Type/Use: Row House/Apartments  
 Location: Darmstadt-Kranichstein Treated Floor Area (TFA): 156.0 m²  
 Standard Occupancy: 4.0 pers. per m²

| Building components                           | Temperature zone | Area m² | U-value W/(m²K) | Temp. faktor f <sub>t</sub> | G <sub>t</sub> kWh/a | kWh/a       | Treated floor area |
|---|------------------|---------|-----------------|-----------------------------|----------------------|-------------|--------------------|
| Exterior Wall – Ambient Air                   | A                | 184.3   | 0.138           | 1.00                        | 76.4                 | 1935        | 12.4               |
| Exterior Wall – Ground                        | B                |         |                 | 0.56                        |                      |             | #VALUE!            |
| Roof/Ceiling – Exterior Air                   | D                | 83.4    | 0.108           | 1.00                        | 76.4                 | 685         | 4.4                |
| Floor Slab                                    | B                | 80.9    | 0.131           | 0.56                        | 76.4                 | 454         | 2.9                |
|   | A                |         |                 | 1.00                        |                      |             | #VALUE!            |
|   | A                |         |                 | 1.00                        |                      |             | #VALUE!            |
|   | X                |         |                 | 0.75                        |                      |             | #VALUE!            |
| Windows                                       | A                | 43.5    | 0.777           | 1.00                        | 76.4                 | 2580        | 16.5               |
| Exterior Door                                 | A                |         |                 | 1.00                        |                      |             | #VALUE!            |
| Exterior Thermal Bridge (length/m)            | A                | 116.9   | -0.030          | 1.00                        | 76.4                 | -266        | -1.7               |
| Perimeter Thermal Bridge (length/m)           | P                |         |                 | 0.56                        |                      |             | #VALUE!            |
| Ground Thermal Bridges (length/m)             | B                | 11.4    | 0.061           | 0.50                        | 76.4                 | 30          | 0.2                |
| Total of all building envelope areas          |                  | 392.1   |                 |                             |                      |             | kWh/(m²a)          |
| <b>Transmission Heat Losses Q<sub>T</sub></b> |                  |         |                 |                             |                      | <b>5417</b> | <b>34.7</b>        |

Ventilation system: Effective air volume V<sub>RAX</sub> 156.0 m³  
 Actual Efficiency of Heat Recovery n<sub>HR</sub> 81 %  
 Efficiency of Subsoil Heat Exchanger n<sub>SOX</sub> 33 %  
 Energetically Effective Air Exchange n<sub>v</sub> 0.300 (1 0.87) + 0.019 = 0.058

|  |                   |                    |                           |                      |       |           |
|--|-------------------|--------------------|---------------------------|----------------------|-------|-----------|
| Ventilation Heat losses Q <sub>L</sub> | V <sub>v</sub> m³ | n <sub>v</sub> 1/h | C <sub>air</sub> Wh/(m³K) | G <sub>t</sub> kWh/a | kWh/a | kWh/(m²a) |
|  | 390               | 0.058              | 0.33                      | 76.4                 | 568   | 3.6       |

|  |                      |                      |                                       |       |           |
|--|----------------------|----------------------|---------------------------------------|-------|-----------|
| <b>Total Heat Losses Q<sub>L</sub></b> | Q <sub>T</sub> kWh/a | Q <sub>v</sub> kWh/a | Reduction Factor Night/Weekend Saving | kWh/a | kWh/(m²a) |
|  | ( 5417 + 568 )       | 1.0                  |                                       | 5985  | 38.4      |

| Orientation of the Area                     | Reduction Factor see Windows | g-Value (perp. radiation) | Area m² | Global Radiation Heating Period kWh/(m²a) | kWh/a       |             |
|---|------------------------------|---------------------------|---------|---|-------------|-------------|
| 1. East                                     | 0.40                         | 0.00                      | 0.00    | 207                                       | 0           |             |
| 2. South                                    | 0.44                         | 0.50                      | 30.42   | 352                                       | 2343        |             |
| 3. West                                     | 0.41                         | 0.50                      | 2.00    | 210                                       | 85          |             |
| 4. North                                    | 0.45                         | 0.50                      | 11.04   | 131                                       | 323         |             |
| 5. Horizontal                               | 0.40                         | 0.00                      | 0.00    | 318                                       | 0           |             |
| <b>Gross Solar Heat Gains Q<sub>S</sub></b> |                              |                           |         |   | <b>2752</b> | <b>17.6</b> |

Internal Heat Sources Q<sub>I</sub> kh/d Heating Period d/a Specific Power q<sub>I</sub> W/m² A<sub>TFA</sub> m² kWh/a kWh/(m²a)  
 0.024 • 205 • 2.10 • 156.0 = 1608 10.3  
 Free heat Q<sub>F</sub> Q<sub>S</sub> + Q<sub>I</sub> = 4360 kWh/a kWh/(m²a)  
 Ratio free heat vs. losses Q<sub>F</sub> / Q<sub>L</sub> = 0.73  
 Utilization of heat gains η<sub>G</sub> (1 - (Q<sub>F</sub> / Q<sub>L</sub>)²) / (1 - (Q<sub>T</sub> / Q<sub>L</sub>)²) = 93%

|  |                                 |       |           |
|--|---------------------------------|-------|-----------|
| <b>Heat Gains Q<sub>G</sub></b>              | n <sub>G</sub> • Q <sub>F</sub> | kWh/a | kWh/(m²a) |
|  | 4074                            | 26.1  |           |
| <b>Annual Heat Requirement Q<sub>H</sub></b> | Q <sub>L</sub> - Q <sub>G</sub> | kWh/a | kWh/(m²a) |
|  | 1910                            | 12    |           |
| Limit kWh/(m²a)                              |                                 | 15    |           |
| Requirement met?                             |                                 | YES   |           |