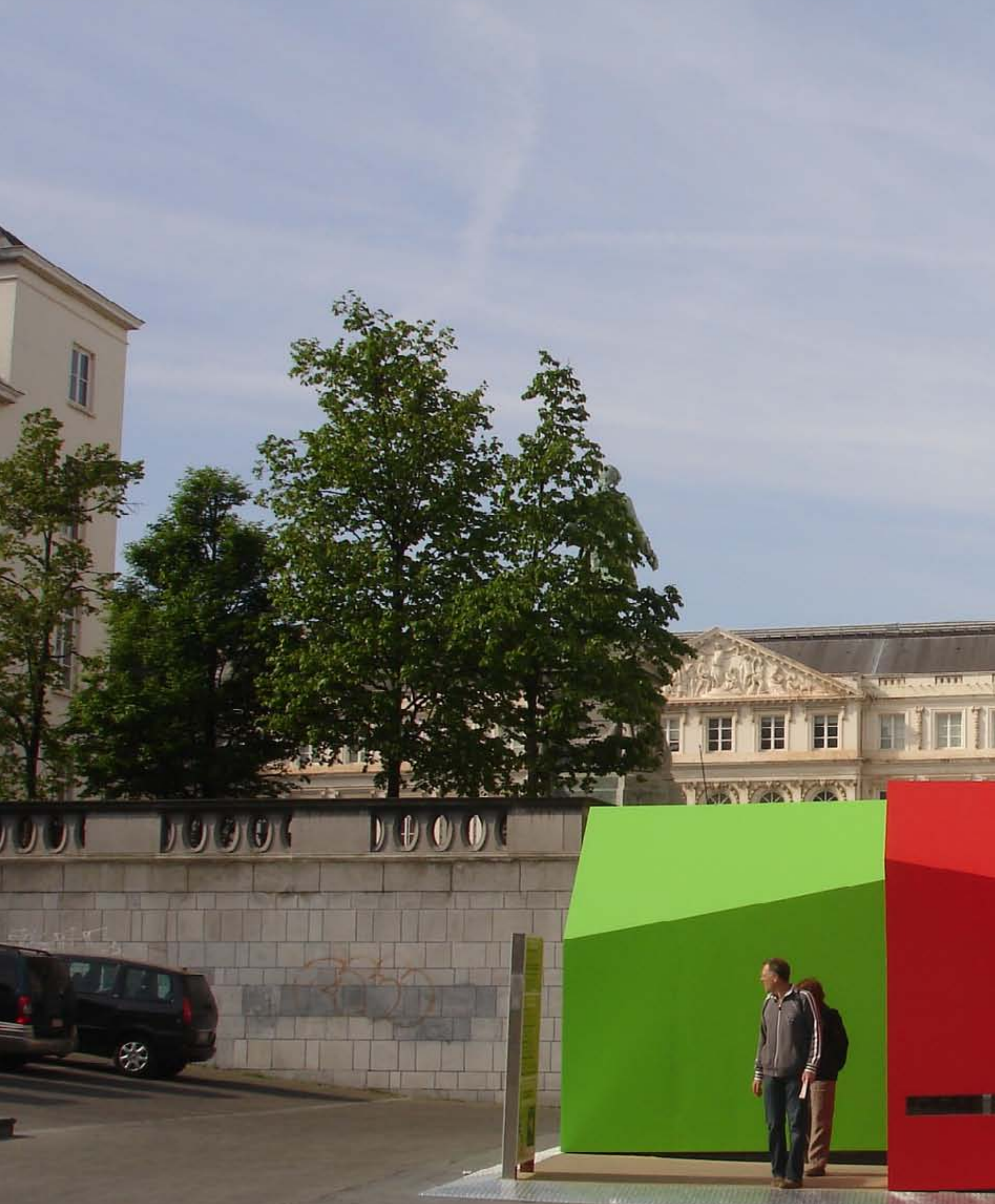
passive architecture

strategies, experiences & viewpoints in Belgium

be.passive pmp ULB Faculté d'Architecture La Cambre Horta bruxelles environnement .brussels



In April 2007, pmp asbl and php asbl[1] , two non-profit organizations, organized in Brussels an **Ice Challenge** event to promote the insulation of buildings. Two large blocks of ice weighing 1.3 tons each were placed in two pavilions, a green one (very well insulated) and a red one (totally not insulated). The first block melted away to noth-ing in 11 days. Thanks to the insulation, the second block still weighed 456 kg after 44 days, as Brussels citizens could verify[2].

Ice Challenge | Brussels | Bruxelles Environnement - pmp - php | A2M

foreword

This book has come into being at the initiative of **be.passive asbl**, a non-profit organization which relays to professionals and the general public the most up-to-date experience in passive design in Belgium. It is the fruit of collaboration with the Platforme Maison Passive, the Faculty of Architecture of the Université Libre de Bruxelles, and Brussels Environment.

In it the varying viewpoints of architect, engineer, lawyer, contractor, project owner, teacher and enthusiast meet and intersect. All share here their experience of the realities of passive design in Belgium. They have gathered together what you need to know in order to start to design passive buildings, and make energy part of the solution, not part of the problem! You can extend your reading of this book with the thousands of pages available free of charge on the website of architecture magazine **be.passive**[3].

The passive standard is developing rapidly, offering concrete ways to build in an eco-responsible manner. In so doing it enables project owners and architects to contribute to the common good. Beyond good intentions, this is also a matter of professional responsibility. Society has always demanded guarantees: that any building be solid, watertight and healthy to live in. Today, a new energy-related guarantee is emerging: that every building be economical and sustainable, and so contribute to resolving today's global energy and climate issues.

be.passive

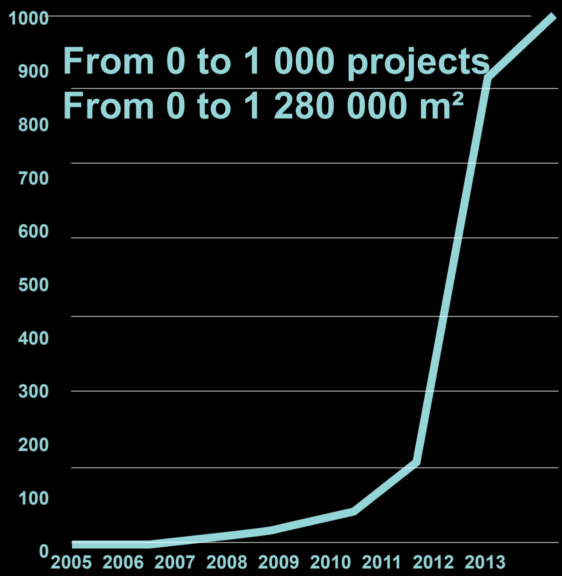
pmp

ULB Faculté d'Architecture La Cambre Horta

bruxelles environnement .brussels

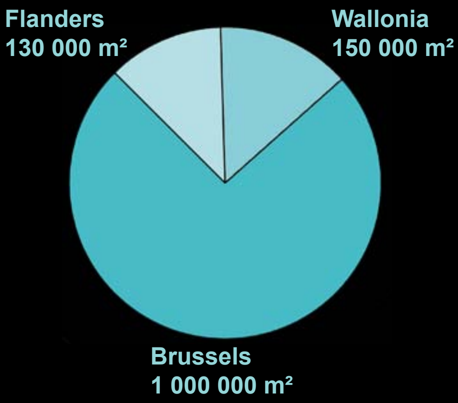
This new “social contract” distils regulatory requirements that would not have surprised observers This new “social contract” distils regulatory requirements that would not have surprised observers of the planet, from long before the first oil shock (1973) up until the latest IPCC[4] reports on Climate Change (2014). The enthusiasm for passive building is proof of this, with over 1.5 million square metres of buildings built or planned to passive standards across Belgium over the last ten years. But it has caught other practitioners napping. This book is also for them. It will not impose any solution they do not wish for: passive design does not replace architectural design. It will be for architects what Sancho Panza was Don Quixote: a servant, at times abrupt in his manner, but always in the service of his master.

To our knowledge, Brussels-Capital has been the first region in Belgium to draw the consequences of this new situation. It is thanks to it that this book is in your hands. We express our gratitude to the administration of Brussels Environment for supporting and enriching our project. Any errors in this text, however, are ours.

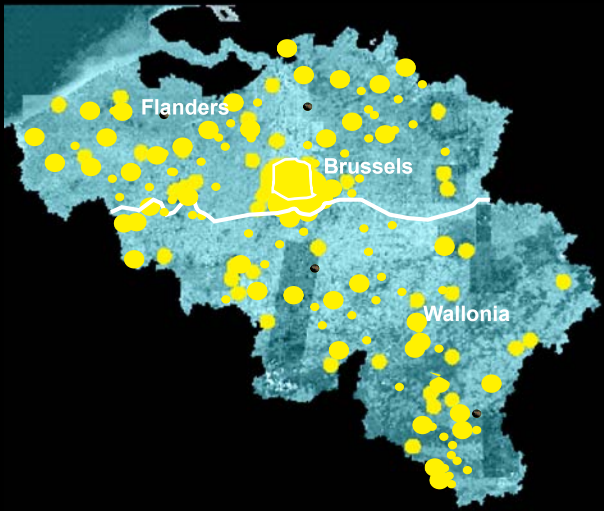


Inventory of passivehouse projects in Belgium (beginning of 2014)

References:
1 www.maisonpassive.be ; www.passiefhuisplatforme.be.
2 **be.passive** 02, p.56.
3 www.bepassive.be.
4 Intergovernmental Panel on Climate Change, www.ipcc.ch



Passivehouse project in m² per region

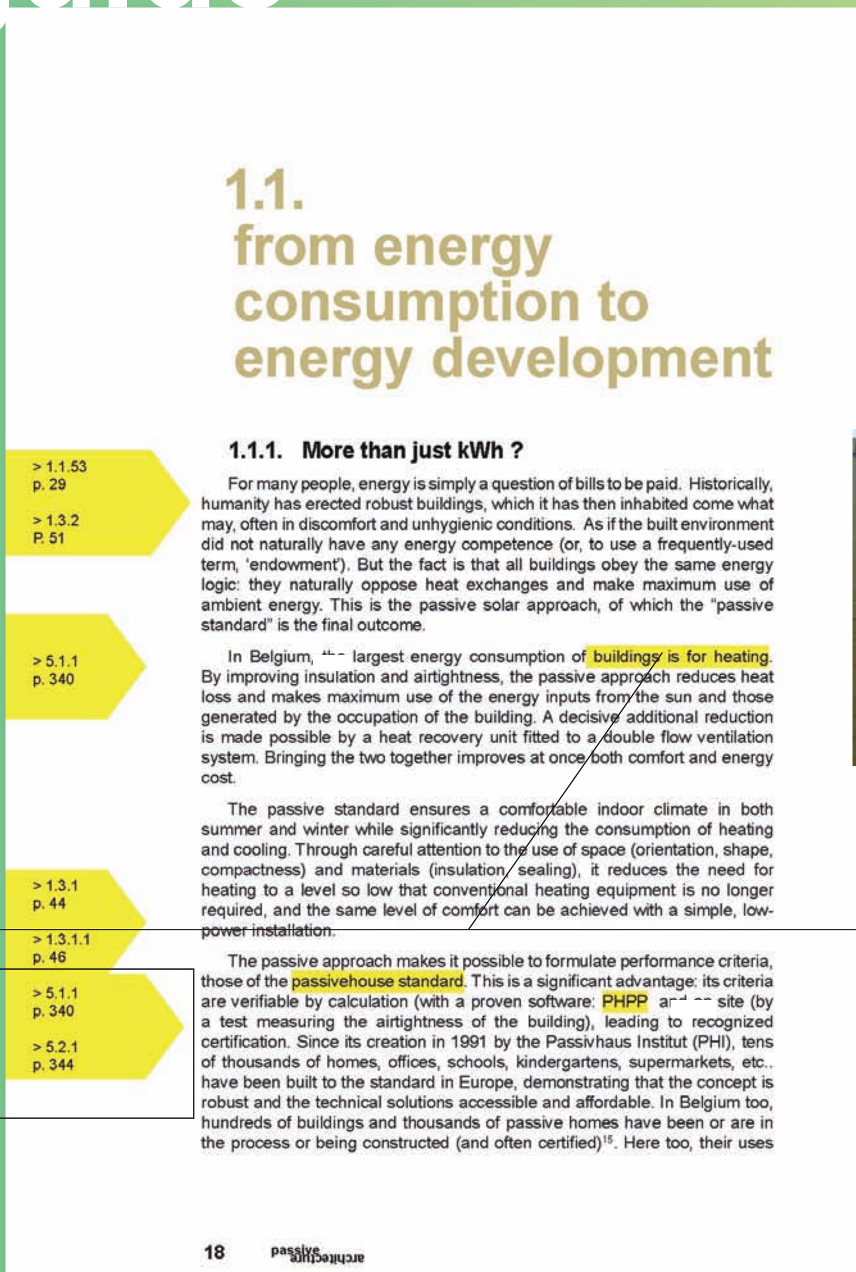


Passivehouse projects in Belgium


Flanders
Wallonia

Brussels

user guide



1.1.
from energy consumption to energy development

1.1.1. More than just kWh ?

> 1.1.53 p. 29
> 1.3.2 P. 51

For many people, energy is simply a question of bills to be paid. Historically, humanity has erected robust buildings, which it has then inhabited come what may, often in discomfort and unhygienic conditions. As if the built environment did not naturally have any energy competence (or, to use a frequently-used term, 'endowment'). But the fact is that all buildings obey the same energy logic: they naturally oppose heat exchanges and make maximum use of ambient energy. This is the passive solar approach, of which the "passive standard" is the final outcome.

> 5.1.1 p. 340

In Belgium, the largest energy consumption of buildings is for heating. By improving insulation and airtightness, the passive approach reduces heat loss and makes maximum use of the energy inputs from the sun and those generated by the occupation of the building. A decisive additional reduction is made possible by a heat recovery unit fitted to a double flow ventilation system. Bringing the two together improves at once both comfort and energy cost.

The passive standard ensures a comfortable indoor climate in both summer and winter while significantly reducing the consumption of heating and cooling. Through careful attention to the use of space (orientation, shape, compactness) and materials (insulation, sealing), it reduces the need for heating to a level so low that conventional heating equipment is no longer required, and the same level of comfort can be achieved with a simple, low-power installation.

> 1.3.1 p. 44
> 1.3.1.1 p. 46
> 5.1.1 p. 340
> 5.2.1 p. 344

The passive approach makes it possible to formulate performance criteria, those of the passivehouse standard. This is a significant advantage: its criteria are verifiable by calculation (with a proven software: PHPP and on site (by a test measuring the airtightness of the building), leading to recognized certification. Since its creation in 1991 by the Passivhaus Institut (PHI), tens of thousands of homes, offices, schools, kindergartens, supermarkets, etc.. have been built to the standard in Europe, demonstrating that the concept is robust and the technical solutions accessible and affordable. In Belgium too, hundreds of buildings and thousands of passive homes have been or are in the process or being constructed (and often certified)[15]. Here too, their uses

18 passive architecture

The "highlighting" in yellow is used to refer to other parts of the book in order to delve into the issue in greater detail, or simply to provide an additional angle of incidence on the subject.

Tout petit, tout petit la planète
Plastic Bertrand

... of our way of life (comfort, well-being, mobility) and is the subject of increasing regulation (EPB[19], taxation, etc.) to counter certain forms of inequality (insecurity, energy vulnerability). Energy consumption is an environmental and economic problem because it mobilizes large financial flows. It is also a social problem because *"heating and lighting are inalienable rights"*[20] in our societies.

1.1.2. An energy approach to buildings?

Let us start by distinguishing between energy that "goes up in smoke" (the energy used to operate a building and energy that is converted into material and functionality (embodied energy). To reduce the operating energy consumption of buildings, there are just three basic principles, formulated by the *Trias Energetica*[17] :

1. Reduce demand and implement every possible measure to promote sobriety in order to "consume less";
2. Use renewable energies (RE) to "consume differently;

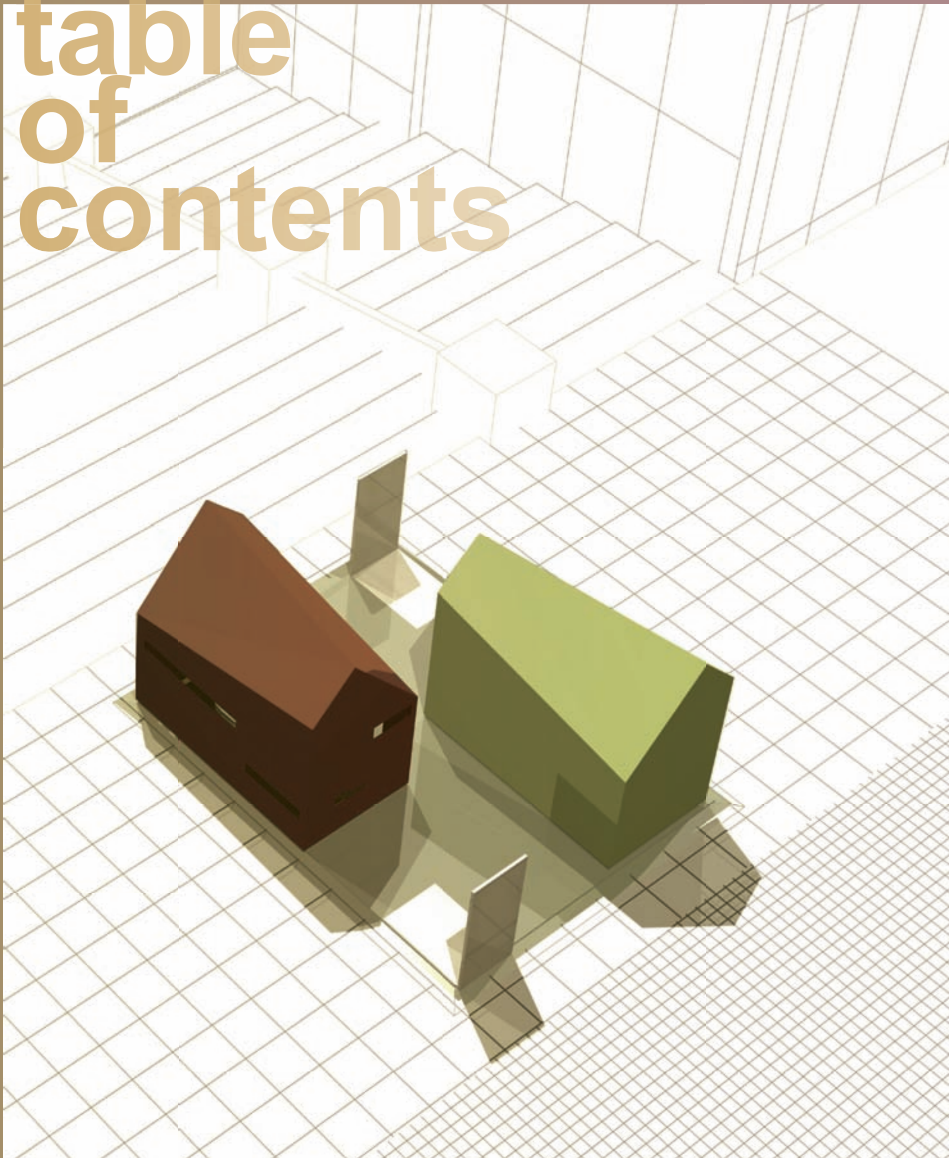
19

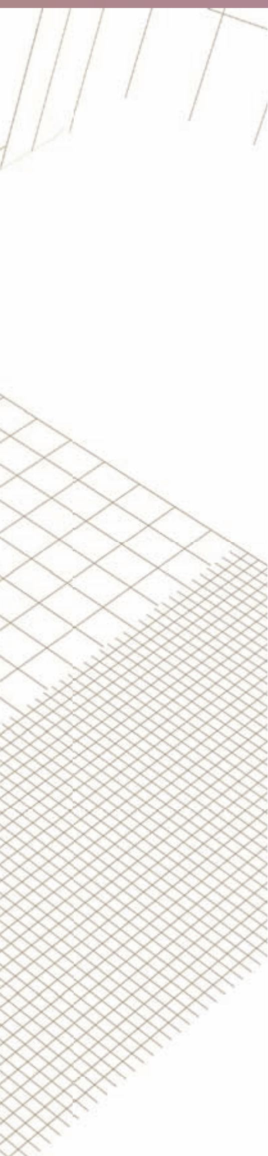
define
01

The "GPS":
This area is used to find one's way in the book. Each chapter is differentiated by a colour and a word; e.g. Chapter 01 = "define" and colour ochre

The notes are listed at the end of the chapter.

table of contents





from passive approach to passivehouse standard

define

01

tout petit, tout petit la planète

(*A very, very tiny Planet*, Plastic Bertrand)

Bernard Deprez

Let's be quite clear from the outset: the problem is not one of architecture, but of energy. Fissile and fossil fuels are not renewable. The planet still has considerable reserves of coal, oil and gas, but extracting them is becoming increasingly expensive and risky. It generates international tension, pollution and extravagant costs.[5] According to the European Union (EU), pollutants from the combustion of fossil fuels increase Belgium's mortality figures by 12,400 deaths a year.[6] That is proportionally four times more than China![7] Fossil fuels account for 85% of global warming.[8] Scientists estimate that CO2 emissions have exceeded the "limits of the planet".[9] The IPCC[10] believes they need to be reduced by 85% by 2050.

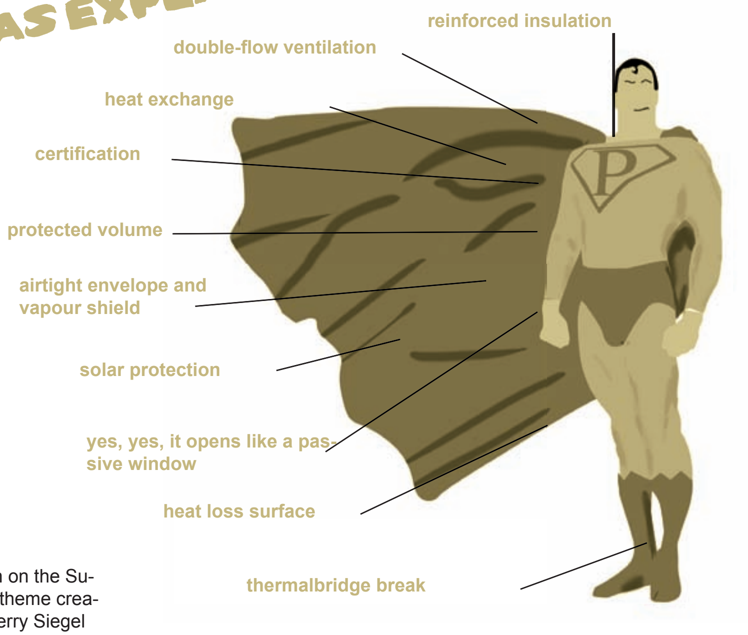
Leaving the situation unchanged reinforces this destructive scenario. In Europe, buildings consume 40% of primary energy. This makes them a key part of the solution.[11] With very low renovation and new construction activity, only ambitious objectives will respond to the IPCC's requirements. But 2050 is the horizon for which buildings are designed or renovated today: it needs therefore to be the horizon of our designers.

What is the energy logic of this world which is not limitless? The possibilities are many, but the simple accumulation of technologies is not enough! A critical approach is necessary to avoid errors, ineffective gadgetry and the rebound effect.[12] Recent studies[13] have shown that Europe and Belgium can convert to an economy 100% powered by renewable energy (RE). This "energy transition" calls on us to transform our manufacturing chains, and to revise our urban and rural planning, our architectural typologies and our building traditions. For Rem Koolhaas, "*energy efficiency criteria are required for new construction. They need to aim at near-zero consumption like the passive standard.*"[14]

The fact remains, however, that in terms of energy, a building does not function in the same way as a machine or a solar panel. The passive approach is based not on a particular individual piece of technology, but on the intrinsic energy-conserving potential of any structure intended to be inhabited. When considering siting, walls, materials and the rest, the builder is invited to add a new quality - energy efficiency - to the traditional ones of robustness, functionality and spatiality.

Before being a "standard", "passive" is the natural energy logic of buildings, the logic which reveals and takes full advantage of the energy potential of any building. Its effectiveness is based on the materials used in its construction, much more than on its technical equipment. That is why passive building is addressed both at construction and at renovation, and as much at low energy as it is at zero energy: with the same principles leading to the same results, the actual performance will depend on the specifics of each situation.

SUPERPASSIVE AS EXPLAINED TO MY MOTHER



Variation on the Superman theme created by Jerry Siegel and Joe Shuster

1.1. from energy consumption to energy development

1.1.1. More than just kWh ?

> 1.1.53
p. 29

> 1.3.2
P. 51

For many people, energy is simply a question of bills to be paid. Historically, humanity has erected robust buildings, which it has then inhabited come what may, often in discomfort and unhygienic conditions. As if the built environment did not naturally have any energy competence (or, to use a frequently-used term, 'endowment'). But the fact is that all buildings obey the same energy logic: they naturally oppose heat exchanges and make maximum use of ambient energy. This is the passive solar approach, of which the "passive standard" is the final outcome.

> 5.1.1
p. 340

In Belgium, the largest energy consumption of buildings is for heating. By improving insulation and airtightness, the passive approach reduces heat loss and makes maximum use of the energy inputs from the sun and those generated by the occupation of the building. A decisive additional reduction is made possible by a heat recovery unit fitted to a double flow ventilation system. Bringing the two together improves at once both comfort and energy cost.

The passive standard ensures a comfortable indoor climate in both summer and winter while significantly reducing the consumption of heating and cooling. Through careful attention to the use of space (orientation, shape, compactness) and materials (insulation, sealing), it reduces the need for heating to a level so low that conventional heating equipment is no longer required, and the same level of comfort can be achieved with a simple, low-power installation.

> 1.3.1
p. 44

> 1.3.1.1
p. 46

> 5.1.1
p. 340

> 5.2.1
p. 344

The passive approach makes it possible to formulate performance criteria, those of the passivehouse standard. This is a significant advantage: its criteria are verifiable by calculation (with a proven software: PHPP and on site (by a test measuring the airtightness of the building), leading to recognized certification. Since its creation in 1991 by the Passivhaus Institut (PHI), tens of thousands of homes, offices, schools, kindergartens, supermarkets, etc.. have been built to the standard in Europe, demonstrating that the concept is robust and the technical solutions accessible and affordable. In Belgium too, hundreds of buildings and thousands of passive homes have been or are in the process or being constructed (and often certified)[15]. Here too, their uses are as varied as their architectural styles. Here too, examples of low energy or passive renovation abound[16].

Other criteria derived from the passive standard also exist: EnerPHit [17](which certifies the renovation of existing buildings to passive energy levels in Germany) or the EPB "Passive 2015" 'regulations in the Brussels-Capital region.

By focusing on heating, the passive standard brings credibility to any sustainable approach to comfort, well-being and health, energy independence, maximizing use of environmental energy, and reducing consumption and polluting emissions. In the Brussels-Capital region, more 56% of the 243 winners of sustainable construction building competitions[18] have been passive.

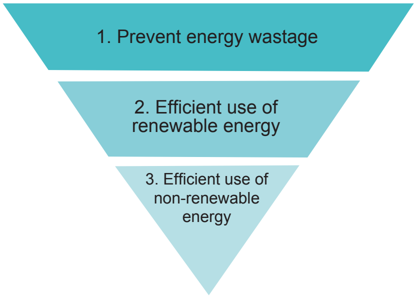
Because energy is at the heart of life, all this is much more than a simple matter of kWh. It structures all sustainable building design, is intimately linked to global balances and is essential to the health of residents. It is at the heart of our way of life (comfort, well-being, mobility) and is the subject of increasing regulation (EPB[19], taxation, etc.) to counter certain forms of inequality (insecurity, energy vulnerability). Energy consumption is an environmental and economic problem because it mobilizes large financial flows. It is also a social problem because "*heating and lighting are inalienable rights*"[20] in our societies.

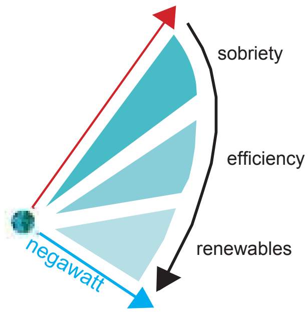
1.1.2. An energy approach to buildings?

Let us start by distinguishing between energy that "goes up in smoke" (the energy used to operate a building and energy that is converted into material and functionality (embodied energy). To reduce the operating energy consumption of buildings, there are just three basic principles, formulated by the *Trias Energetica*[17] :

1. Reduce demand and implement every possible measure to promote sobriety in order to "consume less";
2. Use renewable energies (RE) to "consume differently;

The most sustainable energy is the energy saved





The Negawatt approach[22] highlights the same principles

3. Make technologies more efficient in order to reduce losses and "consume better".

1.1.2.1. To conserve energy or produce it?

> 1.2.2
p. 37

Current RE production technologies are not sufficient to replace fossil fuels. Energy conservation is therefore essential. This is relatively easy in the building sector, but more difficult in other sectors like transport and manufacturing. Conservation and RE production may well be two sides of the same coin, but the two logics are inherently different: :

> 1.3.1
p. 44

- All materials naturally oppose thermal resistance to heat flow; but beyond a certain point, improving the insulation of a building no longer contributes much. The insulation power ("NegaWatt": $U_{uninsulated}$ - $U_{insulated}$) of insulation "ceilings out" at a certain stage.
- Conversely, the power of an RE system is linear: to produce more, just add more technology (capture surface or depth, etc.). The kWh produced by a technical installation does not "ceiling out" (as long as an energy catchment area is available).

What should we then prefer: to insulate and/or produce REs? From an energy viewpoint both are equal. Financially, it depends on the circumstances and technologies (tax incentives, etc.). But in terms of the value of the building, it's another story: only 'half'-insulating a building effectively freezes it in a state where its energy- saving (i.e. "passive") potential is not fully-used, with the risk that it could turn out more expensive to improve it at a later date as this would require changing certain basic features which constitute its "energy endowment". Faced with future energy requirements, insulating today at a less than passive level may lead to situations of 'programmed' obsolescence.[23]

> 5.1
p. 340

1.1.2.2. The passive approach: conserving energy

Energy conservation is an intrinsic phenomenon of building: any architecture is genetically “passive”. The evolution of thermal regulations responds in every respect to the *Trias*: starting with K70 (insulation) in 1984 and extended by the BE500 (which calculates in free inputs), then developed with the EPB to integrate RE, equipment-related losses and primary energy.

The passive standard focuses on the energy conservation potential of the building. Its central criterion is a reduced need: the famous 15 kWh/m²/year. The “limitation” to 15 (without aiming for 0 kWh) is because any further reduction would lead to unreasonable constructive choices (additional cost, thickness, etc.). The passive takes the sobriety principle of the *Trias energetica* to its logical conclusion. To move beyond passive, one has to produce RE and to move beyond architecture into the engineering of heating and ventilation equipment. When active RE technology is included, the (passive) building becomes, strictly speaking, not active, but *hybrid*.

1. Now that’s insulation for you.
2. Turn out the light, I’m too hot
Triple glazing

1.1.2.3. Bioclimatic revisited

The passive approach is 100% bioclimatic. Its principles are universally applicable. Of course, summer-focused strategies are centre-stage in southern countries, as against winter-focused strategies in northern countries. But our temperate climates experience alternating cold and heat, calling for a two-pronged bioclimatic approach. Four winter and five summer strategies are proposed to reconcile comfort and energy savings. Winter strategies are

1. **retaining** heat by insulating walls, airtightness, compactness, and thermal zoning; the heat of the air is retained by using a heat exchanger (possibly extended by a ground-coupled heat exchanger or "Canadian well"); when this is no longer necessary to keep out the cold, it can be by-passed or disabled to return to natural ventilation;
2. **capturing** solar radiation by the orientation of the building and the openings, the quality of glass, etc.;
3. **distributing** heat within the building through fluid design and, in winter, by mechanical ventilation and heat exchanger;
4. **storing** heat by choosing materials with high thermal inertia, and appropriate technical installations (hot water tank).

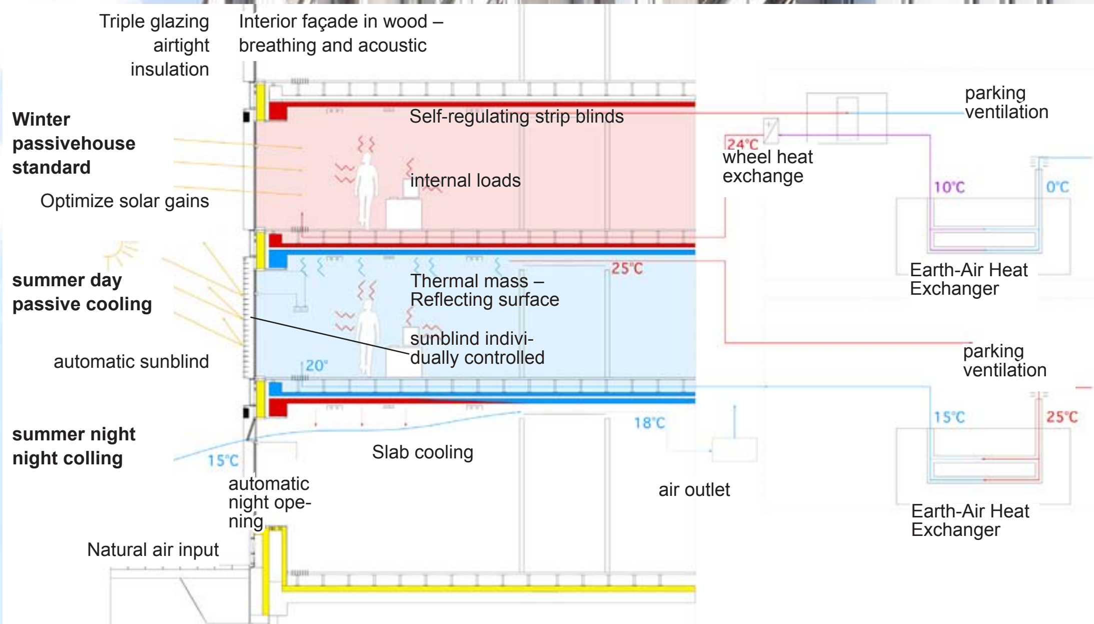
> 4.3.1.3
p. 313

> 2.2.2.4.c
p. 188

In summer, occupants use the heat exchanger (it can be switched off) and windows[24] (they can be opened) depending on their needs and/or habits. Passive solutions combine five summer strategies:

- **protecting** from heat by the same devices as in winter (insulation, airtightness); sometimes in a passive building it will make sense to close the windows to enable the insulation and sealing to function fully as a thermal shock absorber;
- **shading** exposed windows and regulating the actual exposure to the sun as a function of the siting and existing solar protection (roof overhangs, blinds, foliage, etc.).
- **minimizing** internal inputs to reduce unnecessary heat sources (dimming, etc.).

*Aeropolis II | Schaerbeek |
Maison du Travail asbl |
architect: Architectes Associés*


Triple glazing
airtight
insulation
Interior façade in wood –
breathing and acoustic
Winter
passivehouse
standard
Optimize solar gains
Self-regulating strip blinds
internal loads
24°C
wheel heat
exchange
parking
ventilation
10°C
0°C
Earth-Air Heat
Exchanger
summer day
passive cooling
25°C
Thermal mass –
Reflecting surface
automatic sunblind
sunblind indivi-
dually controlled
20°
parking
ventilation
summer night
night colling
15°C
18°C
Slab cooling
15°C
25°C
automatic
night ope-
ning
air outlet
Earth-Air Heat
Exchanger
Natural air input

Nebraska straw bale house, 19th century

"Peat grass" houses in Iceland

Isothermal "Feuillette" house, 1921 and renovation in 2011

- **dispelling** unwanted heat by absorbing the heated air (through thermal inertia), by bypassing the exchanger and allowing intensive natural ventilation;
- **cooling** naturally using water evaporation (adiabatic heat exchanger), a ground-coupled heat exchanger or plant evapotranspiration.

1.1.3. A question of energy endowment!

Designing a building means defining its competence (structural, functional, energy) – or "endowment"[25] –much more than its actual functionality (which can change over time), its energy consumption (user-dependent), its identity or its value (which belongs to its history or the market). A building's endowment forms its "genetic code"[26] and is irrevocably assigned to it at the design stage by features that are defined once and for all: orientation, compactness, materials, dimensions, insulation thickness, weight-bearing capacities, etc. It is this that determines the range of possible uses of the building. And it is very expensive to change a *posteriori*.

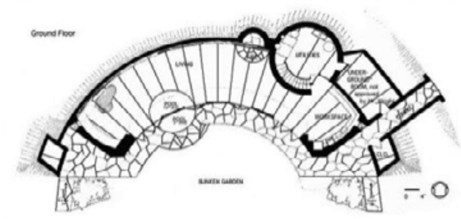
Passive building means investing more in the building in order to conserve energy, and so improve its energy endowment. This results in buildings that are both effective (because very well insulated) and resilient (less dependent on technical equipment). Energy efficiency and resilience relate here to the architectural design, they are not a matter of technical equipment.

> 2.2.1
p. 168

The economic reality of buildings is that they have long lives. Today, every new or renovated building must be or become "endowed' in order to face, at lesser cost, a future that will undoubtedly be conditioned by more stringent energy-saving policies and the fight against global warming. In the future, it will be necessary to mobilize 100% of a building's energy endowment (energy conservation) and 100% of its RE potential (production). Failing to take this situation seriously will lead to lock-in situations that make buildings obsolete and reduce their resale value. Indeed, re-insulating a posteriori will always be less profitable than isolating a priori because its cost can be amortized only against the marginal energy savings made possible by the additional insulation.

> 5.1
p. 340

> 1.2.2.2
p. 38



Jacobs house II, Frank Lloyd Wright, 1944, Wisconsin, USA

1.1.4. Some historical milestones

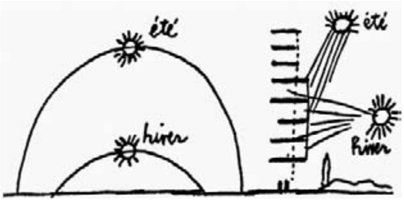
Improving energy competence is a theme that runs right through the history of building construction. In the 18th century, the firewood crisis in Iceland led to the first "passive" houses in fir, covered with grassed earth. In the 19th century, the American pioneers invented the straw house in Nebraska. In 1921, France built the Feuillette[27], an "isothermal" house combining a wood frame and straw insulation. In 1935, the invention of double glazing in the United States popularized *solar homes*.

The 1973 energy crisis reminded people of the need for more energy-efficient homes. The era of "heat waste hunting" saw research into insulating materials and the return of solar, in either passive (windows) or active (solar energy captors) mode. Efforts were made to reduce the main form of domestic consumption: heating.

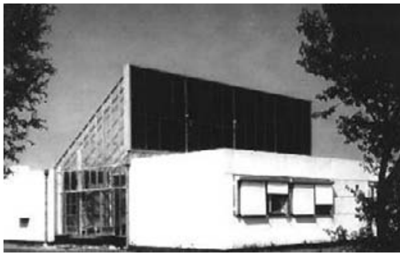
In 1982, Amory Lovins in the United States (Rocky Mountain Institute) and Professors De Herde (UCL) and Hens (KUL) in Belgium worked on optimizing the match between building, climate and occupants. Scientific networks like PLEA (*Passive and Low Energy Architecture*) were created especially to counteract the irresponsible design that characterized the post-modern architecture of their day. Over the years, their international symposia opened up to issues of architecture and sustainable urban development.[28]

Reflection and discussion continued on insulation, thermal bridging, waterproofing, glazing and controlled ventilation. Experiments with very low and zero energy housing were launched in Europe and the United States. The first experimental passive house was built in Copenhagen[29] in 1973. In Sweden and Denmark, the low energy house became in 1985 the standard for new construction. The Maison Pléiade was built in Louvain-la-Neuve in 1992.

The first experiments pointed to the importance, until then underestimated, of airtightness and more efficient fenestration. "Technological Christmas tree" projects were abandoned (too unreliable) in favour of simplicity under the motto *Keep it Simple, Stupid (KISS)*!



“Salutary cut” Le Corbusier

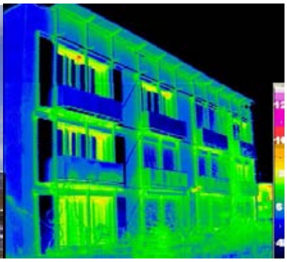


Zero energy house of the DTH on the Copenhagen campus

Passive at 2164 m altitude: the Rocky Mountains Institute of Amory & Hunter Lovins

Princess Elisabeth Polar Station| Antartica | The International Polar Foundation | architect: *Samyn & partners*

Pléiade house in Belgium, architect: Jaspard



Passivehouse Darmstadt-Kranichstein | *Passive House Developers Society* | architect: *Bott- Ridder- Westermeyer*

In 1988, Professors Adamson and Feist worked on a new concept, the Passivhaus. Their goal was to eliminate all conventional heating by using the ventilation system to provide the necessary heating and cooling input: “*A passive house is a building in which thermal comfort (as defined by the ISO 7730 standard) is achieved solely by warming or cooling of the fresh air necessary for the quality of indoor air (DIN 1946), without the use of other air circulation.*”[30] This definition of passive is functional, it contains no specific figures and is valid for any climate: it is a fundamental concept. It was validated in 1991 by the construction of an experimental building with 4 dwelling units in Darmstadt.[31]

1.1.5. A coherent concept

> 1.3.1
p. 44

Passive building is a concept, and one that has its own logic. A clear concept, it translates into clear criteria, which form the passivehouse standard. Other approaches exist, leading to other forms of energy efficiency: they are not "passive" and focus more on the equipment than on the construction of buildings.[32]

1.1.5.1. Rigour and quality

> 1.3.2
p. 51

The passive standard methodology can appear rigorous to a sector that suffers at times from artistic vagueness in defining performance (comfort, energy, light, air quality, price, etc.). Verifying and certifying a building's level of energy performance is a new practice. This transition from an obligation of means ("to strive to") to an obligation of result ("to meet a target") inevitably meets resistance. Yet it is precisely through the imposition of such criteria that many industries have improved the quality of their products, and we can hope for the same in the real estate sector.

1.1.5.2. Making energy-savings accessible

Passive building has become a formidable movement of empowerment in Belgium. In Brussels alone, more than 900,000 m² of passive housing (new or renovated) has already been built or is currently planned.33 The dynamics of the six "Batex" calls for projects[34] in Brussels have been largely driven by passive building, which accounts for over 56% of prize winning entries and 66% of public housing. The passive concept draws the market in the direction of excellence. Even office promotion seems now to be adopting the passive concept with large office tower projects to passive standards.

Project owners, architects, engineers, businesses: all have seized hold of the knowledge and expertise that academics and industrial construction companies once proclaimed to be inaccessible and too expensive! It is this social phenomenon of "knowledge-seizing" that is the strength of passive building and explains why it is experienced as a creative commitment going well beyond the technical questions involved. This is why research is continuing both into materials and equipment and at the architectural level. The process is tangibly open, curiosity-raising and demanding. It is a source of new developments and questions existing certainties (when will we arrive at passive building without mechanical ventilation?[35]).

1.1.5.3. The standard and its derivatives

Fundamentally, the criteria defined by the PHI for different climates in Germany are applicable throughout Belgium, with its similar weather conditions. Unlike the PEB, the PHPP software always uses files representative of local weather conditions. At international level, the PHI and many countries have questioned the universality of the passive criteria. Some have adapted (Finland) or supplemented (USA) them.[36] But whatever the adjustments made here and there, the consistency of the passive approach has led to its adoption by several international organizations.[37]

If the original standard remains the only valid certification reference, it has been adapted by governments to take account of local regulations or situations. In 2010, the city of Aachen created its own standard[38], as did the Brussels-Capital Region with its EPB "Passive 2015" rules, or the Grand Duchy of Luxembourg, where an adapted passive standard will be the norm in 2017.

www.brusselpassief.be

1.2. energy concepts and behaviour of the building

1.2.1. Energy balances

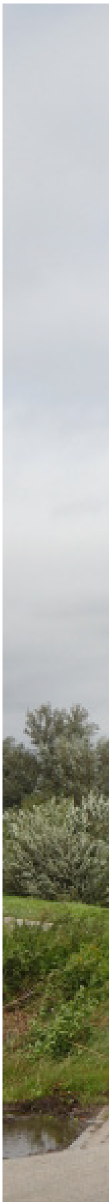
Thermal comfort is achieved in a building when heat inputs offset het losses. These inputs either cost money (heating) or are free of charge (solar and internal inputs). To reduce the need for heating (NHR), we must (1) reduce losses and (2) make optimal use of free inputs. It is this dual role that is played by the three basic principles of passive design: reinforced insulation, airtightness, and heat recovery through the ventilation process. These principles apply to any building, whether certified passive or not, residential or tertiary.

1.2.1.1. Reducing heat loss

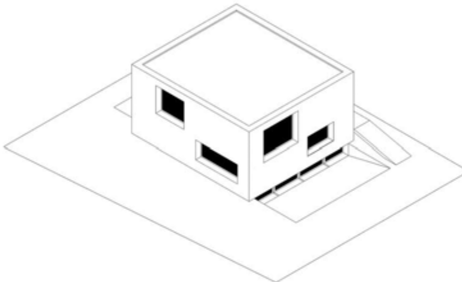
Any building functions as a “bioclimatic processor”: heat transfers occur naturally because the building generates temperature variations ΔT between the inside and the outside. The constructional features of the building determine the total heat loss LB [W/K]: this is the energy passing every second [W = J/s] through the building for a *ΔTT of 1° K.

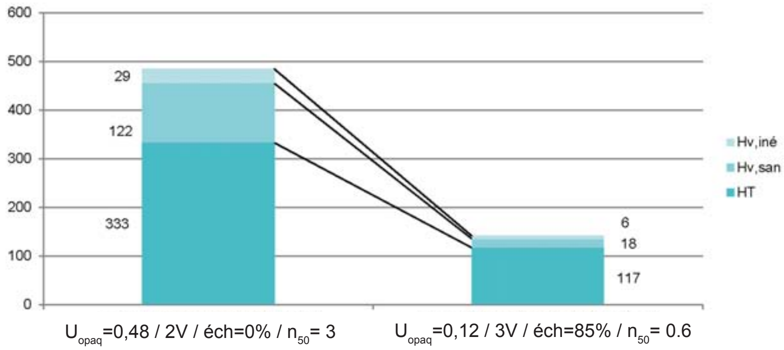
LB depends on (1) the insulation (U, thermal bridges), air changes linked to (2) the ventilation (with a portion of the heat being recoverable) and (3) leakage in the outer ‘envelope’ of the building. Increasing the insulation and airtightness and using a heat exchanger serve to reduce heat loss, as illustrated for a small reference building[40]:

To calculate the effective heat loss of the building we must then evaluate ΔT and obtain a heat loss figure [W] L = LB* ΔT. It remains to estimate the length of time that this heat loss is applicable to the building: this is determined in Degree-Days (DD).



House GBL | *Lokeren* | *Gert Stuyven & Bea Hageman* | architect: *BLAF architecten*





Reduction of heat loss P_B (W/K)

1.2.1.2. Defining Degree-Days

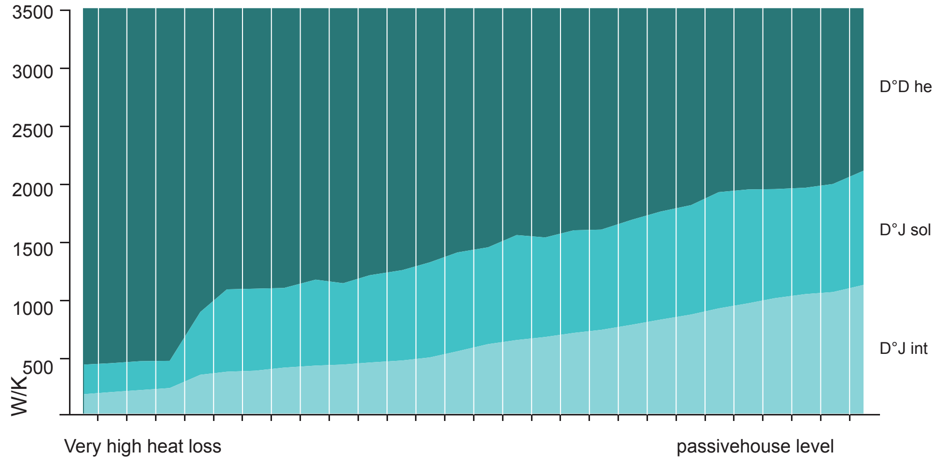
Degree-Days (DD) measure the daily temperature difference between inside and outside that has to be bridged. This value characterizes the climate of a particular place: the figure for Uccle, for example, is 3286 DD during the heating season (for Tint = 20° C).

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
T_{int}	20	20	20	20	20	20	20	20	20	
$T_{ext\ mav,\ Uccle}$	15	11.2	6.3	3.5	3.9	3.2	5.9	9.2	13.3	7.96
ΔT° C	5	8.8	13.7	16.5	16.8	16.1	14.1	10.8	6.7	12
$days_{month}$	30	31	30	31	31	28	31	30	31	273
$D°D_{month}$	150	273	411	512	521	451	437	324	208	3286

In buildings, the temperature difference is bridged with 3 types of heat input: internal inputs generated by the fact of its being occupied (body heat, electrical appliances, lighting, etc.), passive solar inputs through the windows and, where the first two are insufficient, heating. In other words:

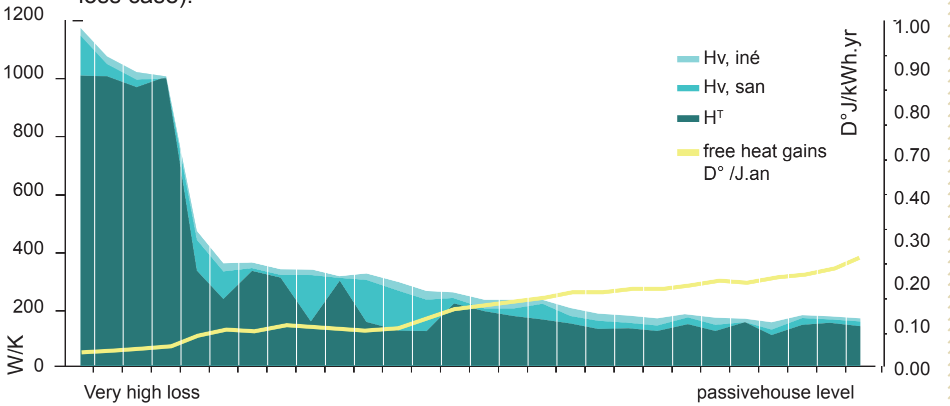
$$D°D_{heating\ season} = D°D_{interior} + D°D_{solar} + D°D_{heating}$$

Insulation, airtightness and heat recovery reduce the share of active heating ($DD^{heating}$ top of graphic next page) by making optimal use of solar and internal inputs: the heating requirement is lowered by better use of solar and internal inputs, depending on the intended use (residential or tertiary[41]) of the building.



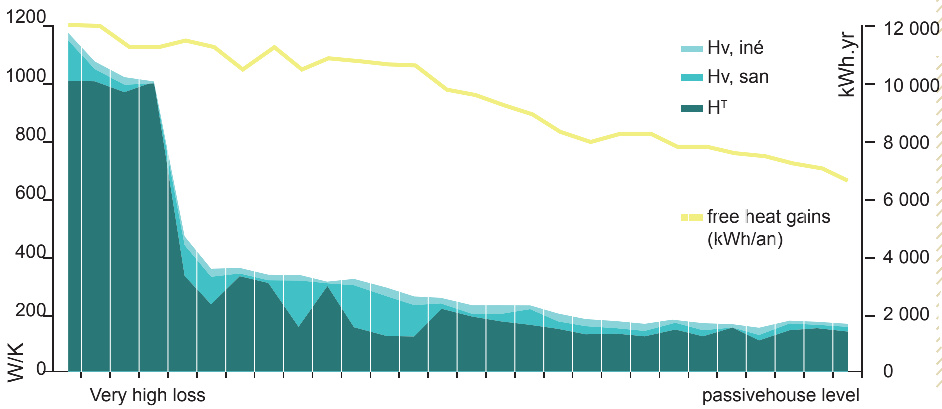
DD: heating, solar gains and internal load

For our reference building, reducing losses to passive level improves the use of free inputs ($DD_{solar+internal}$/kWh) by a factor of 10, with each free kWh contributing to 0.3 DD in passive energy (against 0.03 in the very high heat loss case):



Reduction of losses by free heat gains

Si les D°J gratuits augmentent, la quantité d'énergie gratuite utile pour atteindre T_{int}=20°C diminue en même temps que les déperditions. Ceci rend le bâtiment paradoxalement moins dépendant d'une orientation solaire "idéale".



Reduction of losses by free usefull heat gains

As incident sunlight may be excessive in a particular place, “unnecessary” inputs can increase comfort beyond 20°C in mid-season, but need to be controlled to avoid overheating in summer.[42]

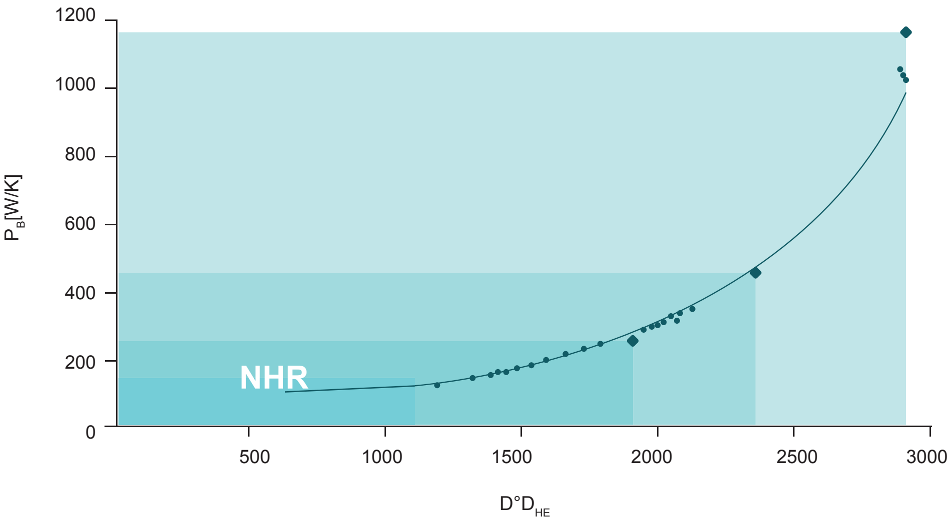
1.2.1.3. Net heating requirement (NHR)

The NHR is the supplementary heating mentioned above:

$$\mathbf{NHR = L_B * D°D_{heating} * 24\ h/d}\ \text{[Wh/year]}$$

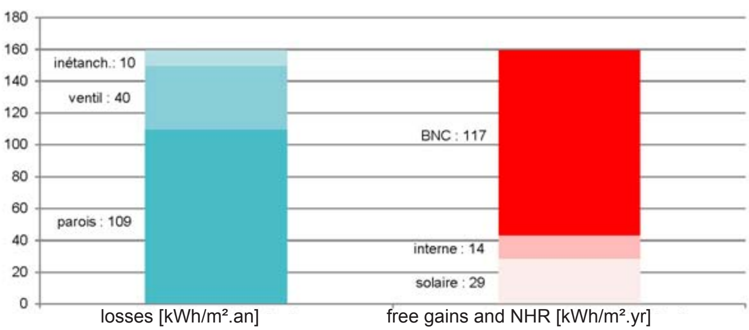
> 1.3.1
p. 44

It is calculated by multiplying a “building” factor (LB W/K) by a “conditions of use” factor (climate and occupation, in DD). The NHR is represented by the rectangle defined by LB and DDheating. Only a combination of measures makes it possible to reduce the NHR to passive level:

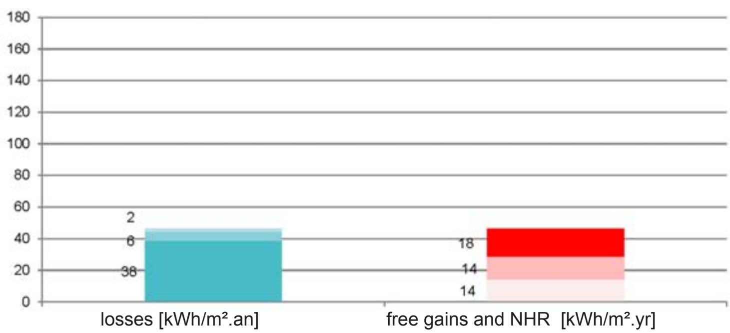


Variation of NHR regarding reduction of L_B and $DD_{heating}$

The curve is not linear because we have seen that DD heating depends on LB. In other words, passive design reduces the supplementary heating requirement by combining the reduction of heat waste and better use of free inputs ($DD_{heating}$). This has the effect of reducing the NHR "by the square". No technical equipment is taken into account here (except the heat exchanger on the bathroom ventilation), i.e. the NHR represents primarily the energy quality of the building's envelope.

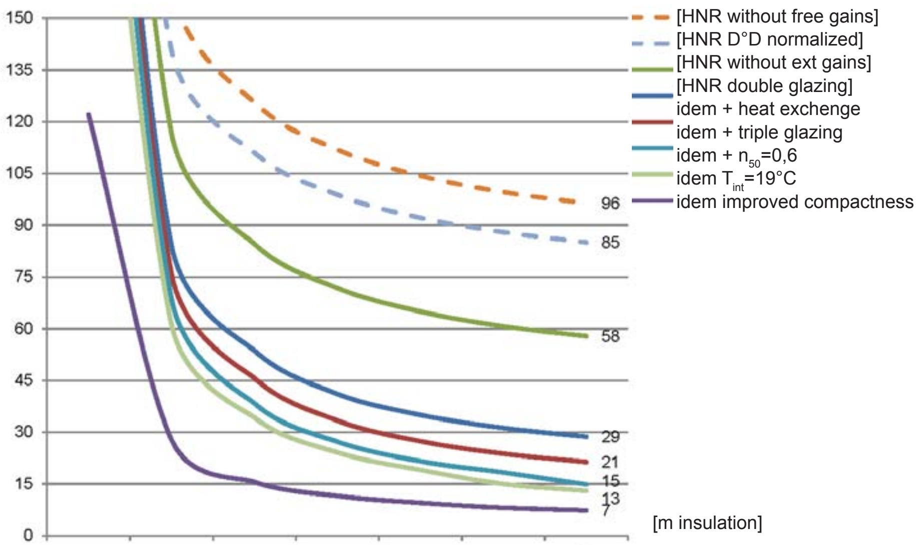


$U_{wal}=0,48$ / 2V / $n_{50}=3$ / $h_{éch}=0\%$



$U_{wall}=0,12$ / 3V / $n_{50}=0,6$ / $h_{ech}=85\%$

For our reference case, a simplistic calculation (without free inputs or with normalized DD) would overestimate the NHR to 96 or 85 kWh/m²/year respectively, whereas the actual values are 58 ($U_{opaque\ walls}$ = 0.10, double glazing, n_{50} = 3 vol/h). Heat recovery (η=85%), triple glazing ($U_{windows}$ = 0.85) and improved airtightness (n_{50} = 0.6) reduce the NHR to 29, 21 and 15 kWh/m²/year. Adjusting the comfort temperature or compactness further reduce the NHR (13, 7).



HNR [kWh/(m².yr)] regarding insulation and passivehouse strategies

1.2.2. What role does insulation play?

Insulation, sealing and heat recovery work together to reduce losses. Insulation is very effective but "ceilings out", with each additional cm less "efficient" than the previous one. This law of diminishing returns makes it impossible to achieve "maximum" isolation (0 W/K), which would necessitate an infinite thickness. Should we despair? Not at all!

1.2.2.1. Insulation also increases the value of free inputs

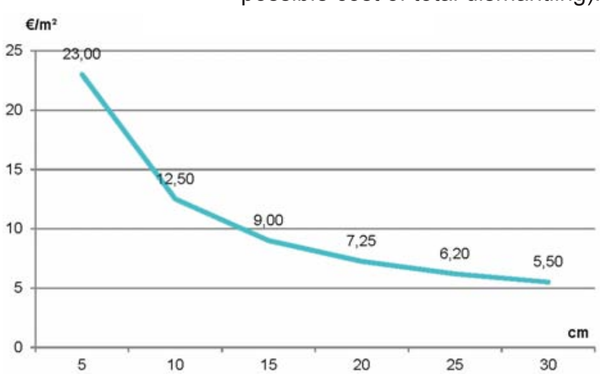
> 1.2.1.3
p. 37

In reality, it is impossible to define the optimal insulation thickness of a simple wall[43]: the calculation makes sense only if it factors in the solar and internal inputs of the building. This is because as well as reducing heat loss through the walls, insulation makes the free inputs more effective. This energy savings effect (graph: NHR reduces from 96 to 58) is often overlooked in a simplistic calculation, but improves the financial return!

1.2.2.2. The cost of insulation is also degressive

The construction price of a building depends on many parameters, including insulation. The most energy-efficient centimetres of insulation are also the most expensive, the following ones considerably less. Comparing the cost per m² to the insulation savings (from U=2 at 0.125 W/m² K), we find that the additional cost is limited for our climate (ΔT = 12 ° C during the heating season).

For example, for insulation blocks with plaster finishing[44], doubling the thickness from 15 to 30% changes the cost/benefit by just 15%. This further supports the initial choice of a thick insulation which prevents subsequent costs. Indeed, to insulate a posteriori over the top of a thin coat of insulation means paying twice the full cost of the first centimetres (without counting the possible cost of total dismantling).



Price per cm [€/m²] - ETICS, source : STO

Cost [€/m²] regarding insulation level [W/m²]

1.2.2.3. Better insulation improves comfort

An non-insulated wall has a surface temperature of 12.5°C in winter, compared with 19.5 ° C for a very well insulated wall. This gives the inhabitant a high level of comfort at lower room temperatures. Given that half of the feeling of comfort is determined by the surface temperature of the walls (and the rest by the room temperature), it is possible to turn down the thermostat with no loss of comfort.

1.2.2.4. Reduced losses limit the required power of heating equipment

Where once a large boiler would have been necessary, a smaller one will suffice. Reducing boiler power also reduces costs.

Thus, insulation, airtightness and heat recovery do much more than reduce heat losses. Calculating the overall real benefits means taking all these different savings into account.

1.2.3. What is the impact of the location?

1.2.3.1. Orientation and density

Taking advantage of the location is a priority in passive design. In urban or rural environments, the site can often naturally integrate passive strategies: patios to cool offices, large south-facing bay windows for housing, cross ventilation for summer comfort, and the like. In dense cities, it is difficult to choose a building's orientation, but party walls and collective housing help save energy, heating equipment and space requirements.

1.2.3.2. Compactness

The compactness of a building measures the ratio between the heated volume and its heat loss surface. Good compactness (C> 2) is an asset in thermal calculations (the envelope through which heat is lost is limited) and also in terms of cost (insulating and sealing the envelope is expensive).

Nonetheless, while high compactness can reduce NHR, it does not reduce other energy consumptions, such as lighting or cooling. If a very compact building receives less daylight (for example through having less outer wall surfaces), it may be unpleasant to live in, with the energy consumption saved on heating possibly reappearing in the form of electric lighting. It may therefore be worth sacrificing a bit of compactness to improve the living qualities of the building and reduce other types of consumption.

1.2.3.3. Openings

The openings are the weak points of any insulation system, but it is also through them that sunlight enters. Their energy balance can be positive when the losses are lower than the solar gains. In this way, large windows can be beneficial to the project, provided that they do not generate overheating in summer.

In housing, it is the NHR that is decisive, with solar inputs favoured by larger openings to the south. Occupation itself (usually in the evening and at night) gives limited internal gains.

For the tertiary sector, especially offices, overheating is often more problematic because occupation is essentially diurnal and significant internal inputs are added to potential solar ones. A simple solution is to provide external solar protections.

> 1.1.2.3
p. 22

1.2.4. The passive "temperament"

Misconceptions abound about passive buildings. It is incorrect to say that

FBZ HQ | *Brussels* | *FBZ* |
architect: *A2M*

one cannot open the windows, but more accurate to say that *one does not have* to open the windows! More broadly, the improved thermal performance of the envelope gives the building a temperament that differs in two respects from that of a traditional construction.

1.2.4.1. Less sensitive to temperature variations

As the heat loss L_B (sensitive to the ΔT factor) is reduced, the ambient temperate inside a passive building (yellow) is less influenced by variation in outside temperatures (blue), with the insulated wall acting as a bioclimatic damper.

If the outside temperature gradually warms, the indoor temperature also rises, but moderately. Conversely, if the heating breaks down in a passive building in winter, the occupant will feel the effects very slowly (because heating input is low) while a traditional building will quickly become uncomfortable. This is an advantage (one has more time to react) and a disadvantage (heating up again also takes time after a period of vacancy).

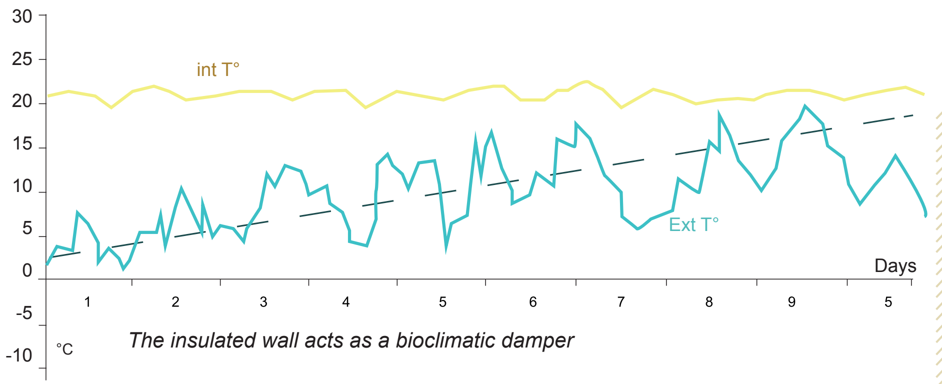
1.2.4.2. More sensitive to free inputs

> 2.2.2
p. 169

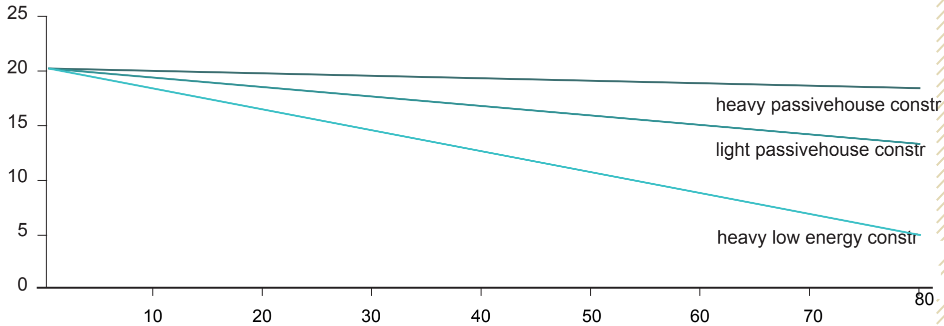
A passive building is more sensitive to changes in internal and solar heat gains. Without heating, a passive building that remains unoccupied in winter (holidays, etc.) cools slowly but inexorably. Similarly, it warms back up slowly. Improving the responsiveness of the building may require overdimensioning the heating system.

> 2.2.2.4
p. 182
> 1.3.1
p. 44
> 1.3.1.2
p. 46

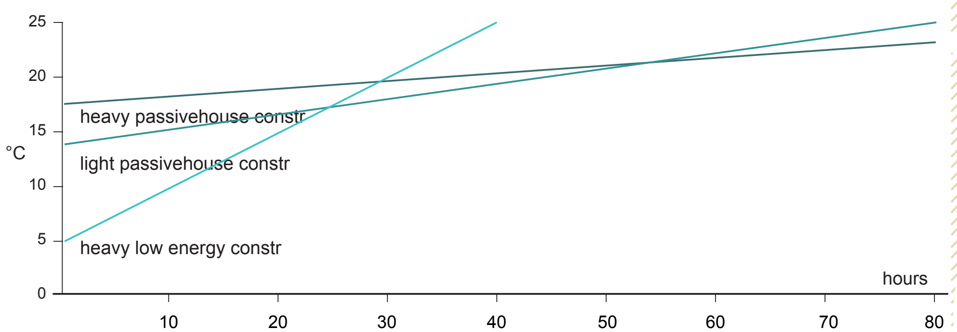
While internal inputs are fairly predictable, solar gains are more variable. That is why the standard has incorporated a criterion aimed at limiting the risk of overheating to 5% of occupancy time. All passive buildings therefore incorporate this feature. In Belgium, with an average cloud cover above 50%, normal occupation (sunshading, airing naturally, etc.) is generally sufficient to maintain a very high level of comfort. In tertiary buildings, higher internal loads call for dynamic studies, possibly leading to alternatives to traditional air conditioning.[47]



The insulated wall acts as a bioclimatic damper



Temperature changes after heating turned off



Evolution of T° from heating system restart

1.3. the passive standard and EPB “Passive 2015” criteria

Bernard Deprez
Marny Pietrantonio

"Passive" brings us to the criteria involved in the certification of the passive standard in Belgium, to the PEB "Passive 2015" rules applicable in Brussels, and to the verification processes for regional premiums.

> 1.3.1
p. 44

> 1.3.2
p. 51

The certification criteria are the sole definition of the passive standard in the strict sense. The PEB "Passive 2015" rules are an adaptation that modifies the criteria of the passivehouse standard. Finally, the Regions support energy-efficient construction (including passive) by premiums that change with considerable regularity. The related validation criteria evolve rapidly and are not described here. It is important to check for updates on the sites concerned.

Brussels-Capital: www.Brusselsenvironnement.be

Wallonia : http//energie.wallonie.be

Flanders : www.energiesparen.be

1.3.1. The passive standard

To ensure the energy efficiency of the project, the designer validates a set of criteria and obtains certification using:

> 2.5.1
p. 242

> 2.2.2.4 A
p. 182

- the PHPP spreadsheet, which determines the energy parameters of the building;
- physical control of the airtightness of the building: a test measures the air change rate (n50) by infiltration by subjecting the building to a pressure difference of 50 Pa between inside and outside;
- (possibly) thermodynamic simulation (large tertiary buildings)

Dubrucq housing | Molenbeek-Saint-Jean | Municipality of Molenbeek-Saint-Jean | architect: B-architecten

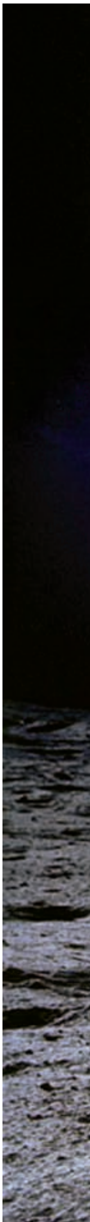
1.3.1.1. PHPP: dimensioning and design assistance

The PHPP spreadsheet is the central validation tool for the passive certification of a building of any type. It at once provides assistance in the design and dimensioning of passive projects and is essential for certification. It comes in the form of an Excel file with multiple tabs that serve to assess all the energy needs of the building (heating, cooling, sanitary hot water, electricity) and its total primary energy consumption. It also offers a computing module for estimating the risk of overheating.

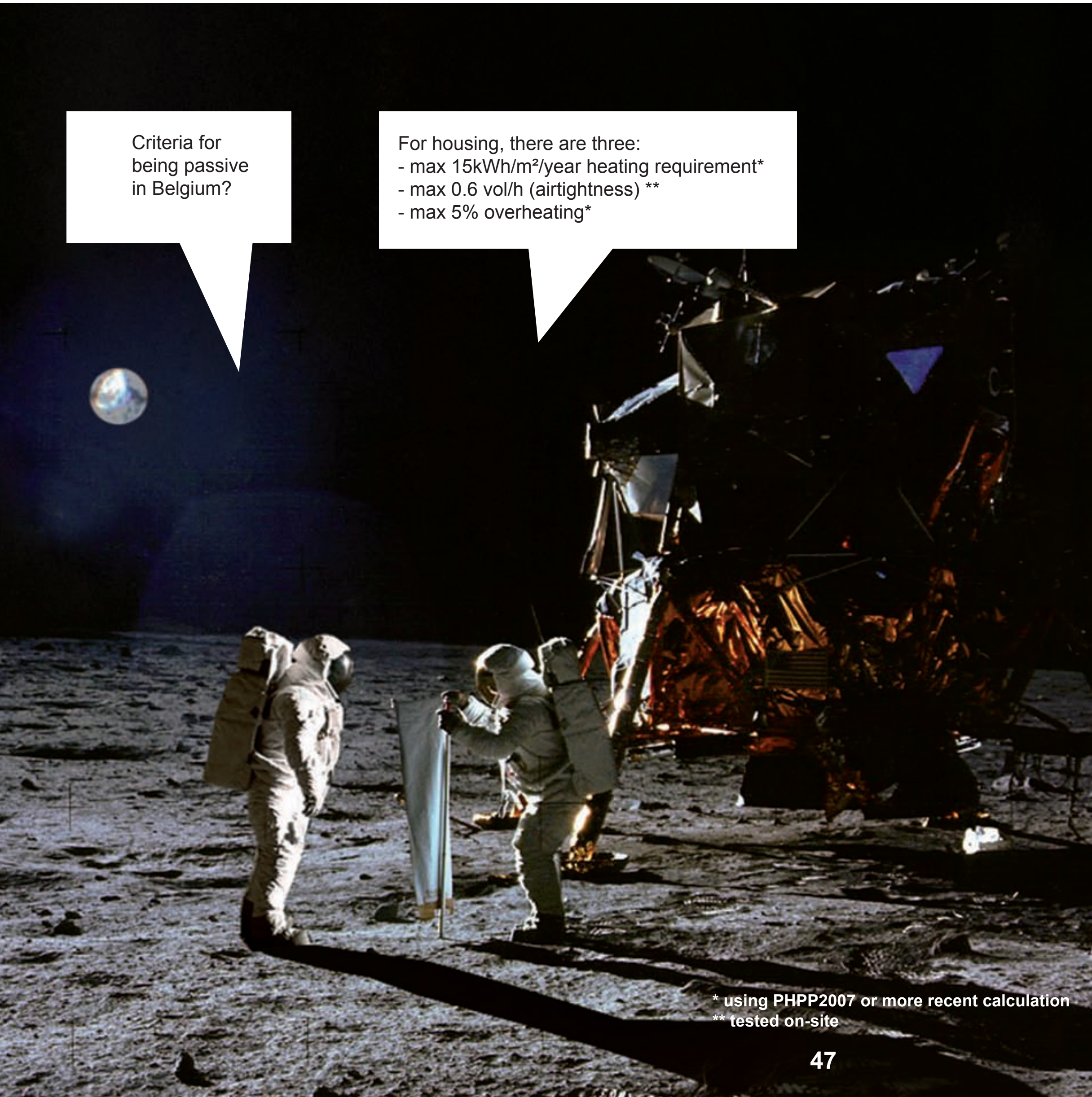
The calculation is monthly and incorporates a whole series of European standards and empirical results. New versions of the software are available today with a “3D” module (Sketchup®) and a “vapour” module (WUFI® Passive). [48]

To spell out the PHPP software encoding rules that need to be followed to obtain a certification or a premium, the passive platforms have written a Vademecum. This document ensures the consistency and neutrality of the certification and is publicly accessible on the platforms’ websites[49]. It is specialized according to the destination of the building (residential or tertiary) for providing the required reference values, defining the calculation methodologies and referencing application standards. This is an evolving tool that also reflects the expertise of construction players. The Vademecum is now considered as an encoding tool, with the PHPP manual serving simply as a commentary on the various sheets.

Finally, we should not that the various versions of the Vademecum are not exhaustive and do not address all the issues that may occur in the encoding. Consultancies are advised to sign up for one or more of the technical introductory courses offered by the platforms.



Photomontage from a photo from the NASA database ©


Criteria for being passive in Belgium?
For housing, there are three:
- max 15kWh/m²/year heating requirement*
- max 0.6 vol/h (airtightness) **
- max 5% overheating*
* using PHPP2007 or more recent calculation
** tested on-site

Brussels Environnement HQ | *Brussels* | *Project T&T* | architect: *Cepezed*

1.3.1.2. Criteria for new and assimilated construction

The PHPP calculation follows the recommendations of the Vademecum in force at the time of submission of the building permit application or more recent ones.

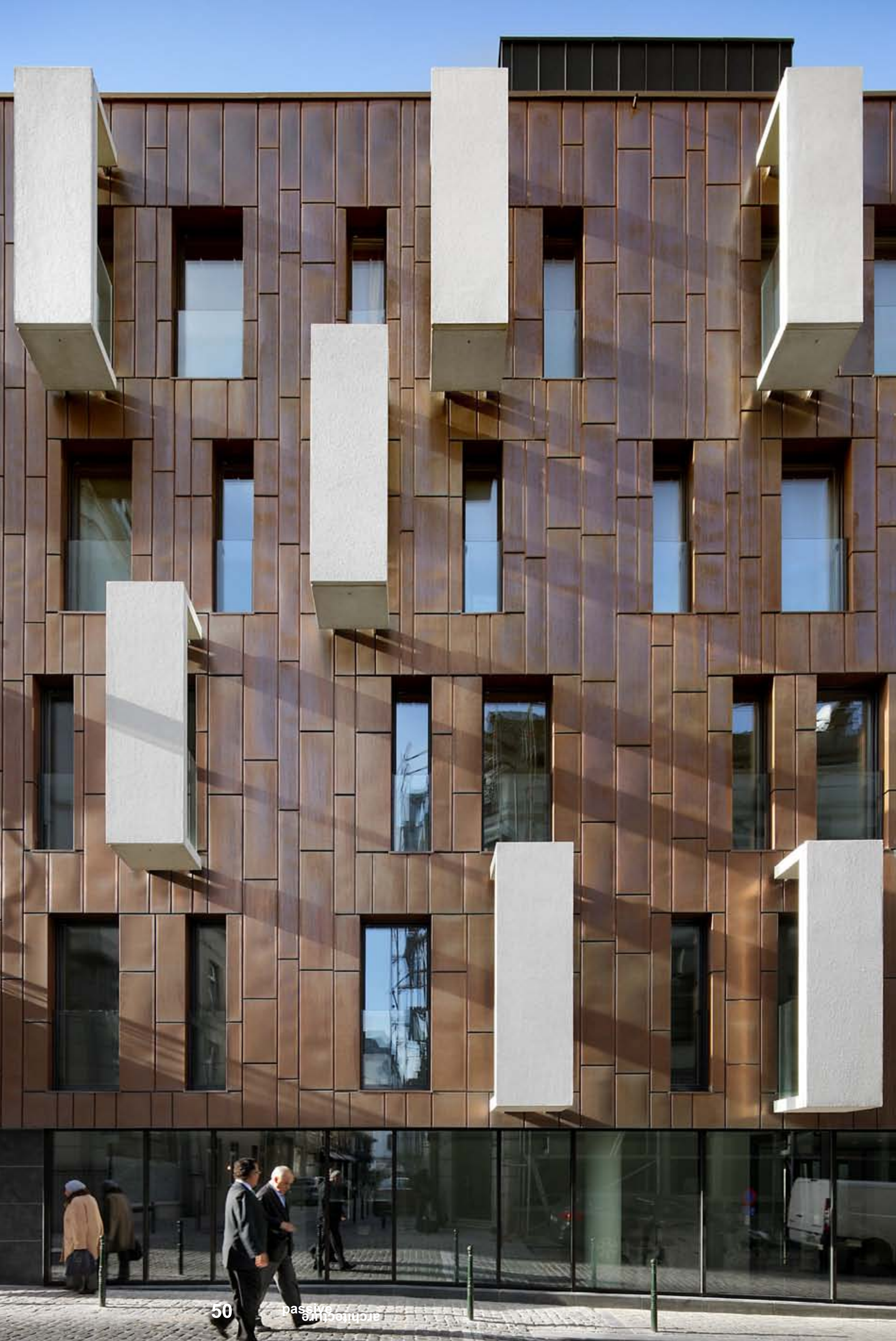
The residential sector includes single-family dwellings, apartments and residential blocks, but excludes nursing homes, shelters, homes for disabled persons and student housing blocks. If a dwelling unit does not include "primary" facilities (bathroom, kitchen, bedroom), it falls within the tertiary sector. If these rooms are present in each unit, but with a shared kitchen or shower, this is collective housing falling under the residential criteria. Certification is by dwelling unit: a building is "passive" if all dwelling units meet the criteria.

The tertiary sector includes all tertiary uses: offices, schools, kindergartens, nursing homes, sports halls, hotels and, more rarely, shops, restaurants, laboratories or hospitals. The criteria are the same, but other calculation assumptions are defined in the Vademecum (internal inputs, legally required indoor temperature, air flow, etc.). It is always advisable for encoders to have someone else validate their assumptions and their calculations of the values in question.

Given these details, every passive building has to meet the following criteria in order to be certified:

> 2.2.2.4
p. 182

	Values to be met in residential buildings (individual/collective)	Values to be met in tertiary buildings
Net energy requirement for heating NHR ≤ kWh/m²/year calculated using the PHPP	15	15
Net energy requirement for cooling NCR ≤ kWh/m²/year calculated using the PHPP	-	15
Air change rate n_{50} ≤ vol/h, measured at a difference of 50 Pa according to NBN EN 13829	0,6	0,6
Overheating percentage (> 25 ° C)% $_{overheat}$ ≤	5% (calculated with PHPP over a full year)	5% (Calculated by dynamic simulation based on working hours according to NBN 15251)
Primary energy consumption PEC kWh_{PE}/m²/annum calculated with the PHPP C is the compactness of the building.	The overall primary energy consumption (excluding equipment) is calculated and mentioned on the certificates in all regions	The specific primary energy consumption calculated with the PHPP software must be less than or equal to CEP ≤ 90 - 2.5 x C



Pepin street housing| *Brussels* | *Kervyn Guillaume, Boels Lucas* | architect: *Conix architects*

1.3.2. EPB “Passivef 2015” in the Brussels-Capital region

The EPB “Passive 2015” requirements that came into force with effect from 1 January 2015 for new and assimilated construction[50] are based on the passive standard criteria, but adapt them to the dense urban context of Brussels where the constraints of party walling, compactness or lack of sunlight owing to neighbouring buildings can make certain requirements of the standard unattainable.

1.3.2.1. The EPB software will replace the PHPP

The calculation is performed using the PEB software. Many calculation assumptions differ from those of the PHPP.[51] This means that buildings meeting the PEB “Passive 2015” are certifiable to the passive standard only if recalculated with the PHPP.

1.3.2.2. The adapted criteria

The criteria of the PEB “Passive 2015” do not strictly correspond to those of the passive standard. They are the outcome of negotiation between government authorities, passive platforms and all professional sectors in Brussels-Capital.[52] It is important to clarify these criteria here, limiting ourselves to those provisions that affect the standard.[53]

A. The net heating requirement (NHR) criterion

Two avenues are available for meeting the NHR requirement:

- a “track A” for situations where the passive criterion of 15 kWh/m²/year is deemed attainable;
- a “track B” for other situations where a new target of X kWh/m²/year

is calculated.

To judge whether the target of 15 kWh/m²/year is attainable, a threshold X is calculated by the EPB software. This incorporates the encoded architectural parameters (walls, windows, orientation, shading, volume, etc.) and compares these with the assumptions described below. Where the X calculated in this way is greater than 15 kWh/m²/year, it becomes the new target.

Assumptions for the calculation of the threshold X:

- $U_{weighted\ average}$ = 0.12 W/m²K for opaque walls;
- $U_{weighted\ average}$ = 0,85 W/m²K for windows and doors;
- taking into account the construction joints using the "PEB-compliant joints" method[54];
- an air change rate n50, by year of filing of the building permit application (BPA), equal to:

Year of the BPA demand	2015	2016	2017	2018
n_{50} [vol/h] assumed for calculating the threshhold X in new building ≤	**1,0**	**0,8**	**0,7**	**0,6**
relaxation of criteria for renovations as-similated to new building	**+20%**			

> 1.3.2.3
p. 55

These assumptions are not criteria to be met but the values set by the PEB software for calculating the threshold X. Provided the building meets the requirements set in the table, the architect is free to choose how to keep within the threshold displayed by the software.

Whatever the specific target (15 or X kWh/m²/year), the EPB software presupposes, in calculating the NHR, the installation of a system D with air heat recovery yield η = 80% in residential (in 75% tertiary) for new units and units assimilated to new. The architect is free to choose the most efficient equipment[55](making the target all the easier to reach) or to prefer another type of ventilation.

In the case of renovations assimilated to new, the NHR is increased by 20% for individual homes and for buildings used as offices and for utilities or education.

B. The criterion of primary energy consumption (PEC)

The EPB introduces **a primary energy criterion** for new and assimilated buildings.

In **residential** construction, the calculation covers heating, hot water and auxiliaries (pumps, fans, pilot burners), less energy produced by cogeneration and/or photovoltaic panels and solar thermal (hot water).

The criterion used by the EPB for new construction is **PEC ≤ 45 kWhPE/m²/year** for track A; this is increased by 1.2*(X-15) for track B. The result is increased by 20% in renovation assimilated to new building.

In **tertiary** construction, the calculation covers heating, cooling, lighting and auxiliaries (pumps, fans, pilot burners), less energy produced by cogeneration and/or solar panels.

The criterion used by the EPB for new construction is **PEC ≤ (95- 2.5*C) kWhPE/m²/year** for track A; this is increased by 1.2* (X-15) for track B. Compactness C is capped at 4. The result is increased by 20% in renovation assimilated to new building.

The calculation here is based on the real technical options.

C. The airtightness criterion

The requirement for an air change rate n_{50} ≤ 0.6 vol/h will apply in 2018. In the meantime, the parameter n50 continues to be used in the calculation of NHR, NCR and PEC: this is the value measured on site during blower door tests. If builders enjoy a respite until 2018, a good n50 remains essential for meeting the other criteria!


1 BCM-425

Maison de l'emploi and kindergarden | Forest | Forest municipality| architect: *A2M*

1.3.2.3. Summary of criteria

Requirements	Individual dwelling	Offices, utilities, education
Net energy requirement for heating NHR ≤ kWh/ m²/year	15 or X	15 or X
Besoin net en énergie de refroidissement BNF ≤ kWh/m².an	-	15
Primary energy consumption PEC ≤ C = compactness (limited to 4) kWh_{EP}/m².yr	45 or 45+(1,2*(X-15))	95-(2.5*C) or (95-(2.5*C))+(1,2*(X-15))
Air change rate n_{50} ≤ [vol/h] measured at a difference of 50 Pa accordance per NBN EN 13829	0,6 (from 2018)	0,6 (from 2018)
Overheating	Max 5% of the time >25°C	(from 2016)
U_{max}/ R_{min}	parts 2 and 3 of Annex XI	parts 2 and 3 of Annex XI
Construction connections	Annex V	Annex V
Ventilation	Annex VI	Annex VII
Technical installations	Annex VIII	Annex VIII

In renovation assimilated to newbuild, the NHR, NCR and PEC requirements are increased by 20%.

References:
5 George **Monbiot**, The Impossibility of Growth, 27.05.2014, www.monbiot.com
6 European Commission, DG Environment, www.cafe-cba.org/assets/baseline_analysis_2000-2020_05-05.pdf
7 **be.passive 18**, p.56.
8 www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-4.html
9 Johan **Rockström** et al, Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 32,www.ecologyandsociety.org/vol14/iss2/art32/
10 **Intergovernmental Panel on Climate Change**, www.ipcc.ch)
11 **be.passive 01**, p.12.
12 When technology improves (for example by being more efficient), users tend to use it more, thereby cancelling some of the expected benefits: this is the rebound effect.
13 **OMA-AMO, Ecofys**, *The Energy Report*; 100% Renewable Energy by 2050, World Wildlife Fund, February 2011, pp. 23, 47, 127. be.passive 07, p.12; Towards 100% renewable energy in Belgium by 2050, www.plan.be
14 Ibidem.
15 **be.passive 18**, p.12.
16 **be.passive 01->18**; 04, Réhab.
17 www.passiv.de> EnerPHit
18 www.bruxellesenvironnement.be > Dossier Bâtiments exemplaires.
19 Regulation on the Energy Performance of Buildings (EPB).
20 Government Accord for the Walloon Region, 2004 to 2009.
21 Developed by StadsOntwerp Mid (SOM, TU Delft, 1979), it was popularized in 1996 under the name of Trias Energetica by the Onderneming voor Nederlandse Energie en Milieu (Novem) (wikipedia).
22 Invented by American scientist Amory **Lovins**, the concept focuses on the production of energy savings (negative Watts) rather than energy production (Watts). See also www.negawatt.org
23 **be.passive 07**, p.88.
24 **be.passive 07**, p.58; 11, p.20.
25 A term frequently found in the Anglo-Saxons world.
26 **be.passive 07**, p.88.
27 **be.passive 15**, p.84; 17, p.78.
28 www.arct.cam.ac.uk/PLEA/Origins.aspx
29 Today it is the university hostel; Korsgaard et al, DTH-No-Energihus, Technical University of Denmark, 1978.
30 http://passipedia.passiv.de/passipedia_de/grundlagen/anmerkungen_zur_geschichte
31 www.passivhaustagung.de/Kran/Passivhaus_Kranichstein.htm.
32 **be.passive 19**, Thema.
33 **be.passive 18**, p.12. Updated figures (May 2014).
34 www.bruxellesenvironnement.be > Dossier Bâtiments exemplaires
35 **be.passive 15**, p.80; 17, p.84.
36 **be.passive 11**, p.44.

Bruyn Ouest housing | *Neder-Over-Heembeek* | *CPAS Brussels city* | architect: *Pierre Blondel*

37 **iPHA**, The International Passive House Association, www.passivehouse-international.org; **GPBC**, Global Passive Building Council, www.globalpassive.net
38 www.aachen.de > Aachener Standard 2010
39 www.bruxellesenvironnement.be > Professionnels > EPB
40 **be.passive 07**, dwelling in Lokeren, BLAF architecten; NHR calculations following NIT 155.
41 **be.passive 02**, p.84.
42 **be.passive 03**, p.54; 03, p.80; 05, p.56;07, p.43;10, p.60; 11, p.48
43 More precisely, this optimum calculation represents only the heat loss effect, not that of the insulation, the impact of which is broader. It corresponds only to the pataphysics an uninhabited, sunless planet!
44 Public supply and installation prices, STO (March 2014).
45 **be.passive 05**, p.58.
46 **be.passive 05**, p.56.
47 **be.passive 03**, p.54.
48 www.passiv.de; www.ibp.fraunhofer.de
49 www.maisonpassive.be et www.passiefhuisplatform.be
50 Units assimilated to new ones are those where the renovation affects more than 75% of the heat loss surface and where all technical installations are replaced; ->www.bruxellesenvironnement.eb> InfoSheet Exigences EPB 2015.
51 **be.passive 04**, p.53, p.56; 05, p.54.
52 **be.passive 13,** p.26.
53 Other changes affect the internal logic of the EPB -> www.bruxellesenvironnement.be> EPB
54 Ibid.
55 In this case the EPB software considers the actual performance of the installation.

construction, structure, technical system, cost efficiency and control

design

02

2.1. Three basic principles

Aline Branders
Julie Willem

The passive building standard does not contain any formal, material or aesthetic restrictions, making it very attractive and extremely flexible. Based mainly on calculations, it is for instance a lot less restrictive than certain current urban planning regulations. Though a large north-facing window would obviously have a negative impact on heating requirements, this can be compensated through the use of a material with better insulation properties, through thicker roof insulation or through a slightly more powerful MVHR.

The purpose of this chapter is not to come up with ready-to-use “recipes”, but instead to look at various points requiring attention and to provide construction strategies, with the overall aim of achieving the optimal **balance** between thermal, aesthetic and energy-saving aspects and construction reality.

As with any high-performance construction, the passive building standard requires particular attention to be paid to the building's envelope, with the focus on three interrelated aspects: **insulation, airtightness** and **ventilation**. Finally, when designing a “low-tech” passive building, there should be no sacrificing of comfort in favour of technical systems. With a building's level of comfort closely connected with its physical properties, **proper coordination** between the client, architect, design team and building company is of key importance for successful project completion.

> 2.2.2.1
p. 172

The section devoted to insulation focuses on heat flows through the building's envelope, while the one on airtightness looks at uncontrolled flows of air (and vapor). The last section looks at the architectural implications of the ventilation system (for the technical aspects).

Having found the ideal place for their new passive house, Jacques and Christine are now planning its construction. The site is magnificent, offering great views. There is only one drawback ... it faces north.

Does this mean they are going to have to spend the rest of their lives looking at a highly insulated wall blocking those great views? Certainly not. There's no regulation stopping one from opening a window in a passive house. And similarly there's nothing to stop one having large north-facing windows.

the 7 errors game

The house on top is passive.

The house on the bottom is standard.

What is the difference?

Solution: There is no visible difference. The passive house consumes 10 times less per year and that cannot be seen, except on the heating bill.

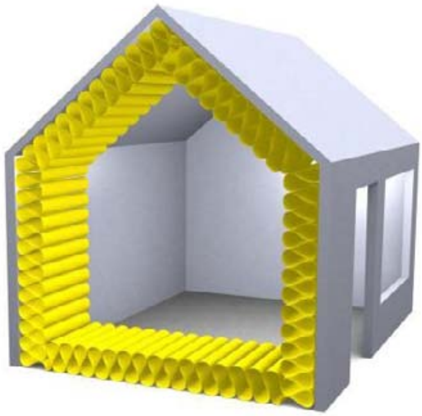
the 7 errors game [2]

The house on the top is passive.

The house on the bottom is passive too.

What is the difference?

Solution: It is not only a matter of differences. The passive standard is a performance to achieve, not a recipe to apply.



2.1.1. Insulation

These days, not properly insulating a new building is deemed irresponsible. With a building's envelope one of its most long-lasting elements, ensuring its quality is a matter of common sense. The principles discussed in this section focus on managing **heat flows** through the building's envelope.

2.1.1.1. Heat flows through the walls

A difference in temperature (ΔT), for example between the inside and outside, naturally results in heat flows affecting the thermal balance. Insulating the walls is a way of counteracting these heat transfers, thus retaining heat (or coolness) within a defined volume.

A. Principle

The ability of a wall to transmit heat is determined by its U value, i.e. its thermal conductivity. Expressed in watts per meter squared kelvin (W/m²K), the value denotes the transfer of heat (in watts) through one square metre of a structure divided by the difference in temperature across the structure. A low U value indicates a high level of insulation, i.e. it is dependent on the thickness of the insulation and on its thermal conductivity coefficient (λ).

Under the passive building standard, the average U value for opaque walls is normally around 0.12 W / m²K. It is generally easier to provide roofs with thick insulation, thereby achieving U values under 0.10 W/m²K.

> 5.2
p. 344

> 2.1.2.2
p. 114

As regards glazing, a distinction is made between Ug (the U value of the "glass", generally between 0.5 and 0.6 W/m²K for triple glazing) and Uf (the U value of the frame, generally between 1.1 and 0.66 W/m²K). Average Uw ("window") values are not much use, as they are dependent on the form of the window in question (including the relationship between frame and glazing). Paradoxically, it is better to have large windows (reducing the proportion of

U

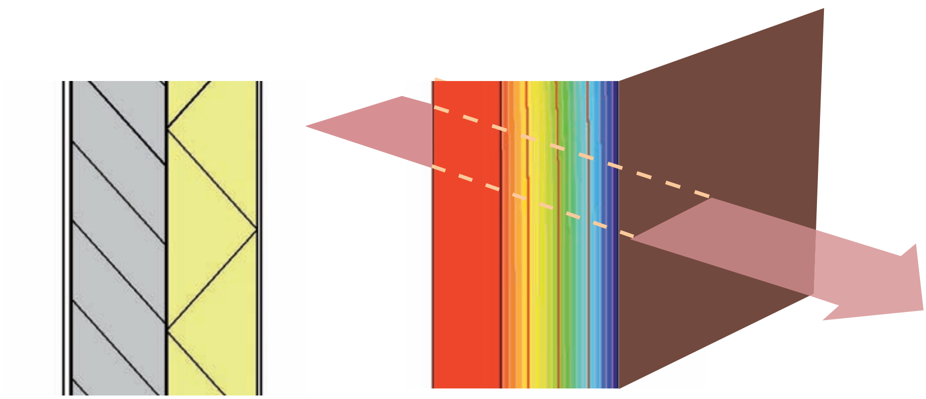
Heat transmission through a wall

Unit W/m^2K

$U = 1 / R$

where
$R = \Sigma (d\ [m] / \lambda\ [W/mK]) + R_{si} + R_{se} + R_a$

where:
di = thickness
λ = the material's thermal conductivity coefficient
Rsi – Rse _ Surface resistance
(Ra = Air space resistance)



frames vis-à-vis glazing) than small windows which become the weakest points in the building's envelope.

A number of different insulating materials have seen the light of day, including cellulose, straw[1], feathers, wood wool and even recycled clothes. However, a material's thermal performance is not the only criterion needing to be taken into account: its use also has to be considered. For example, when a load is applied, the insulation material must be able to resist compression. Similarly, if the wall will be conducting vapor, the material should preferably "breathe".

> 2.1.1.3
p. 95

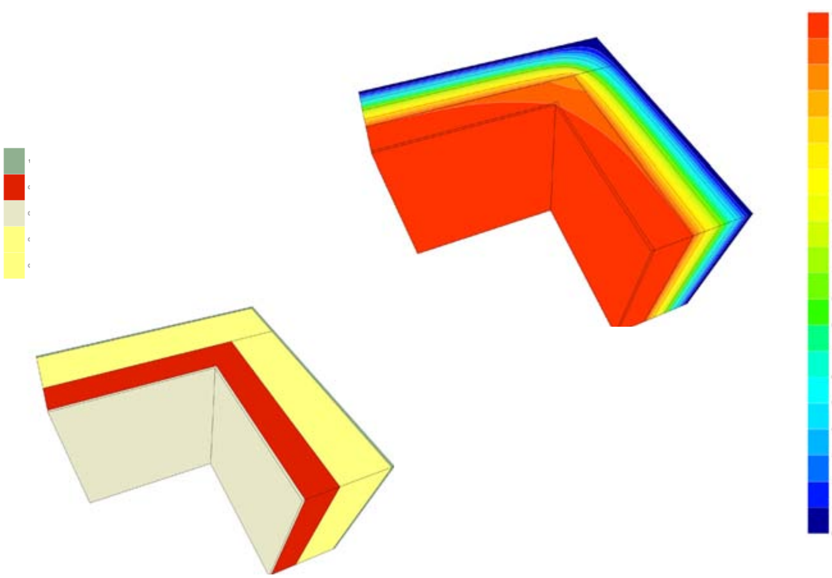
B. In pratice

The effectiveness of any insulation is dependent on its being consistently applied to the whole of the building's envelope (“insulation continuity”). Dependent on the building's structure, there are three main ways of insulating external walls[2].

1) External insulation

The easiest was to apply insulation, especially for brick-built constructions, is to do it externally. Using currently available insulation materials, its thickness will generally be between 20 and 30 cm. It can be fitted using either adhesive or mechanical fittings, whereby a thick layer of insulation will often require the latter).

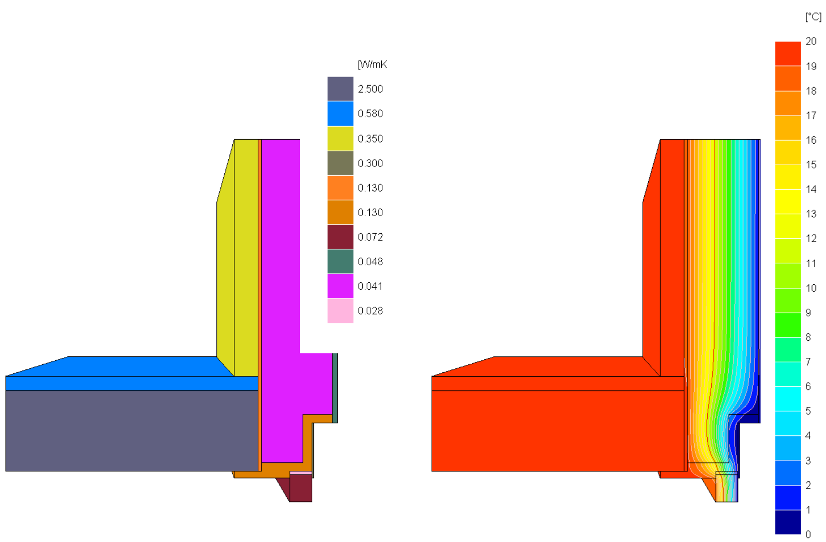
A further possibility is to construct a secondary external structure made of timber frames filled with insulation material.



IPFC | Nivelles | Province of Brabant wallon | architect: A2M

2) Cavity wall insulation

To reduce the thickness of the walls, a further option involves creating a cavity wall into which insulation (e.g. cellulose) is then blown. A "lightweight" timber-framed cavity wall will have structural and acoustic limits, though it is possible to overcome these using a combined structure made up of heavy concrete blocks and columns, combined with a lightweight timber casing as the façade.



In this case the envelope is more sensitive to openings and subsequent modifications. Where necessary, a fireproof layer may need to be added on the inside, thereby increasing the façade's thickness. The timber casing can be prefabricated or made on site.

However, there are also a number of passive building projects where the walls are made entirely of wood.

Combined structure: Crèche and partments[3]

Crèche Saint-François | Schaerbeek | Municipality of Saint-Josse-Ten-Noode | architect: O2 architects

Close-up view of the timber casing[4]

IPFC | Nivelles | Province of Brabant wallon | architect: A2M

Housing units in wooden bearing structure [5]

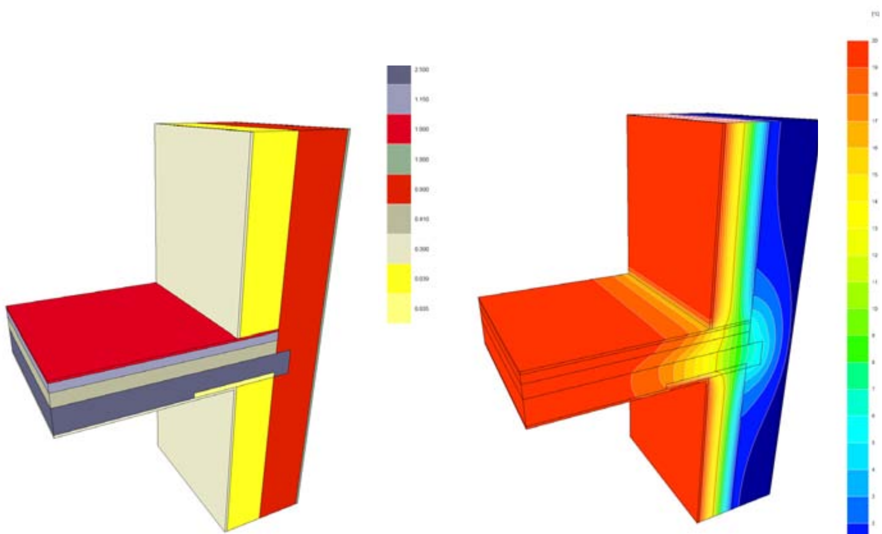
Logements rue Fin | Molenbeek-Saint-Jean | Fonds du Logements de la Région de Bruxelles-Capitale | architecte: Carnoy-Crayon

> 2.1.1.2
p. 72

CPAS de Forest | Forest | Municipality of Forest | architect: A2M

3) Inside insulation

As a way of controlling heat transfers, inside insulation is more complex as it generally has to overcome structural obstacles (floor slabs, shear walls, etc.). Although this method presents hygrothermal and mechanical risks, it is often used in refurbishment projects for technical, cost-saving, planning or ownership reasons which make inside insulation the only feasible option.



2.1.1.2. Linear thermal bridges

The curse of all insulation projects, thermal bridges have a terrible reputation. However, they cannot be avoided, as any insulation - whether applied externally, internally or within a cavity wall - is subject to obstacles and modifications altering heat transfers. Whether modifications to materials, the geometry or junctions between different elements are involved, these need to be taken into account when calculating a building's overall heat loss. The heat loss of a building's envelope via thermal transmittance is induced not only by thermal transfers through the walls, but also by linear disruptions (window frames, changes in thickness / materials, corners, parapet walls, foundations, etc.) and non-linear disruptions (anchor points, columns, etc.).

A. Principle

In the same way as the U value expresses a surface's thermal conductivity, the linear thermal transmittance coefficient Ψ (Psi) denotes the heat transfer (loss) through a linear junction. Expressed in W/mK, the Psi value denotes the heat passing through 1 m of a junction between two environments where the difference in temperature is 1 K.

In the diagram next page, a window frame is modelled using calculation software (inside temperature: 20°C; outside temperature: 0°C). We see that the similar temperature curves (isotherms) remain parallel within the wall, though start curving the nearer they get to the junction. To evaluate this disruption, the software calculates the "real" heat flow through the junction and then deducts the "arithmetic" flow of the surfaces (fictitiously calculated as if the curves remained parallel). This calculation allows us to exactly quantify the disruption caused by the linear junction.

> 2.1.2.2 c
p. 118

It is important in the design stage to look closely at such details with a view to reducing as far as possible any heat losses due to linear junctions.

Ψ

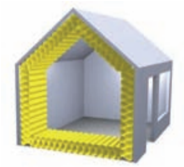
Linear thermal bridge

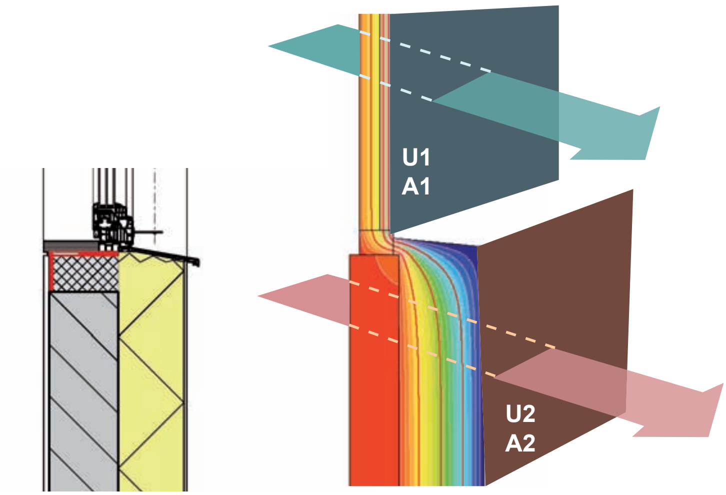
unit = W/mK

$$\Psi = \frac{Q2 - Q1}{L * (\theta int - \theta ext)}$$

where

Q2 = calculated heat flow
Q1 = Σ (Ai * Ui * θint)





However, even though it is easier to meet passive building standard criteria with a construction free of any thermal bridges, this is not really realistic, especially as two minimum conditions need to be met:

- •the building's specific net heating requirement must be significantly lower than 15 kWh / m² p.a. in the design phase, thus allowing for a margin of safety;
- •the solution must not create new problems such as a risk of surface condensation.

The Ψ value is not sufficient to eliminate all risk of surface condensation[6]. However, the "temperature factor" ft provides an indication of the risk of condensation from individual heat flows. This method compares the minimum temperatures of inside surfaces and of environments.

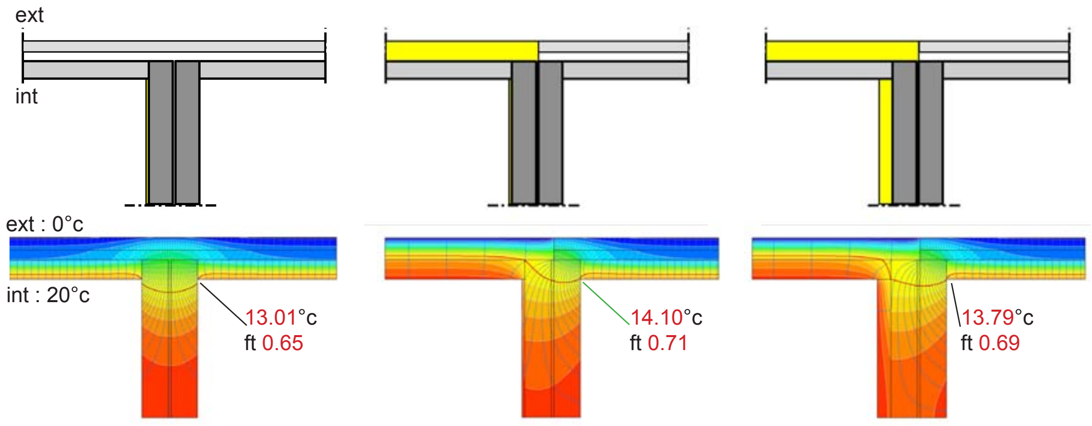
FT temperature factor:

$$ft = \frac{Tsurf\ \mathrm{int} - T\ ext}{T\ \mathrm{int} - Text} > 0{,}7$$ [7]

Relationship between the minimum difference in temperature of inside and outside surfaces and the maximum difference in the inside and outside temperature.

> 2.3.2.2
p. 210

In a Belgian climate, this factor cannot be lower than 0.7, i.e. corresponding to a minimum temperature of 12°C under normal activity conditions (living room, bedroom, office).



Junction between a party wall and the facade building wall

Though this limit allows us to rule out the main problems associated with condensation, it is not sufficient to cover exceptional situations such as rooms with higher humidity levels (e.g. a bathroom, kitchen or swimming pool).

B. In practice

1) Foundations

Among the most sensitive items of a building's envelope, the foundations present a range of constraints related to the building's construction and overall stability. Even if heat loss to the ground is less important than that of the roof to the outside, a number of projects calculated down to the last penny look to save every possible kWh. This is why we hear about piles insulated with polyurethane or other footings encased in polystyrene.

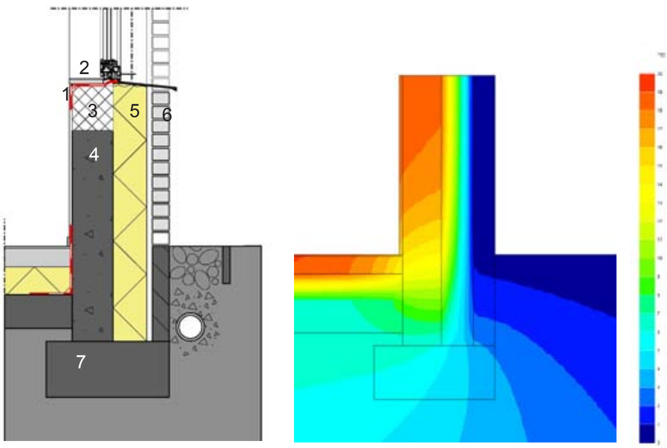
Not only can such solutions endanger a building's stability, but they also risk swallowing up a major slice of the construction budget. Here as well, proper coordination plays a vital role: would it not be better to apply a bit more roof insulation, to insulate the ground-floor columns or to use more effective façade insulation? What is the actual impact of the selected solution on the building's overall energy footprint?

The foundations of facades insulated on the outside often raise the following question: how far down does the insulation have to go to cancel out the thermal bridge? However it is not just the depth that matters. The whole project needs to be taken into consideration when analysing the impact:

- how long a timeframe is being considered?
- what is the project's overall energy footprint?
- is there any health risk?

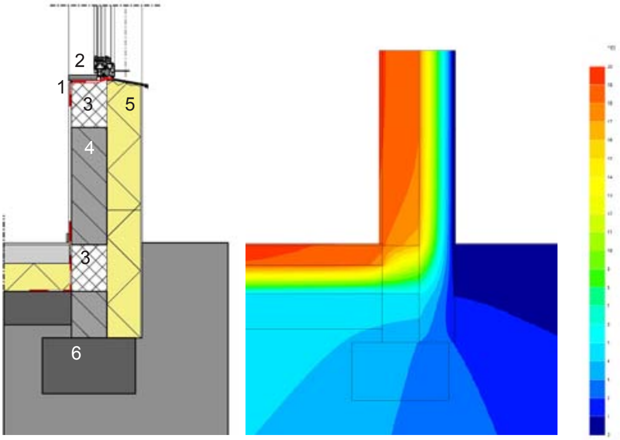
Finally, there is always the practical aspect: if the foundations start 60 cm deep and only 50 cm of insulation is needed from a thermal point of view, it is a lot easier (and better) to just place insulation against the foundations.

1 plaster
2 window sill on air tightness strip
3 Xella© light aerated concrete block
4 concrete wall
5 Neopor© graphite-impregnated EPS insulator
6 Betorix© block cladding
7 reinforced concrete foundation



Junction with no insulation block in the brickwork: Ψ=0,27 W/m.K

1 plaster
2 window sill on air tightness strip
3 Xella© light aerated concrete block
4 concrete wall
5 Neopor© graphite-impregnated EPS insulator
6 reinforced concrete foundation

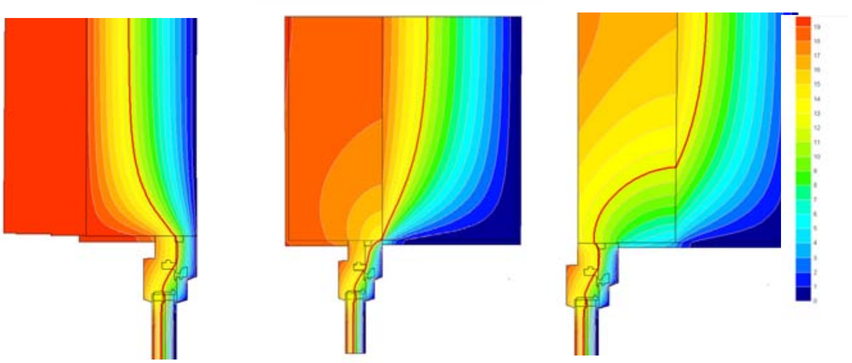


Junction including an insulation block in the brickwork: Ψ= - 0,02 W/m.K

2) Window frames

Due to the change in the building materials used, a linear disruption occurs where the windows join with the walls. Even if seemingly not that harmful, such disruptions are to be found repeated throughout the building and can have an impact amounting to several kWh/m² p.a. on the overall energy footprint.

The position of the frame in relation to the insulation also plays a determining role, as we can see in two extreme external insulation examples:

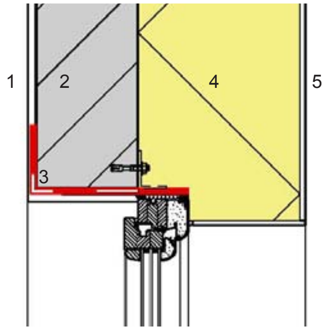


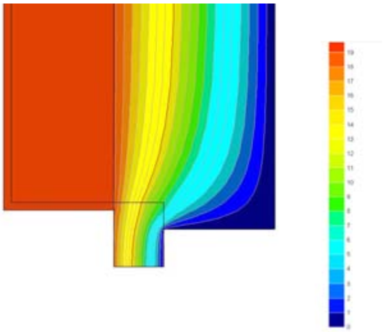
Ψ= - 0,11 W/m.K *Ψ= 0,44 W/m.K* *Ψ= 0,50 W/m.K*

The 12°C isotherm is in red. In the second example, it can be seen to be getting dangerously close to the inside surface, with the wall approaching 13°C. This situation, as well as being uncomfortable for an occupant, also brings with it the risk of condensation.

From a strictly thermal point of view, the frame's optimal position is when it is flush with the insulation. This is quite simple to achieve when for example the insulation is integrated in a timber structure, but more complex when the window is part of a brick-built wall, where this would lead to the frame jutting out into the outside insulation. This complicates the fitting of windows (corner irons, cuts, junctions).

1 plaster
2 concrete block
3 air tightness
4 Neopor© graphite-impregnated EPS insulator
5 STO© external coating

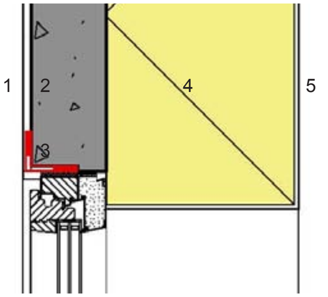


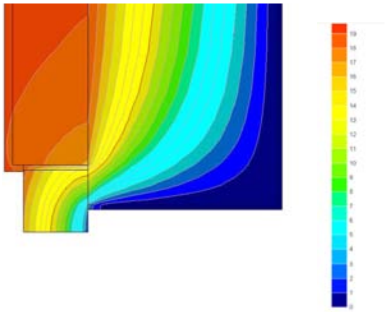


Ψ= *-0,11 W/m.K*

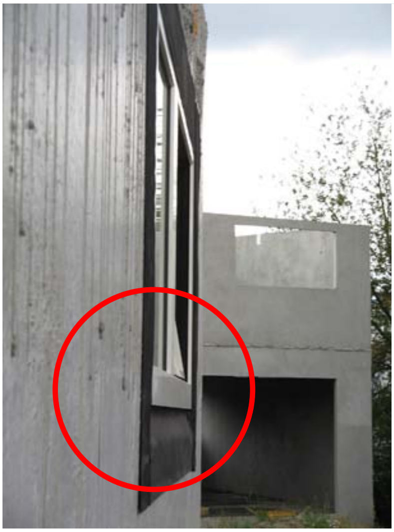
From a practical and cost-efficient angle, a good solution is to have the fixed part of the frame itself covered by the external insulation, thereby reducing the negative impact of the thermal bridge without causing any undue installation work. From a thermal point of view, though this method is not optimal, it does not require lots of cuts in the insulation and allows the insulation to be fixed to a smooth surface, thereby speeding up installation and keeping costs down. Last but not least, the result is better in terms of continuous insulation.

1 plaster
2 reinforced concrete wall
3 air tightness
4 Neopor© graphite-impregnated EPS isolation
5 STO© external coating





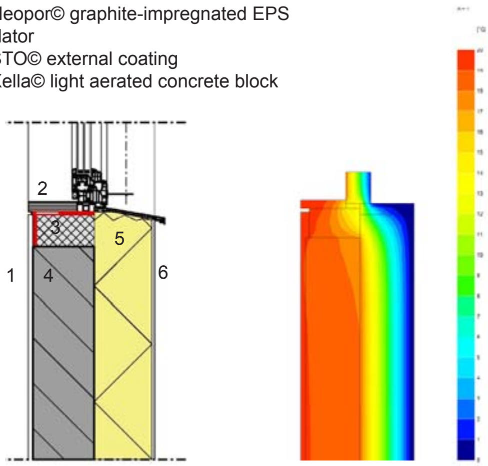
Ψ= -0.12 W/m.K



This method implies specific attention being accorded to the bottom of the frame, as the insulation must not cover the window sill. Several solutions ensuring insulation continuity are available:

- extending the frame's bottom section,

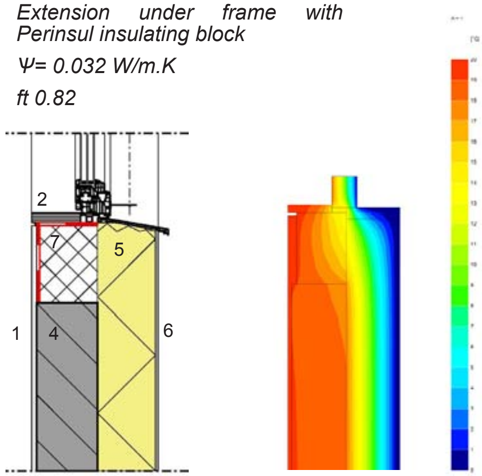
1 plaster
2 window sill on air tightness strip
3 Perinsul insulating block
4 concrete block
5 Neopor© graphite-impregnated EPS isolator
6 STO© external coating
7 Xella© light aerated concrete block



Extension under frame with Perinsul insulating block

Ψ= 0.032 W/m.K

ft 0.82



Extension under frame with light aerated concrete block

Ψ= 0.028 W/m.K

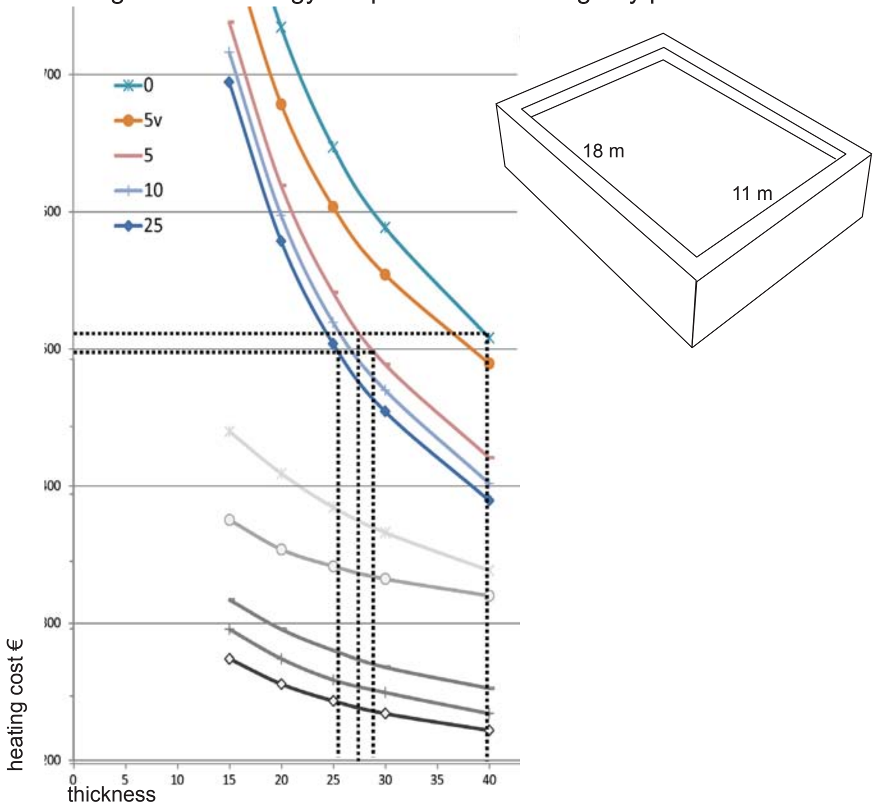
ft 0.82

- where a brick-built wall is involved, installing a layer of insulating blocks under the sill[8].

This type of junction represents a good compromise between the thermal footprint and ease of installation. Such solutions are often dependent on the quality of collaboration and the flexibility of the project's design and construction team.

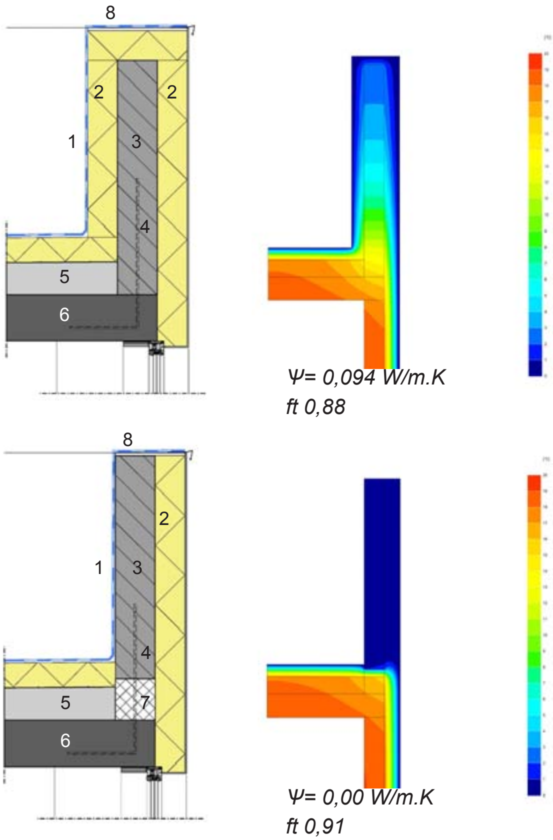
3) Parapet walls

Dependent on their form and how they are implemented, junctions with a parapet wall can have a major or absolutely negligible effect, and it is important to determine the influence of such a junction on the building's overall energy footprint before setting any priorities.



Comparison of two types of roof and the cost of insulation / parapet wall

There are several ways of limiting this thermal bridge, the most common of which is to completely cover it with insulation. Though this solution is interesting from a thermal angle, it raises other problems, such as how to fix coping stones. Other solutions involve building the wall with insulating blocks or including a thermal barrier in the wall.



1 watererproof membrane
2 Neopor© graphite-impregnated EPS insulation
3 concrete block
4 anchoring
5 screed concrete
6 reinforced concrete slab
7 Perinsul© insulating block
8 aluminium wall covering

Comparison between a parapet wall encased with insulation material and one with a thermal barrier.

4) Architectural details

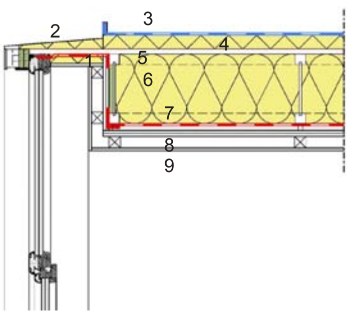
Apart from the strictly thermal, cost and structural aspects, the aesthetic angle is also important for certain details. Why not immunise certain project features from this kWh quest, especially where aesthetics seem to be of greater importance? There's nothing wrong with accepting a detail with sub-optimal thermal performance, especially when it can be compensated through applying thicker insulation or using building materials with a better energy performance.

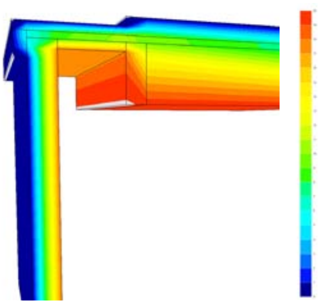
As an example, the diagram below shows a junction with sub-optimal

Holcim HQ | Nivelles | Thomas et Piron | architect: A2M

thermal properties. Yet all that needs to be done is to increase the thickness of the insulation by a few centimetres to achieve the required thermal performance. In doing so, we can avoid the heavy appearance of a thick cornice on the façade. This type of choice, made for instance in favour of aesthetics, is acceptable in a passive building project as long as the overall energy footprint is not unduly impacted (i.e. remaining below 15 kWh/m² p.a.) and as long as no health risks (e.g. mould) are involved.

1 aluminium cover on frame profile
2 aluminium sheet
3 airtightness
4 rock wool insulator
5 SRN panel
6 cellulose insulator in F J1 profile
7 vapor barrier
8 plasterboard panel 2 x RF 30
9 plasterboard panel





Ψ= 0,27 W/m.K

In the case of balconies, other than the renowned separate metal constructions typical of the Vauban neighbourhood in Freiburg im Breisgau in Germany, products known in Belgium for many years, such as frames with integrated thermal barriers, can be used.

> 2.3.2.3
p. 211

9

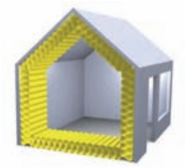
Connection for balcony, source: Schock[9]

A further possibility is to use different thicknesses of insulation on a façade, for instance to hide metal columns.

5) Inside insulation

When having to resort to inside insulation, greater attention generally needs to be paid to details. In any refurbishment project, it is quite common that certain thermal bridges cannot be fully eliminated. Their impact nevertheless needs to be taken into account, checking:

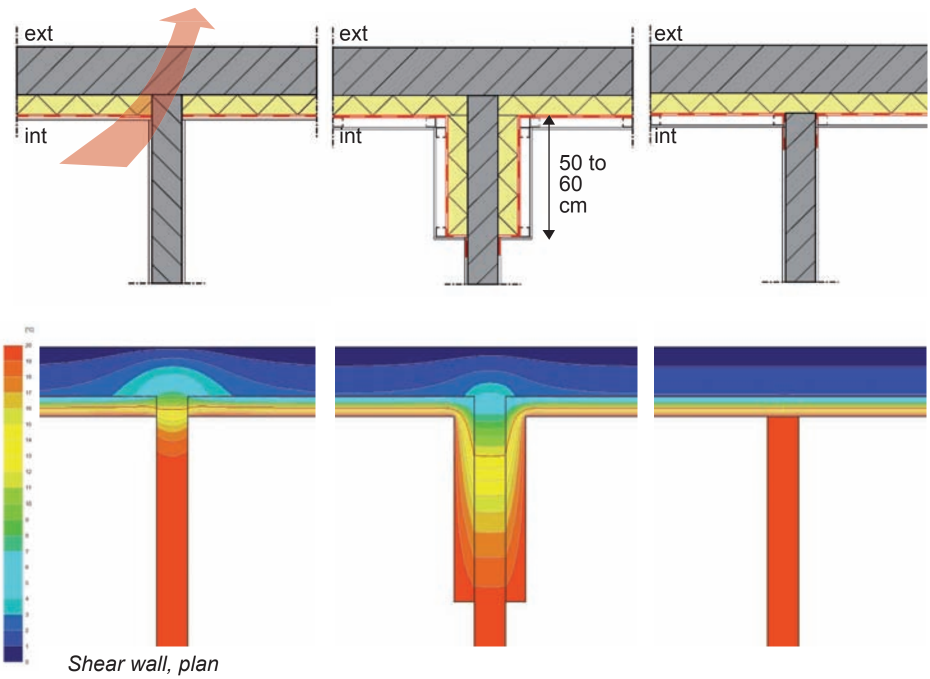
- their influence on the building's overall heating requirement,
- the risk of condensation associated with the lower temperature of an inside surface parallel to a thermal bridge.



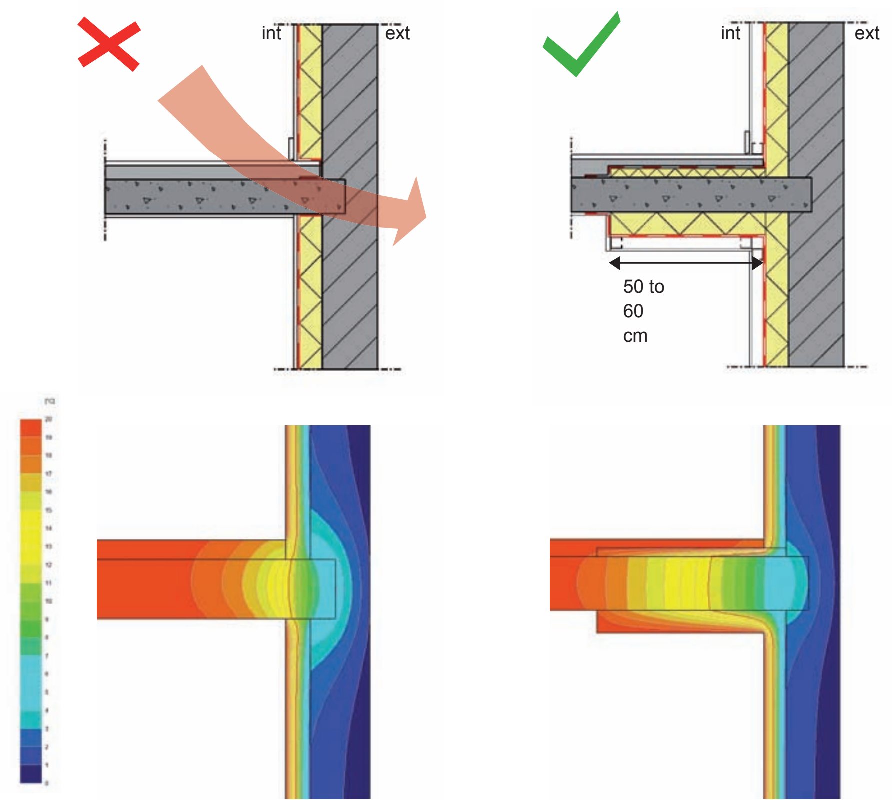
- *Shear wall or concrete slab*

Junctions between shear walls or floor slabs and outer walls insulated on the inside constitute a thermal bridge. The ideal solution would be to cut through the wall or slab to ensure insulation continuity. However, in practice such a solution is generally quite costly and brings with it stability problems. Occasional anchors will generally be needed to brace the façade.

A simpler solution is to add insulation to the element causing the thermal bridge over a certain breadth. Although the thermal bridge is not completely eliminated, its impact can be greatly reduced. As the dew point is not reached on the surface, surface condensation is avoided.



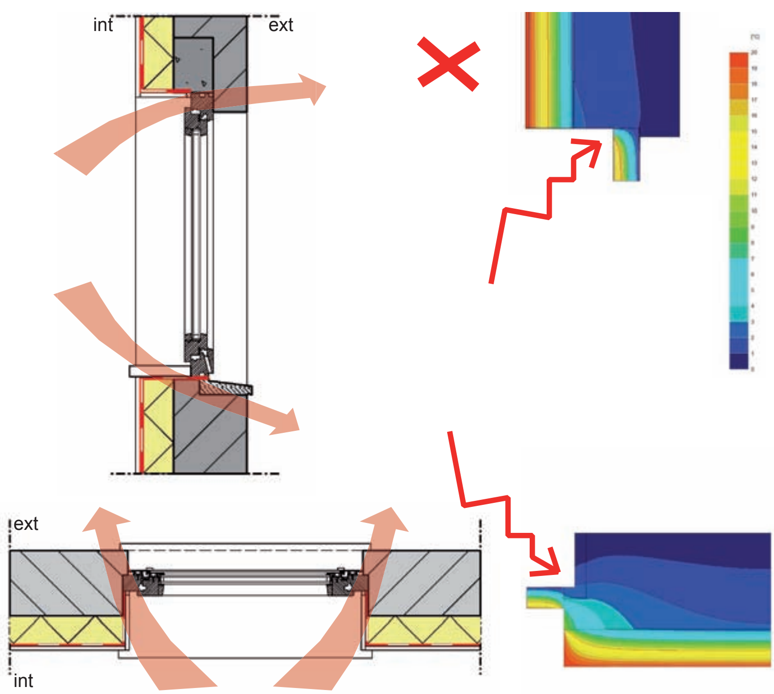
Shear wall, plan



Slab in external wall, cross section view

- Window frames

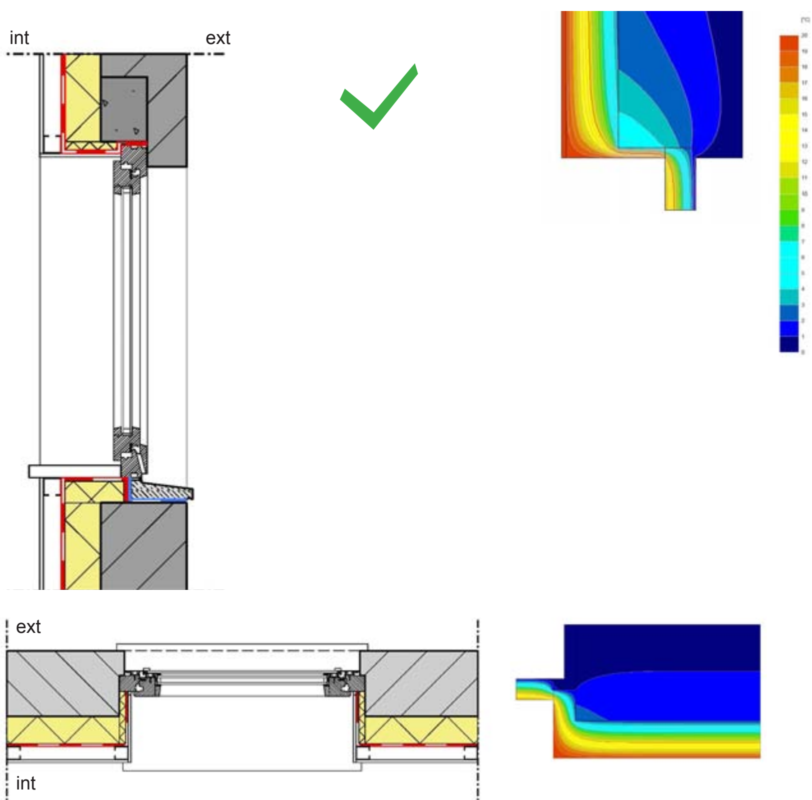
Insulation continuity is also a concern when dealing with window frames, both to improve thermal performance and to avoid any surface condensation parallel to the thermal bridge. When refurbishing a building, this often results in reducing the size of the window's bay (dependent on the thickness of the insulation). In certain cases, one can think about widening the bay to optimise solar gains, although the impact on the building's stability and the associated costs can be considerable. When dealing with a listed facade, the existing frame may need to be retained in order to preserve the facade's external appearance. In such a case, an additional frame with a better energy performance can be installed inside.



Non-continuous junction between the frame and the internal insulation

Place du Béguinage housing| Bruxelles | Régie Foncière from Brussels City | architect: A2M

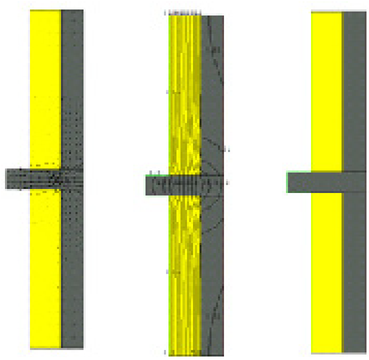
Whatever the solution chosen, continuity between the insulation and the frame needs to be guaranteed. The junctions may vary somewhat dependent on where the frame is actually placed.



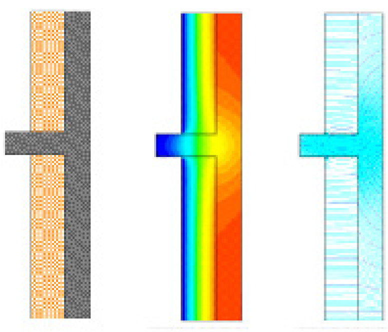
Continuous junction between the window frame and the internal insulation

C. Design tools

A number of software packages are available for calculating heat flows through linear junctions. They can also visualise isotherms, helping users to verify inside surface temperatures and the risk of condensation.



Therm©: Freeware based on an Excel® spreadsheet. Used to determine the Ψ values of junctions.



Bisco©: A commercial software package featuring a range of applications and allowing the direct determination of the Ψ value of a linear junction.

X_i

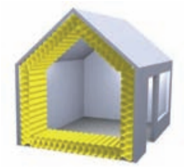
Localised thermal bridge

Unit W/K

$$X_i = \frac{Q2 - Q1}{(\theta int - \theta ext)}$$

with

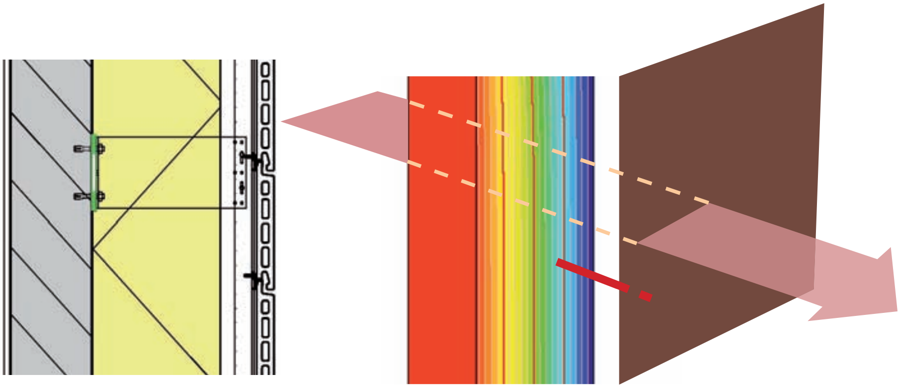
Q2 = calculated heat flow
Q1 = Σ (A1 * Ui * θint)



2.1.1.3. Localised thermal bridges

A. Principle

The non-linear thermal transmittance coefficient X (Xi) reflects the disruption caused by a non-linear thermal bridge (columns, anchors) in heat transfer. Similar to the value Ψ which, expressed in W/mK, reflects linear disruptions, the X value refers to a non-linear point and is thus expressed as W/K



Modelling enables us to determine the heat flow through the whole element (i.e. the non-linear thermal bridge and the wall). From this figure, the calculated heat flow through the wall without disruption is then deducted.

B. In practice: anchors

Certain anchors, such as those anchoring railings, stairs or balconies, can be weak points in a building's envelope.

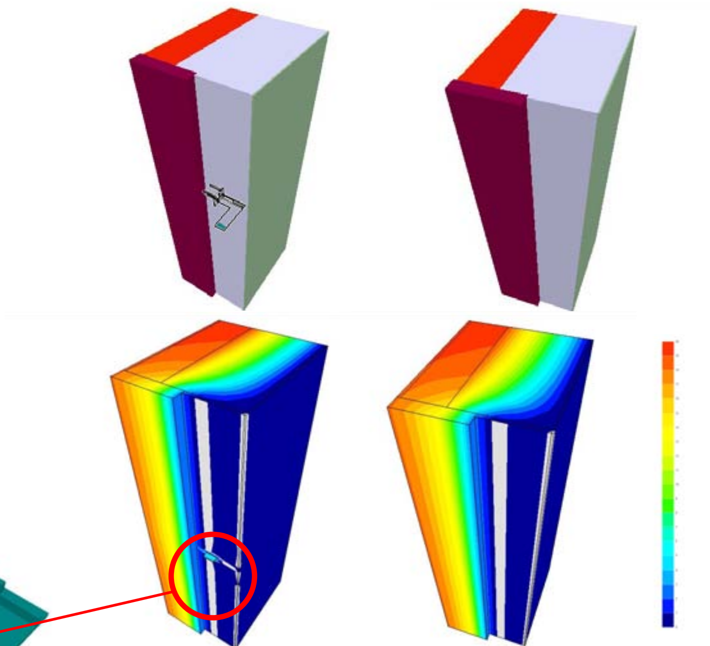
There are however a number of ways to reduce their impact:

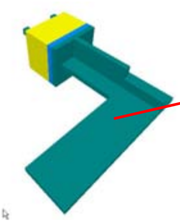
- by lengthening the path of the heat from the inside to the outside,
- by inserting non-compressible thermal barriers,
- by minimising the points of contact.

Calculations show that even when such non-linear thermal bridges are dealt with using one of the above measures, they have little influence on the overall result. In the diagram, although each window has four anchors, their overall impact is a mere 0.6 kWh/m² p.a.

Loossens street housing| Jette | Foyer Jettois | architect: A2M


ENSE DE CIRCULER
UR LE CHANTIER
RBODEN DE WERF
TE BETREDEN





	wall with anchors	wall without anchors
	12,068 W	11,2 W
θint	20 ° C	20 ° C
θext	0 ° C	0 ° C
U1	0,078 W/m².K	0,078 W/m².K

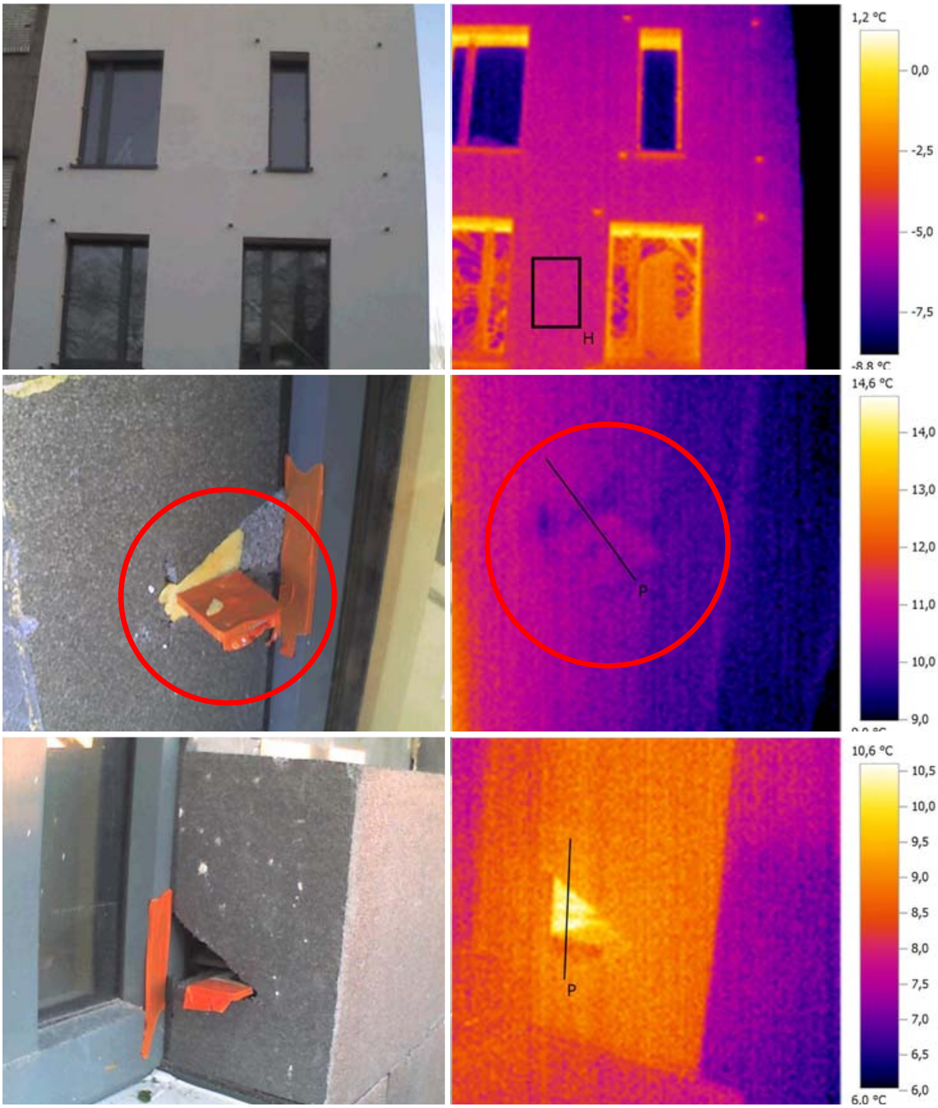
$X_i = (Q1 - Q2) / (\theta int - \theta ext)$

$X_i = (12{,}068 - 11{,}2) / (20 - 0)$

$X_i = 0{,}043$ W/K

The thermography carried out on the next page shows the same result as the thermal bridge simulation (display above). We see that the attachment has the same temperature as the external surface, which means that the internal heat does not pass through the attachment.

On the contrary, in the two plates on the bottom, because there is no insulation in the retightening around the attachment, the internal temperature appears clearly.

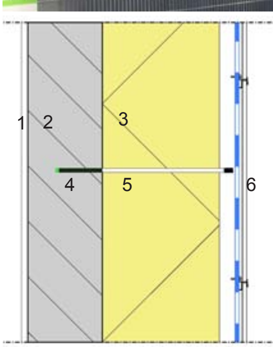


1,2 °C
0,0
-2,5
-5,0
-7,5
-8,8 °C
H
14,6 °C
14,0
13,0
12,0
11,0
10,0
9,0
P
10,6 °C
10,5
10,0
9,5
9,0
8,5
8,0
7,5
7,0
6,5
6,0
6,0 °C
P

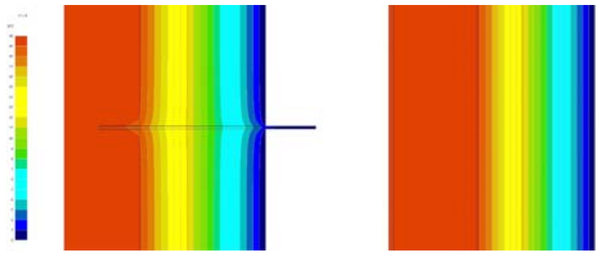
Loossens street housing| Jette | Foyer Jettois | architect: A2M

Another case of anchor management for a project with a total cost identical to the cost of a standard building.

In the case of the street facades, the thermal break is achieved by the polyamide pin (Borgh Facafix©) in which the Eternit Equitone Tectiva© lining lathwork screw is fixed.



1 plaster
2 sand-lime block
3 Neopor© graphite-impregnated EPS
4 Borgh Facafix© polyamide pin
5 Borgh Facafix© screw
6 Eternit Equitone Tectiva© eterior cladding on wood lathwork

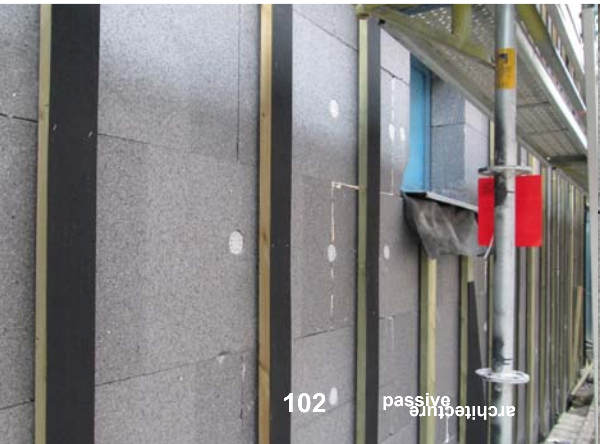


	wall with anchors	wall without anchors
Q	4,906 W	2,217 W
θint	20 ° C	20 ° C
θext	0 ° C	0 ° C
U1	0,078 W/m².K	0,078 W/m².K

$X_i = (Q1 - Q2) / (\theta int - \theta ext)$

$X_i = (4.906 - 2.217) / (20 - 0)$

$X_i = 0.13$ W/K

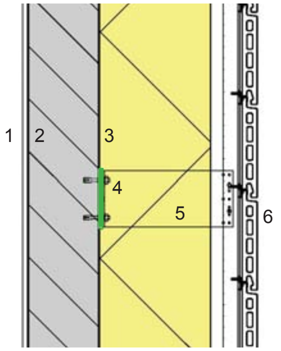


Experience shows that there are many existing products and techniques which can be adapted with a view to reducing the impact of thermal bridges without recourse to expensive solutions. For example, the owner of the FBZ office project in the Marly avenue (see below) wanted the cladding to be made of relatively heavy (33 kg/m²) terracotta cassettes.

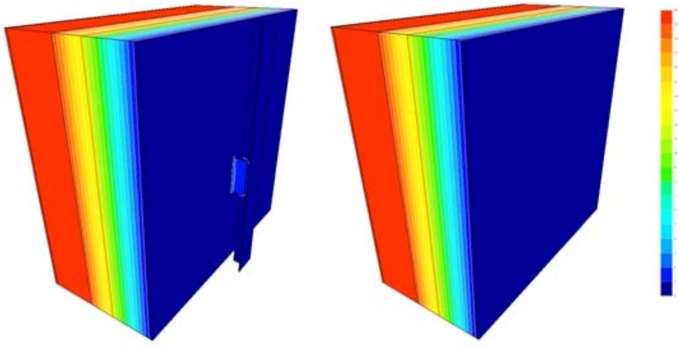
For insulation reasons, the terracotta cladding was to be suspended about 30cm away from the supporting wall. Several solutions were looked at: creating a roof-mounted structure from which to hang the cassettes, adding columns under the overhang, etc. However, none of these seemed satisfactory from an aesthetic or energy-saving perspective, and the team ended up coming up with a simple solution: anchors available on the market[10] carry the cladding, and are complemented by a small thermal barrier inserted between the anchor and the supporting wall.

FBZ HQ | Brussels |
FBZ | architect: A2M

This solution entails an additional heat loss estimated at 1.1 kWh/m² p.a. (in relation to the whole project), yet meant that the team was able to avoid a costly secondary structure. In an overall project assessment taking the energy footprint, cost efficiency, ease of implementation and aesthetics into consideration, this “weakness” is easily compensated, while at the same time achieving an enormous saving in implementation effort.

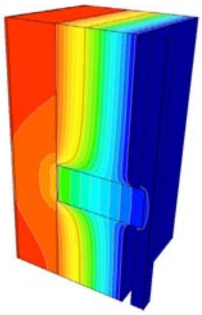


1 plaster
2 concrete block
3 rock wool insulation
4 Thermostop© thermal break
5 Etanco© profile structure
6 Terreal© terracotta decorative claddding panel



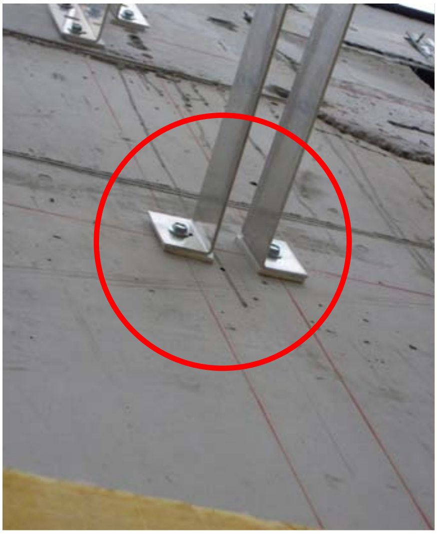
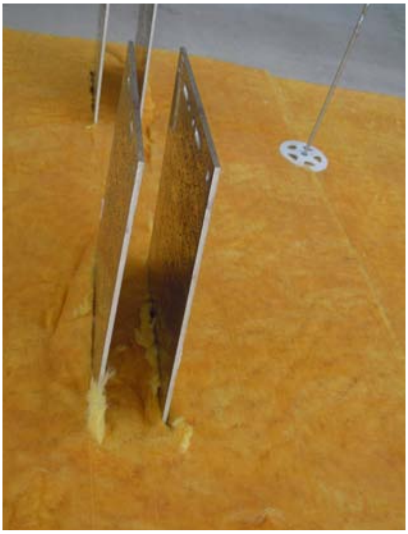
	wall with anchor	wall without anchor
Q	5,013 W	2,636 W
θint	20 ° C	20 ° C
θext	0 ° C	0 ° C
U1	0,132 W/m².K	0,132 W/m².K

$$X_i = (Q1 - Q2) / (\theta int - \theta ext)$$
$$X_i = (5,013 - 2,636) / (20 - 0)$$
$$X_i = 0,119 \text{ W/K}$$



The attached details show a sectional plan to the right of the attachment. We note that the Thermostop© thermal break suffices to limit the thermal bridge.

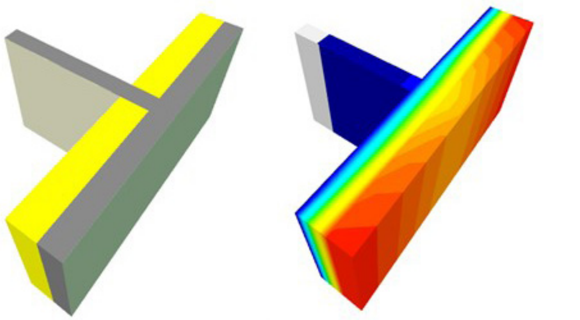
The photo (next page) on the top left shows the implementation of the Thermostop© between the attachment and the concrete wall.

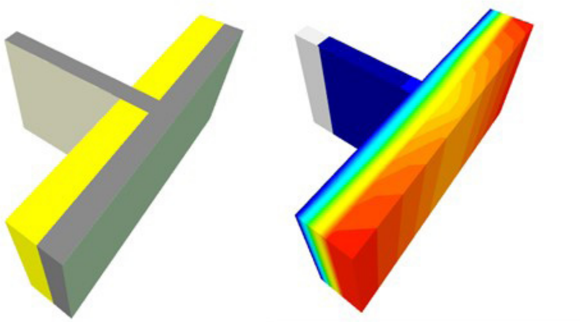
FBZ HQ | Brussels |
FBZ | architect: A2M

C. Design tools

Pour calculer les flux de chaleur à travers les raccords ponctuels, plusieurs logiciels permettent l'encodage de détails en 3 dimensions.



Eurokobra©: Freeware enabling users to determine Ψ and χ values for different types of junctions.



Trisco©: The commercial version of Eurokobra, allowing users to enter all type of details and materials for determining the Ψ and χ values.

FBZ HQ | Brussels |
FBZ | architect: A2M

2.1.2. Airtightness

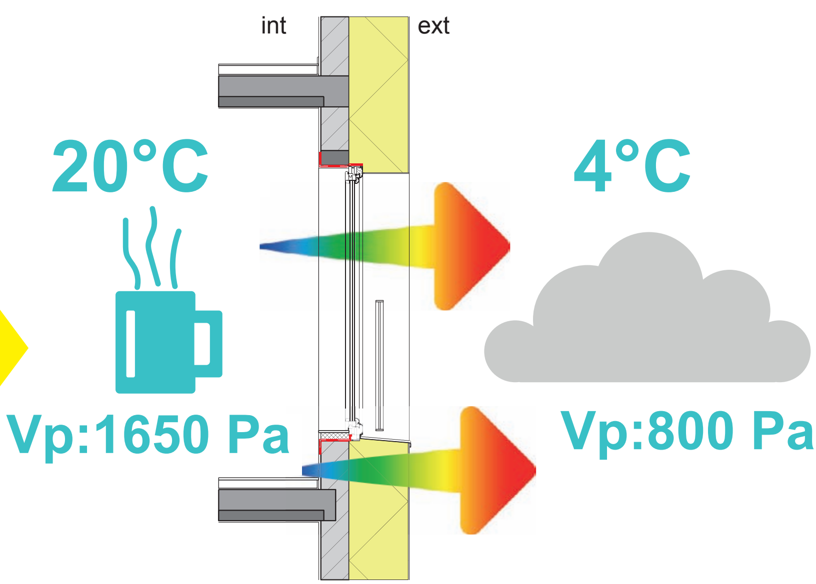
In the section on insulation, we looked mainly at *heat flows*. This section is devoted to airtightness, focusing on **air and vapor** flows through the building's envelope.

2.1.2.1. Air flows

In the same way as a difference between the inside and outside temperature (ΔT) causes heat flow, a difference in air pressure (Δp) leads to air flows through a wall. These air flows can be either controlled (via ventilation) or uncontrolled. We will start by looking at uncontrolled air flows through the envelope

There are two basic principles governing transfers; hot to cold + high pressure water vapour to low pressure.

> 2.5.1
p. 242



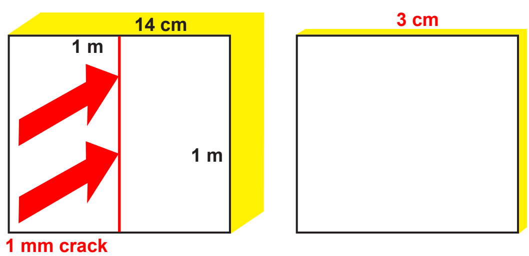
A. Principle

The aim of airtightness is to minimise air leakages and infiltration, as these can have quite a major impact on comfort and on the effectiveness of insulation and ventilation.

1) Impact of airtightness on the energy footprint

Though insulation can be considered as a building's "pullover", a short walk along the dike in Ostend will act as a quick reminder that, without anything to stop the wind, insulation is ineffective.

Taking 1 m² of wall insulated with a 14 cm layer of rockwool as an example, a crack 1 mm wide and 1 m long will cause as much heat loss as if the insulation were only 3 cm thick. This ridiculous leakage reduces the envelope’s energy performance by a factor of 5.



U = 0,3 W/m²K **=> U = 1,44 W/m²K !**
Calculated with wind at force 2-3 (20 Pa), Ti= 20°C, Te=-10°C

The passive standard sets the criterion for uncontrolled air renewal at max. 0.6 vol/h at a pressure difference of 50 Pa between inside and outside. At this level of pressure, a 1 cm² hole corresponds approximately to a leakage rate of 2 m³/h.

Another way of illustrating this effect is to take a case where only the airtightness parameter can vary, with all other parameters – insulation, technical systems and volume – remaining constant. The overall energy

Besoin de chaleur de chauffage annuel:	15	kWh/(m²a)
Résultat du test d'infiltrométrie:	0,6	h⁻¹
Besoin en énergie primaire (eau chaude sanitaire, chauffage, électricité auxiliaire et domestique):	85	kWh/(m²a)
Besoin de chaleur de chauffage annuel:	22	kWh/(m²a)
Résultat du test d'infiltrométrie:	1,5	h⁻¹
Besoin en énergie primaire (eau chaude sanitaire, chauffage, électricité auxiliaire et domestique):	93	kWh/(m²a)
Besoin de chaleur de chauffage annuel:	77	kWh/(m²a)
Résultat du test d'infiltrométrie:	7,8	h⁻¹
Besoin en énergie primaire (eau chaude sanitaire, chauffage, électricité auxiliaire et domestique):	156	kWh/(m²a)

Extracts from the french PHPP "verification" sheet showing the overall result

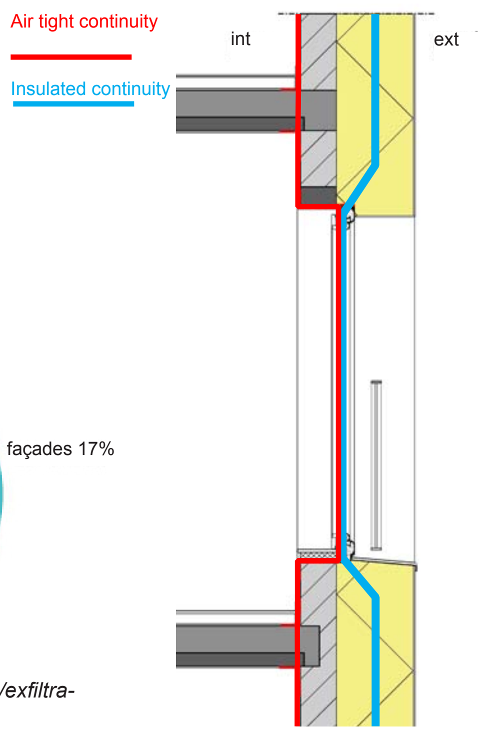
Lack of air tightness under the window sill

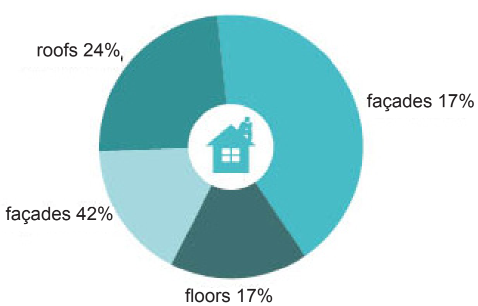
requirement is 15 kWh/m² p.a. at 0.6 vol/h at n_{50}, rising to 22 kWh/m² p.a. at 1.5 vol/h and to 77 kWh/m² p.a. at 7.8 vol/h, i.e. energy consumption can rise by a factor of 5.

2) Airtightness strategy

Taking a house as an example, the main sources of leakages are the facades, followed by the junctions of outside windows and doors and the roof. To cut back leakages, suitable and consistent measures need to be taken, with all elements of the envelope participating in the overall result.

It is important in the design phase to define the airtightness level. As with





Breakdown of heat losses through in/exfiltration the insulation, this level needs to be continuous. One simple and effective way of checking this is to review all project details, using two different colours to mark insulation continuity and airtightness continuity. This will highlight the junctions requiring attention and will often simplify implementation through anticipating the next steps.

For roofs or casing, it is necessary to provide both an air barrier on the inside and a windshield on the outside, to prevent the wind from penetrating the insulation, as air currents may reduce its thermal resistance.

A material is generally considered to be an **air barrier** when its air permeability, at $\Delta p=50$ Pa, is less than 0.1 m^3/m^2h. However, this value is currently not (yet) widely used, though other properties, discussed below allow a material's airtightness to be assessed.

2.1.2.2. Humidity and vapor flows

In many cases, no distinction is made between airtightness and vapour-tightness. Nevertheless, though these two principles generally complement each other, they are related to different physical phenomena. With air the primary carrier of vapour, it is obvious that airtightness has a lot to do with vapour-tightness. However, as water vapour molecules are very small, an airtight barrier will not necessarily be effective against vapour transfers by diffusion.

Thus, though a vapour barrier can play a role in ensuring airtightness, by contrast an airtight wall is not necessarily vapour-tight. For example, a windshield placed on the outside of a roof will stop air getting into the insulation, but will let through water vapour, allowing the latter to escape from the wall. In such a case, reference is made to breathing building materials.

Though often overlooked, vapour transfers need to be taken into account when designing the envelope, in the same way as external waterproofing. An order of magnitude: a 4-person household will generate 5 - 15 kg of vapour a day . This must not be allowed to form condensation on inside surfaces. Too much humidity can cause a range of illnesses, while also negatively influencing the thermal performance of building materials, the mechanical

resistance and durability of structural elements and the quality of inside air.

Subject	Production rate	Quantité	Total production rate [kg / day]
Occupant	1,000 kg/day/person	4	4,000
Electric cooking Gas cooking	0,375 kg/day/person	4 0	1,500 0,000
Personal hygiene (bath, shower, etc)	0,625 kg/day/person	4	1,40
Laundry drying	0,350 kg/day/person	1	1,70
Cleaning	1,750 kg/day/person	1/7	0,035
Green plants	0,250 kg/day/person	5	0,150
Total	**0,030 kg/day/person**		**9,150 kg/day/person**

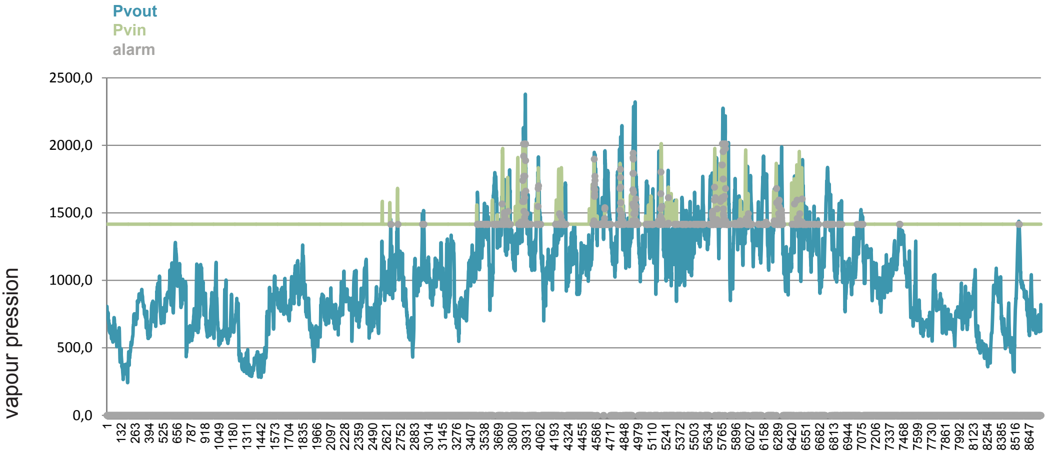
Vapour production breakdown *(source: PMP)*
Simulation for a 4-person household

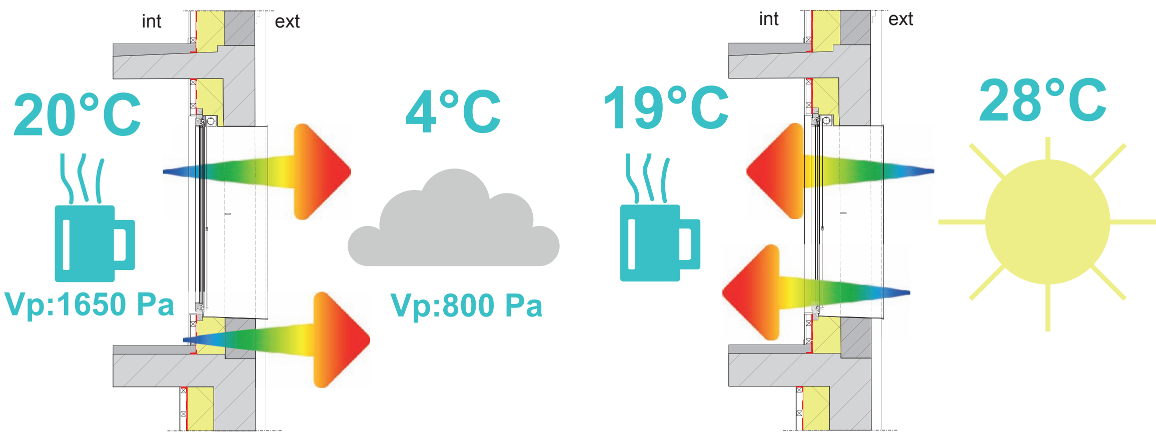
In many cases, the problems associated with vapour transfer are worsened by having too thick insulation. Certain types of structure present greater risks, including lightweight timber structures and ones with inside insulation.

A. Principle[12]

Gases always move from where the pressure is highest to where it is lowest, thereby maintaining balance. Vapor molecules similarly move from one environment to another to achieve an even distribution.

In our temperate or cold climates, it is often warmer inside than outside. As water vapour is more often to be found in hot air, vapour pressure is generally higher inside, and this difference leads to transfers through a building's envelope. To stop air or water vapor entering the envelope and impacting its performance, air and vapor barriers can be installed inside, i.e. on the warmer side of the insulation.





In spring and summer, there is a possibility of the temperature and vapour pressure being higher outside than inside, meaning that the vapour flow can go in the opposite direction.

Moreover, whatever its source (rain, rising damp, condensation), the moisture present in any material will tend to move to the surface. Such transfers of water within materials are mainly caused by capillary action . Put simply, any moisture in a material will move from the wettest to the driest zones.

B. Vapour barrier or vapour check[14] ?

Transfers within a wall are dependent on the properties of the materials used to build it. The water vapour diffusion resistance factor μ (dimensionless) reflects a material's degree of resistance to the passage of water vapour relative to air. When a material has a μ factor = 2, this means that it is twice as resistant to vapour diffusion than air. The lower the value, the more the material is likely to let through water vapor.

μd (ou Sd) [m] = μ [/] x d [m]

μ_d

= μ * thickness of the material

Unit m

where

μ = = resistance coefficient for water vapor dissemination (in relation to a layer of still air)

As resistance is also dependent on the thickness of the element crossed, the value μd (or Sd) [m] is used, where d is the thickness of the material in the wall. An μd of 1 m is equivalent to the water vapour diffusion resistance that a 1m-thick stationary layer of air would exert.

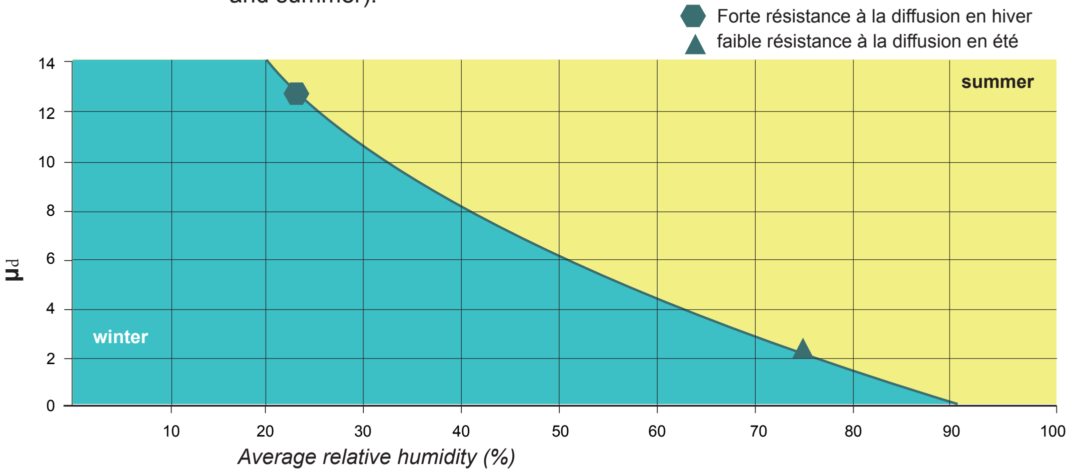
The ideal situation is to give priority to water vapour moving outwards through designing walls made up of different layers with decreasing μd values from inside to outside.

A vapour barrier is a barrier with a relatively high μd value (generally higher than 10 m). Suitably placed, it can greatly reduce vapour diffusion, regardless of how it is applied.

A vapour brake generally has a lower μd value (often lower than or equal to 10 m). However a "vapour brake" is a commercial term without any set μd threshold value, meaning that users should pay attention to the values listed in its technical specifications. The use of a vapour brake rather than a vapour barrier maintains a wall's ability (at least in part) to dry out inwards in summer.

Material	**Thickness (e)**	**Sd (μ x e) value**	**Source**
Air – reference value	1 m	1 m	EN 12524
Plaster	0.015 m	0,06 to 0,015 m	EN 12524
Glass wool	0,2 m	0,2 m	EN 12524
Cellulose	0,2 m	0,4 m	EN 12524
Under-the-roof wood fibre insulating panel	0,022 m	0,11 m	EN 12524
OSB panel	0,022 m	0,66 à 4,4 m	EN 12524
Vapour brake	0,001 m	4,5 m	
Vapour brake with variable Sd	0,0002 m	0,25 to 10 m	
Vapour barrier	0,0002 m	20 to 50 m	
Reinforced concrete	0,2 m	10 m	
Polyethylene	0,00015 m	50 m	EN 12524
Aluminium sheet	0,00005 m	1500 m	
PE sheet	0,00015 m	8 m	
Glass	0,006 m	+∞	

The µd of a humidity-controlled (hygrovariable) vapour brake or vapour barrier is dependent on relative humidity. Such membranes do not let through any great amount of vapour when relative humidity is low, and become more permeable as relative humidity rises. This characteristic slows down outward vapour transfer when inside air is drier (mainly the case in winter) while helping walls to dry out when relative humidity is higher (generally in spring and summer).



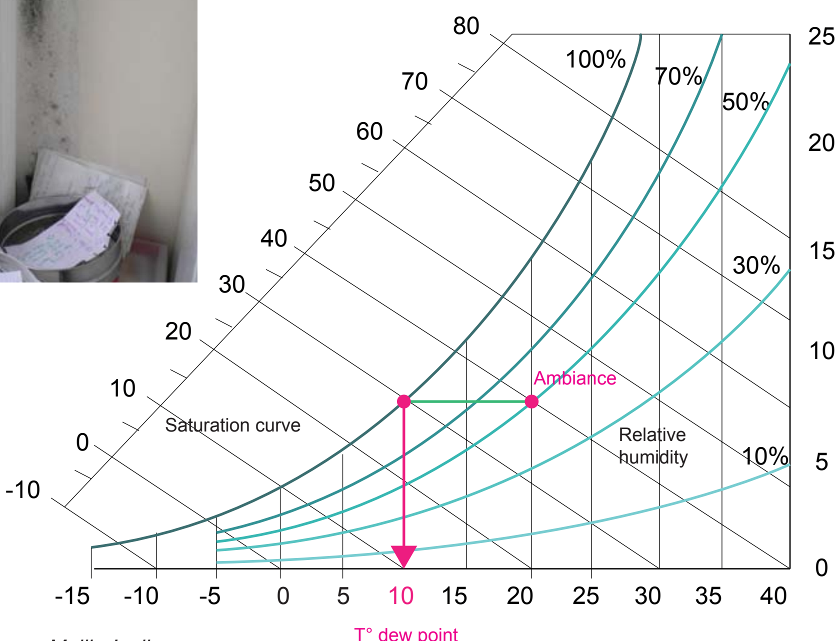
C. Condensation

Water vapour transfers are the result of convection or diffusion, and involve the risk of condensation forming in the building's envelope. Such condensation can be either superficial or within a wall. Though condensation inside a wall is rarely visible, it can have major consequences on the performance and durability of structural elements. Damp can also constitute a health risk for a building's occupants, especially when it leads to mould developing within a wall.

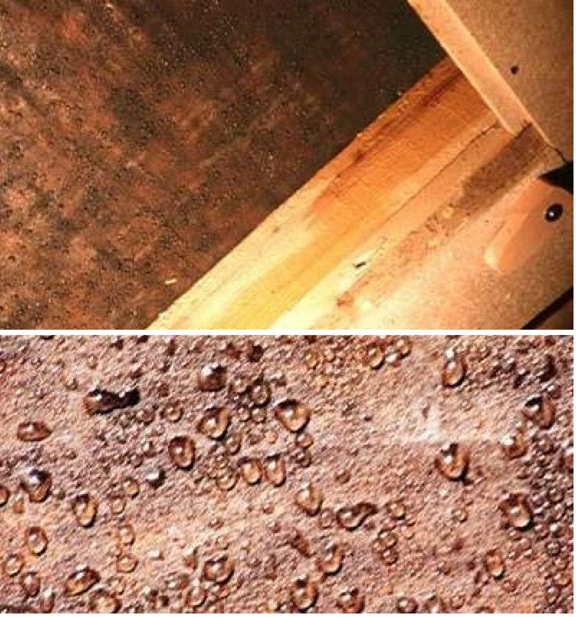
1) Surface condensation

Where the temperature of a wall's surface is lower than the dew point, condensation will develop on that surface. A low surface temperature is often the result of a thermal bridge (for instance a lintel). When this occurs regularly, damp will progressively increase and - dependent on the material and temperature - the surface can become a bed favouring the development of mould.

Mildew in a cold area



Mollier's diagramme



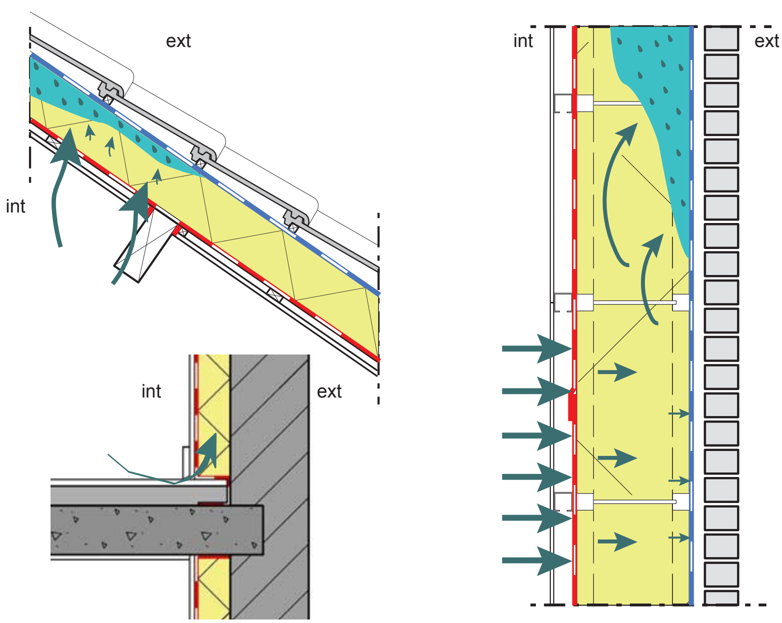
Condensation in the under-layment of a roof (illustration Fraunhofer-Institut)

2) Condensation within a wall as a result of convection

> 2.1.2.4
p. 127

Faults in the airtightness of an envelope's inside surface can cause air to get inside the wall. When such transient air is hot, it will contain a certain amount of water vapour. One coming into contact with a surface whose temperature is lower than its dew point, condensation will occur. Condensation is often concentrated along faults in the wall, and can result in high amounts of condensate.

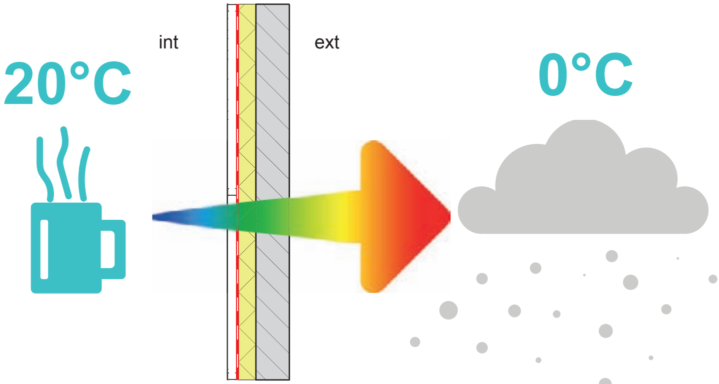
Convection flows can be caused by such factors as faulty design, bad implementation or subsequent drilling. Through anticipating such problems and ensuring airtightness, such phenomena can be avoided in the majority of cases.

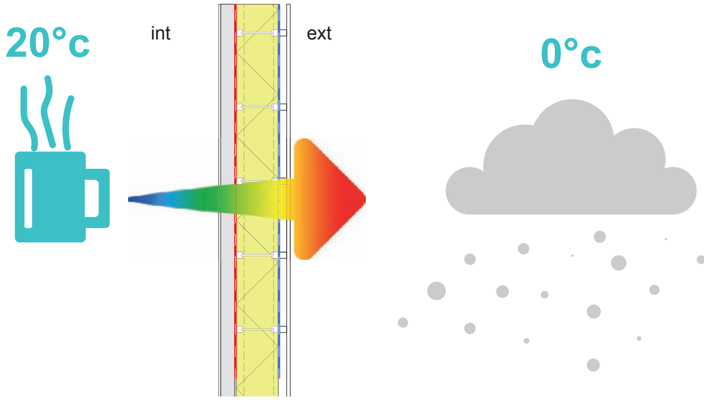


Heat transfers by convection is often due to defects in workmanship in the air tighness of the building enveloppe

3) Condensation within a wall as a result of diffusion

Air containing vapour will find its way into a wall as a result of diffusion within the materials used to build the wall. As it moves outwards, air cools in line with the hygrothermal characteristics of the wall's components. Should the dew point be reached somewhere, condensation will develop. This phenomenon is often found in walls insulated on the inside and in timber-framed structures with built-in insulation.





D. Strategies

There are three basic principles governing the optimal management of damp in a building

1) Stopping the damp at source

> 2.1.2.4 /C.5
p. 147

Various measures can be taken to deal with damp coming from outside. These include waterproofing, a watertight roof, rain and wind shields, a water-repellent facade, anti-capillary treatment, casing the walls to avoid direct contact with the ground, and sealing the foundation slab.

To deal with inside damp, the most effective remedy is ventilation, as this reduces the pressure of inside vapour and avoids major pressure differences resulting in vapour transfers through the walls. The recommendation is to keep the inside temperature close to 20°C and relative humidity to 30 - 60%.

2) Avoiding condensation

Although ventilation allows the amount of water vapour within a building to be reduced, a certain amount will always be present. Everything needs to be done to ensure that this moisture remains as vapour, thereby limiting condensation in the building. To achieve this, a number of measures are necessary.

a. Limiting thermal bridges

Through maintaining surface temperature above the dew point, surface condensation can be avoided.

> 2.1.2.2 /C.2
p. 118

b. Limiting airtightness faults

> 2.1.2.3
p. 125

Through preventing convection transfers, the resulting risk of condensation similarly disappears. We should also remember that, in this case, the amount of moisture is generally higher and the damage greater than with condensation caused by diffusion (a smaller and better distributed amount of vapour).

c. Limiting diffusion transfers

A strategy often put forward for regulating moisture levels within walls involves using components whose resistance to vapour diffusion µd declines, the nearer they are to the outside. This limits the amount of vapour going through the wall, while at the same time allowing any moisture within the wall to continue moving in an outward direction, thus limiting the risk of condensation within the wall. Different norms recommend an µd value of 5 for the innermost layer and of 1 for the outer layer. As regards timber structures, the CSTC recommends that the µd value of the innermost layer be at least 6 times and preferably 15 times higher than that of the outer layer[17].

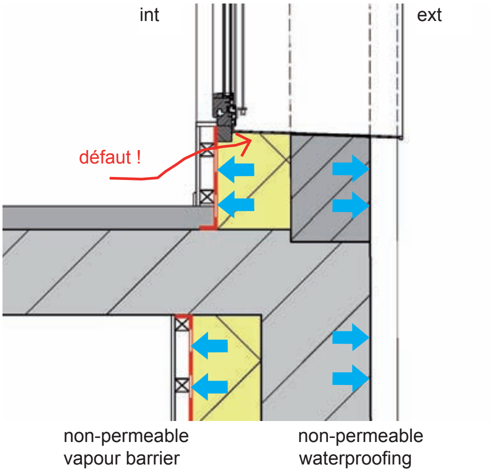
3) Ensuring a wall can dry out

In practice, it is difficult to prevent condensation (whether on the surface or within a wall) and to control all other sources of damp. Even if the building's envelope has been designed with great care, construction phase mistakes, a faulty ventilation system or any other unexpected situation cannot be ruled out. It is therefore of crucial importance to give great priority to the ability of a wall to dry out. Damp within a wall does not need to be a problem, insofar as it can get out fairly quickly and does not accumulate over time.

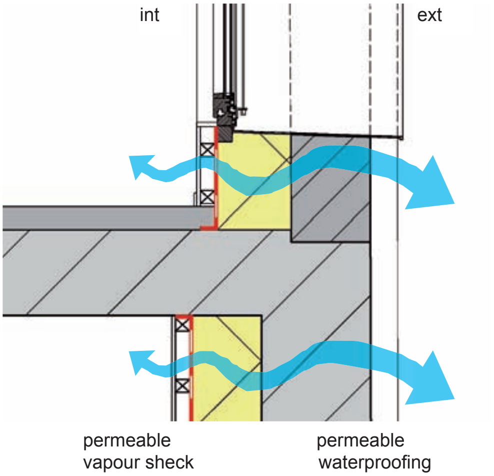
The principle of allowing water vapour to permeate outwards through a wall is generally to be welcomed. However, empirical rules suggesting a relationship between inside and outside µd values are to be used with caution.

Strict compliance can, especially when a building has inside insulation, require the additional installation of a vapour-tight membrane (a vapour barrier with a very high µd value). Given diffusion transfers which can be reversed in mid-spring, mid-autumn or summer (vapour pressure higher outside than inside a building) and water transfers which can go in either direction within a wall, the general recommendation is to maintain a certain vapour permeability on the inside, thereby improving the drying properties of a wall. For all these reasons, it is deemed a good idea to check the wall using an appropriate dynamic software package

Condensation in the vapor barrier (illustration Fraunhofer-Institut)



> 2.1.2.2 /D
p. 122



Dependent on where used, the use of a vapour brake with either a fixed or variable µd value will often suffice, allowing drying to take place without completely blocking inward vapour flow through the wall. Such membranes - acting either as a brake or a barrier - also act as an air barrier, thus limiting the risk of condensation caused by convection. Crucial importance does however need to be attached to their proper installation.

At the same time, if any waterproofing is to be applied to the outside surface (e.g. rendering, paint, a water-repellent or a windshield), this must be able to let water vapour through in order to promote drying[18].

2.1.2.3. Design tools

There are many recommendations on how to manage damp in walls. However, it is important to first check the composition of the walls in question. Certain tools use simplified methods to do this, while others incorporate all hygrothermal parameters of the materials, together with climate-related factors. Although entering the data is more complicated and the cost higher, the latter tools have the advantage of providing results better reflecting reality. In all cases, whatever the tool used, the walls are always considered to have been built perfectly. Unless explicitly entered, the software packages do not take any account of possible faults in the installation of membranes, (window) openings, etc. However, transfers caused by convection can have major consequences. These tools therefore need to be used with care, applying overall design strategies.

The Glaser method

This static tool (an Excel spreadsheet) uses as its basis a constant temperature and level of humidity on both sides of the wall. The only parameters taken into account are the thermal conductivity λ [W/mK] of the materials used in building the wall and their water vapour diffusion resistance µ [-]. This is thus a simplified method not taking any account of the water content of the materials, transfers of water or external effects (rain, sun, wind), all of which can have quite a considerable impact on the hygrothermal exchanges within a wall.

On account of this simplification, the method is extremely safe. A number of different wall compositions are discarded, as they do not represent any real risk. On the other hand, especially with inside-insulated walls, the strict application of the results obtained from the Glaser method often lead to the selection of a very airtight membrane for the inside of the wall. However, in practice, it seems that a less airtight membrane may in many cases be better, as it helps drying.

Dynamic software packages taking heat and humidity into account

A number of dynamic software packages assess the hygrothermal behaviour of walls in a more accurate manner. To better reflect real-life physical phenomena, it is crucial to take account of the hygrothermal properties of all materials used in a wall, as well as the influence of the outside environment (rain, wind, sunshine, shade, etc.). With heat and moisture transfers dependent on certain common parameters, it is of great importance to assess these together, taking into account their mutual interactions. For example, thermal conductivity varies dependent on the level of humidity, while state changes require a certain amount of energy (latent heat).

WUFI® is one of the most frequently used and user-friendly software packages, though others also exist, including DELPHIN, MOIST and MATCH.

Their use is more complicated and requires more time, though their results generally better reflect reality than those of static tools.

Isolin[20]

Designed specifically for assessing inside insulation, this tool combines the results of some 7,000 WUFI®Pro dynamic simulations on brick-built walls insulated on the inside. A number of different configurations are offered and the tool is fairly easy to use. It provides detailed results and allows an analysis in greater depth for anyone requiring such.

2.1.2.4. In practice

As yet, no Belgian database on the airtightness of structural elements and construction techniques exists. Nevertheless, here are a few observations from practical cases. One non-scientific way of testing a material is to throw a bucket of water over it: if the water passes through it, so will air. This test shows us for instance that a concrete slab has a better chance of being airtight than screed or terracotta bricks.

A. Externally applied insulation

1) Walls

Generally speaking, in a brick-built building airtightness is achieved through dry-lining[21]. In such a structure, airtightness is an item not requiring any in-depth knowledge or state-of-the-art technology, but instead requiring time and precision.

Concrete blocks and bricks are not airtight, and therefore an additional air barrier is needed. Sand-lime bricks are similarly insufficient, and even a thin layer of plaster will not ensure airtightness.

Certain typical junctions also require attention:

- the junction between the dry-lining and the floor slab: this interrupts the airtight barrier created by the dry-lining and, given that screed generally “floats” on the slab (floating screed), leakages may occur between the slab and bricks;
- the recesses for electrical sockets in brick-built walls;
- when in contact with the building's envelop, certain utility shafts and rooms will need to be dry-lined. This must be done before any pipes, ducts, etc. are installed; the dry-lining behind stair stringers, if these are located against an outside wall; or behind any bathroom facilities (the trivial example of wall-mounted toilets, where dry-lining is necessary behind the flushing system);
- a thin layer of plaster is not sufficient, with any layer needing to be at least 0.5 cm thick [22];
- vertical joints need to be carefully sealed and strengthened to avoid cracks.

If it is not possible to dry-line the bricks on the inside, another way to achieve airtightness between the bricks and the insulation (always on the warm side) is to use a special airtight adhesive . In such a case, junctions with window frames can also be implemented from outside.

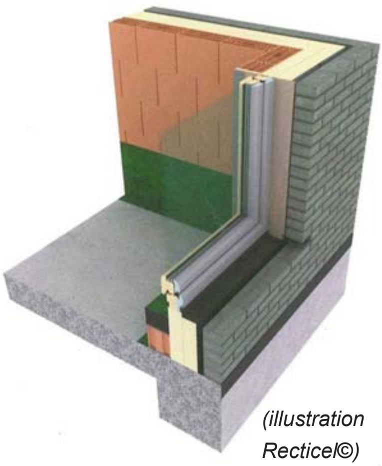
When the walls are made of concrete (either prefabricated or poured on-site), they will generally already be airtight, insofar as they have a certain thickness and joints have been made properly. In the case of prefabricated

Brooklyn housing | New-York USA | Ridgewood Bushwick Senior Citizens Council | architect: Chris Benedict R.A.

walls, all joints must be perfectly executed.

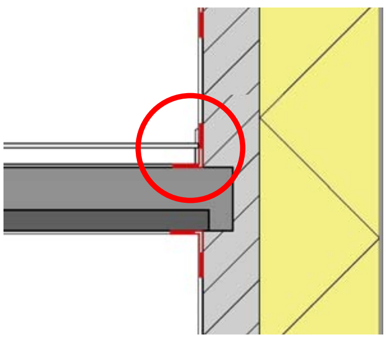
2) Junctions with floor slabs

Where the inside plaster does not reach down to the concrete floor slab, a membrane will need to be installed before pouring the screed (as this is not watertight). Where the wall includes a membrane to prevent upward capillary action, a stand-by membrane will still be needed, as there is a risk of the



(illustration Recticel©)

dry-lining cracking along the anti-capillary barrier or - even worse - of helping damp to rise.

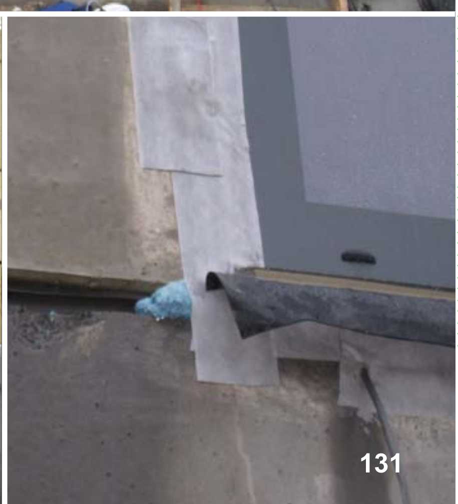


3) Junctions with (window) frames

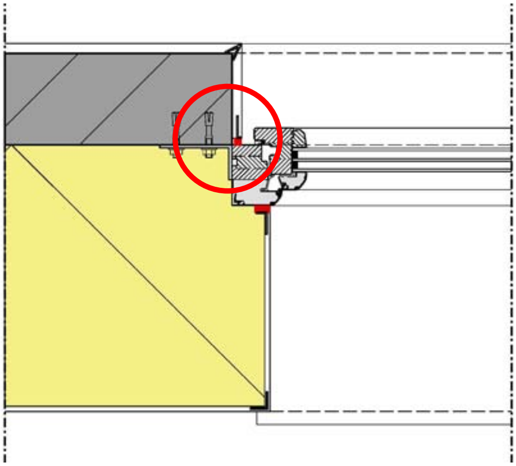
For brick-built walls, adhesive tapes can be used for the junction between the dry-lining and the wooden frame. These are usually made up partly of mesh which is then hidden under the dry-lining and of a self-adhesive band. Though pre-installing these tapes ensures optimal adhesion (little dust, no rain or damp), there is a risk of them getting damaged during transport.

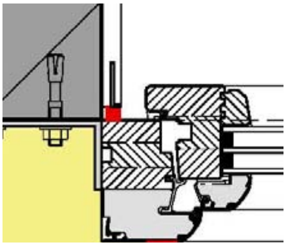
As concrete walls are airtight, the junction may be executed either from inside or outside. The frame's composition is also important. For example, frames made of wood and aluminium with integrated polyurethane insulation have holes allowing condensate to escape in the front bottom of the frame. As air passes through the polyurethane, an outside junction is not advisable. In such a case, it is the wood which acts as an air barrier, and not the aluminium cladding.

In certain cases, it may be to sufficient to carefully seal the junction with expanding foam[24].



The CSTC[25] has summarised various ageing tests on junctions executed with either adhesive tapes or silicon joints. It seems that there is no significant difference between these two techniques. "The lab tests show that an airtight junction can be obtained following the NIT 199 recommendations through using end profiles for the plaster coating, coupled with a flexible joint (and its bottom seal), provided that great care is taken during installation allowing performance to be maintained over time."





Dependent on the type of construction used, the complexity involved in achieving airtightness can differ, as reflected by the greater use of flexible materials and more expensive membranes in timber constructions.

4) Outside surface condensation

Surface condensation may occur on the outside (triple glazing, render on top of insulation, metal cladding etc.). At night in clear weather, the surface temperature of exposed walls can be 6 - 8° C lower than the outside air temperature[25] If this temperature is below the dew point of the outside air, condensation will occur.

In buildings without much insulation, such over-cooling linked to radiation to the sky is offset by thermal losses inducing an outside surface temperature near or above the outside temperature. In passive building by contrast, heat loss through the walls is very limited, with the result that such over-cooling is not offset. Condensation will thus be a frequent occurrence, for instance above the anchor points of the insulation underneath the render. To avoid this, anchors with a low thermal transmittance coefficient (X) need to be used.

Surface condensation occurs uniformly and causes a darkening of the render, except around the anchors of the thermal insulation panels, as these cause slightly higher heat losses.
(illustration Fraunhofer-Institut)

B. Integrated insulation

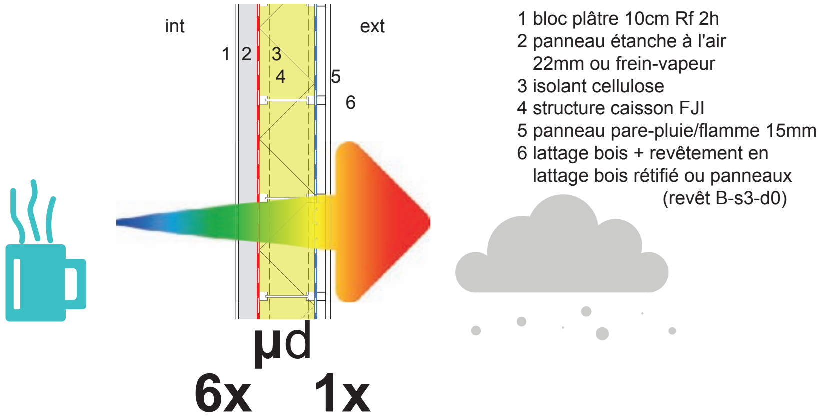
1) Vertical walls

> 3.2.2
p. 298

The work necessary to make insulated timber structures[27] airtight needs to be executed perfectly, and this airtightness has to be maintained throughout the building's life. Such structures are more susceptible to design and execution problems.

> 2.1.2.2 / D.2
p. 122

In the case of timber frame walls, finding materials meeting a range of criteria can sometimes resemble an obstacle course. It is not always easy to come to grips with all rules and to properly install the materials. There are several barriers, both inside and outside, encasing the insulation. The outside panelling plays the role of a windshield, while the inside panelling or membrane must also form a vapour shield. To stop moisture remaining in the insulation, the successive layers are increasingly "open" to vapour. General opinion is that a factor of 6 between the inside and outside μd is sufficient[28], though checking it with the help of dynamic tool could be an interesting exercise.



On the inside it is a good idea to protect airtightness through dry lining or gypsum blocks which can also serve as fire protection.

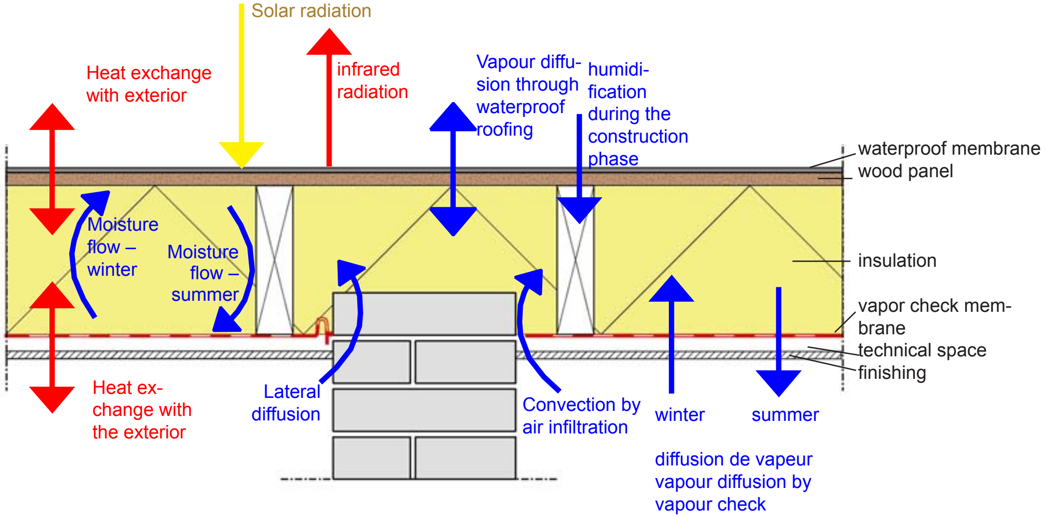
The outside must be similarly protected by a rain shield or cladding allowing any vapour in the wall to escape. Such a material needs to meet several criteria at once, being open to vapour, possessing structural capabilities and, in certain cases, being non-combustible. Indeed, the new fire regulations in Belgium specify the outside cladding of medium-sized and high buildings must be category B-s3, d0 (basically non-combustible). A maximum of 5% of the visible surface area of a façade is not subject to this requirement.

Interior		**µ**	**ép**	**µd**
Durelis vapor bloc	**D1**	243	0,01	2,43
	D2	243	0,012	2,92
	D3	243	0,015	3,65
OSB EGGER	**O1**	200	0,012	2,40
	O2	200	0,015	3,00
	O3	200	0,022	4,40
	O4	200	0,025	5,00
Exterior				
Hidroflam	**H1**	50	0,012	0,60
	H2	50	0,016	0,80
	H3	50	0,018	0,90
	H4	50	0,022	1,10
Celit	**C1**	5	0,018	0,09

Composition	**µdi**	**µde**	**composotion ratio (min 6 !)**
D3 15mm/ H1 12mm	3,65	0,60	**6.08**
D3 15mm / H2 16mm	3,65	0,90	**4.05**
O3 22mm / H1 12mm	4,40	0,60	**7.33**
O3 22mm / H2 16mm	4,40	0,80	**5.50**
O4 25mm / H2 16mm	5,00	0,80	**6.25**
O1 12mm / C1 18mm	2,40	0,09	**26.67**

2) 2) Compact flat roofs

Turning to flat roofs, similar principles apply, though the outside layer is generally more watertight and less open to water vapour. This means that greater attention has to be paid to allowing the roof to dry out inwards. There are different ways of doing this[29] and it is crucial to check which is best using dynamic simulation.

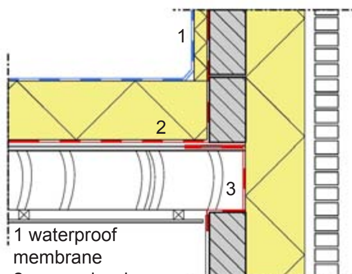


Air and vapour flows in a compact flat roof (source: Jonas Eyckens)

3) Execution

When working with a timber frame, a higher amount of work is required, along with greater precision. During the design phase, membranes need to be foreseen in advance, to be installed in the course of execution. Attempting to install these a posteriori can turn out to be a never-ending adventure, whereas advance planning often allows execution to progress without any great hitches, as seen in the following examples:

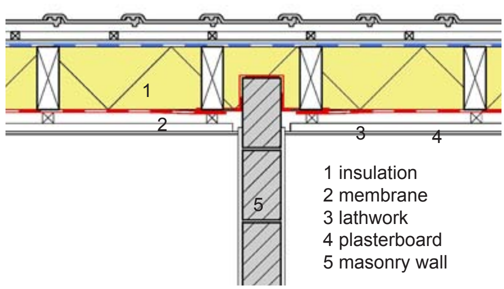
- a membrane placed on the upper side of the brickwork, upon which the floor joists lie;



1 waterproof membrane
2 vapour barrier
3 connection membrane

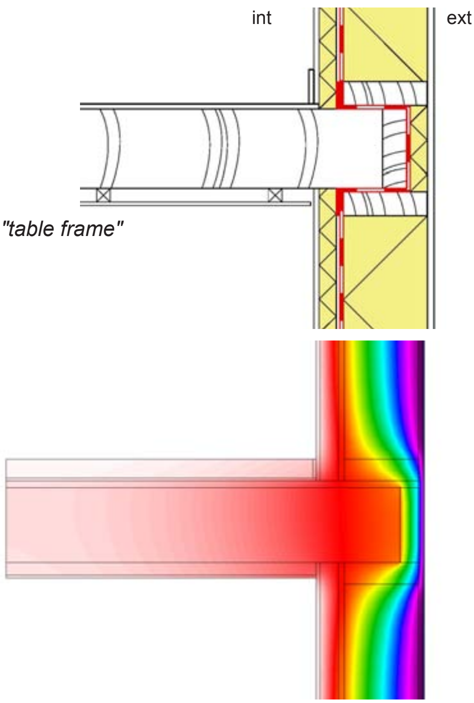
Installation of a membrane in the case of beams resting on the masonry (illustration, magazine CSTC -Contact nr. 33 (2012)

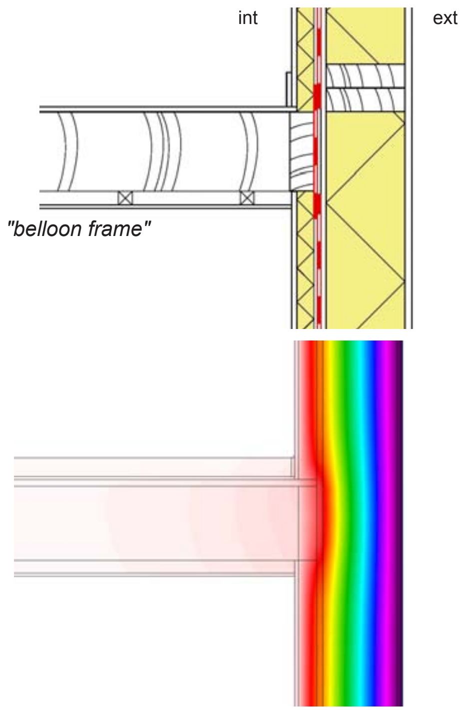
- A membrane placed on top of the ridges or inside walls when executing the roof's frame:



Connection between partition and ridge dial. The continuity of the air barrier is ensured by a suspense membrane (illustration, magazine CSTC -Contact nr. 33 (2012)

- edge of the floor slab encompassed by a membrane and resting on an outside frame[30] :





For this type of structure, it is very important to define where exactly the membrane is to be positioned. Whereas in the first two diagrams above, a continuous airtight seal is ensured, we see (on the left) that the membrane goes from the insulation's cold side, bringing with it the danger of creating condensation within the structure. To correct this, a sufficiently thick layer of insulation is needed.

4) What about OSB ?

The airtightness properties of OSB panels vary[31], and a number of on-site tests have shown that certain OSB panels do not meet up to expectations with regard to their role as an air barrier. These findings apply to panels of different types, thickness and manufacturer, and sometimes even for panels of the same brand, though from different batches.

No manufacturer currently guarantees the airtightness of his product, though one manufacturer (Egger) does guarantee its μ value. Though this is a value reflecting vapour permeability, it also reflects a product's airtightness. Moreover, there are other types of panels[32] which do guarantee a degree of airtightness.

5) The durability of adhesive tapes

The use of airtightness systems using adhesive tapes is much more common in timber constructions. Several studies have looked at the durability of the adhesives, their resistance, etc.

However, this is usually not where the problem lies. Most problems are associated with execution, as seen for instance by the fact that the best adhesive is ineffective when applied to a dusty surface. Situations such as the one below (old wooden joists traversing a vapour brake) are to be avoided as much as possible:

> 2.1.2.2 /D
p. 122

> 2.1.2.2 /C.1
p. 118

In a lightweight structure, mechanical protection needs to be foreseen for ensuring airtightness and avoiding any impairments due to use. A gap 5 cm wide between the air barrier and the dry-lining can play this role, while also allowing the easy installation of wiring and plumbing. For apartments, especially when rented, gypsum blocks help prevent impairments, while at the same time ensuring fire protection between the apartments.

C. Inside insulation

The major risks associated with inside insulation are surface condensation, condensation within the wall (caused either by diffusion or convection) and damage due to frost or to expansion of the brickwork. Secondary risks involve efflorescence (salt deposits appearing in brickwork) and the decrease in thermal inertia through most of the insulated wall no longer being accessible[33].

It is crucial for the insulation to be continuous and completely airtight. From a more general perspective, ways of regulating the level of moisture must be considered during the design phase and during execution, and need to be maintained afterwards. The general principles needing to be taken into account apply fully to all inside insulation where the risks are generally higher.

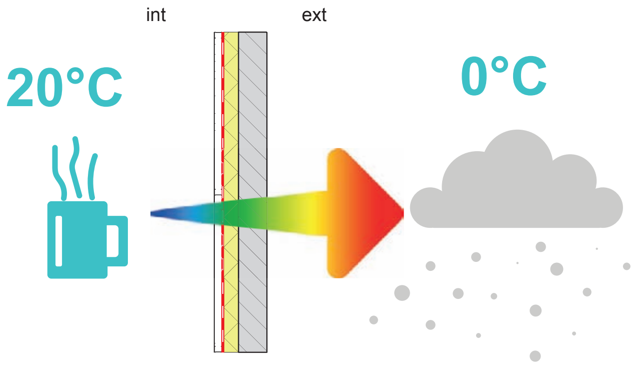
1) Condensation

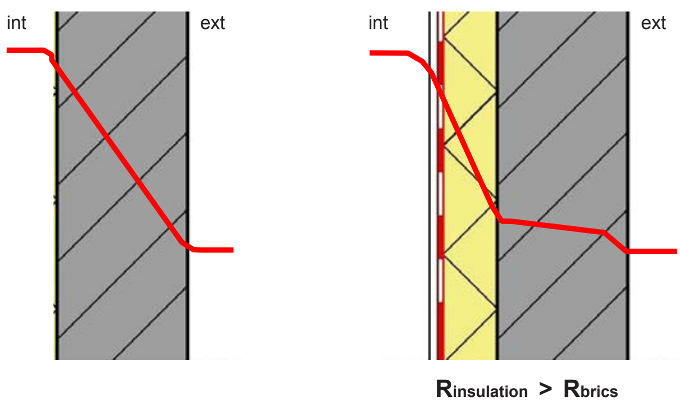
This is a problem often experienced with inside insulation and it is even more difficult to deal with when the insulation material used is thick.

Surface condensation: thermal bridges are generally more difficult to avoid when insulating from the inside, especially when refurbishing a building. If these are not dealt with properly, surface condensation will appear.

Example of mould related to a thermal bridge, (Rechtsanwalt Friedhelm Thome, Köln).

Inside condensation: With inside insulation, the risk of inside condensation increases on account of the composition of the envelope itself, where the drop in temperature between the inside and outside actually takes place within the insulation material. With the latter placed on the inside, the wall itself is much colder. Where water vapour finds a way through the insulation (either by convection or diffusion), there is a risk of it condensing within or behind the insulation, next to the cold wall.





> 2.3.2.1
p. 210

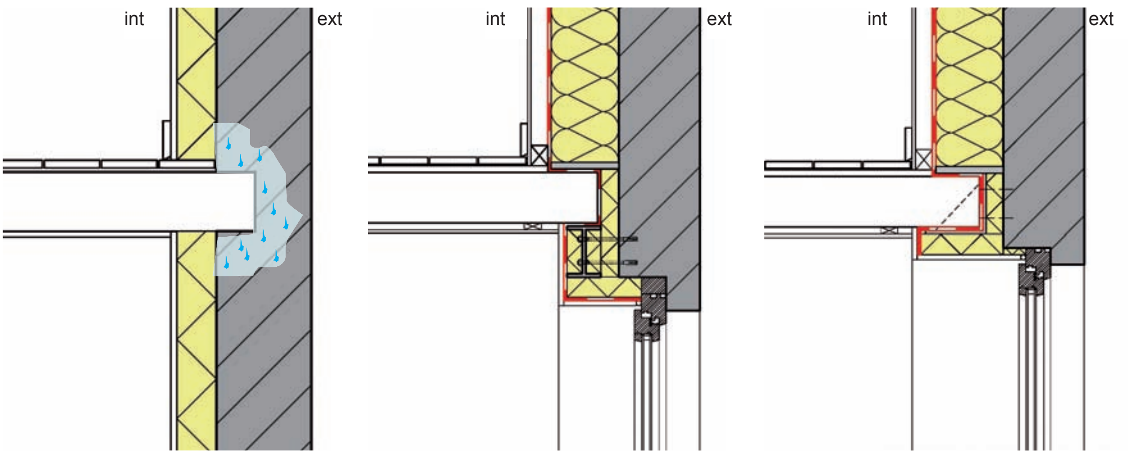
Example of mould due to inside condensation. (Joe Lstiburek).

2) Wood floor structure

Wood floor structure are more difficult to deal with than concrete floors. Although insulation between the joists will reduce the thermal bridge, it is generally a lot more difficult to ensure vapour- and airtightness. Thus, when such a floor is badly designed or executed, the bedding of the joists in the wall can increase the risk of condensation, ultimately leading to the wood rotting and thus to stability problems. To avoid this, the moisture content of the wood must always be less than 20%.

Even with a vapour brake / shield membrane surrounding each joist, the risk will not completely disappear, as wood is porous and vapour transfers by diffusion can take place. When joists are old and cracked, transfers by convection are also possible.

The best way of solving this problem is to cut through the joists and floor and to install a new load-bearing structure ensuring that the insulation is continuous and that the structure is completely vapour- and airtight.

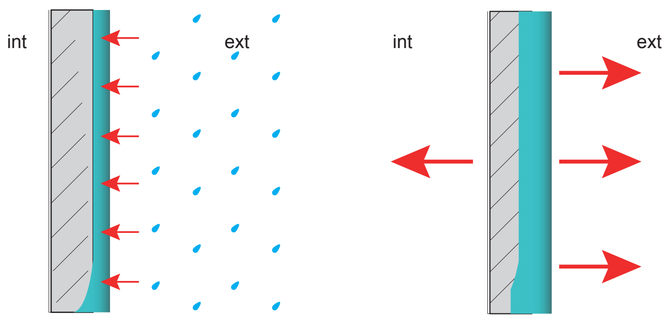


House in Eupen | Eupen | Famille Henz-Noffalise | architect: FHW

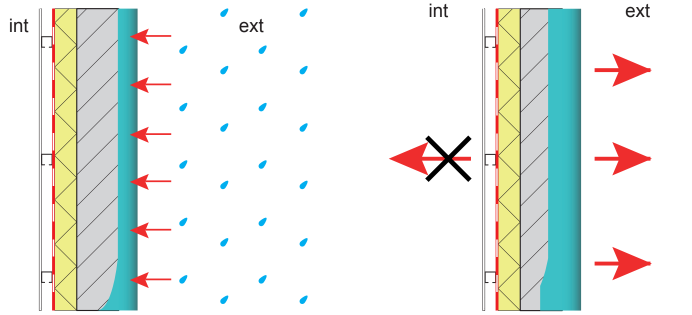
3) Frost and brickwork expansion

Inside insulation leads to walls becoming cold. This means that when a wall has become damp through rain, it takes longer to dry out on account of the lower temperature. Conversely, applying a layer of insulation with a vapour brake / shield to the inside of a wall also reduces its ability to dry in an inward direction.

This drying impairment in both directions leads to moisture accumulating within the wall. In cold weather, the water present on the outside surface of the wall can freeze, thereby increasing the volume of water in the brickwork and possibly causing mechanical deformation in the wall. Whether such problems occur is dependent on a number of factors (type of brick, moisture content, temperature, etc.).



Humdification through rain   *Surface evaporation*



(illustration Fraunhofer Institut)

> 2.1.2.3
p. 125

4) Materials

Materials have different "hygroscopic properties", with some able to store a certain amount of moisture and release it later. This property provides a form of inertia regulating the inner moisture content and reducing the effects of excessively wet or dry environments, and is characteristic of certain natural insulation materials, e.g. ones based on wood, mud or lime. When refurbishing a building and/or applying inside insulation, execution is rarely perfect (e.g. the junctions between the different components) and the use of this type of material can be a way of avoiding damage caused by condensation.

5) "Hydrofuges" waterproofing traetment for exterior finishes

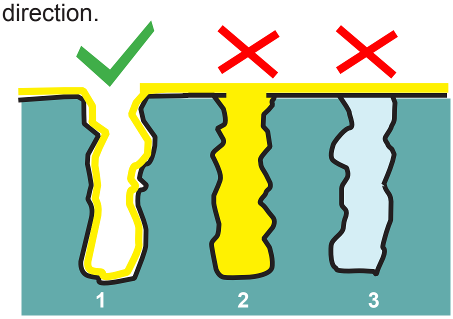
As the drying ability of walls insulated on the inside is greatly reduced, it is very important to control all sources of damp. In the inside of a building, air and vapour shields are used, while on the outside, it is often necessary to waterproof the whole façade to stop rainwater getting in[34].

Whether such a solution is applicable is dependent on a number of factors: the absorption coefficient of the façade material, the type and thickness of the insulation, the type of vapour brake / shield, the direction in which the façade faces, etc. It is thus necessary to check the wall using a dynamic software package.

Similarly it is vital to foresee a waterproof finish not letting rainwater get into the wall while at the same time letting moisture escape, thereby allowing the wall to dry out in an outward direction.

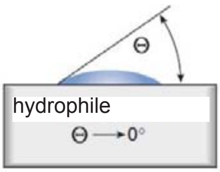
1. "hydrofuge"
2. filling of pores
3 filmogenic sealing

Water repellents based on organosilicon compounds form an ultra-thin film on the walls of the pores without sealing them, thereby allowing a certain permeability to water vapour (EN 1504-2).

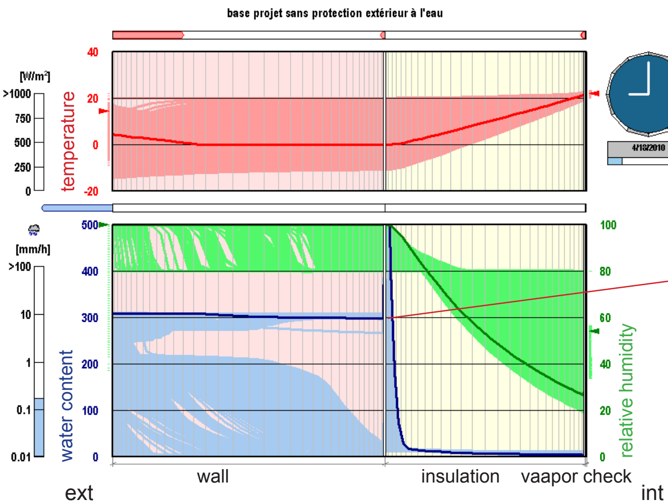


(illustration Wacker Chemie AG)

Simulation of the wall with the interior insulated wall without particular treatment

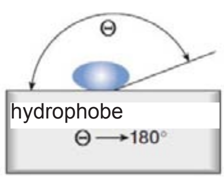


The simulation carried out in Wufi© shows that interior insulation of ca. 20 cm could cause moisture to accumulate between the former bearing wall and the new interior insulation. This is due to the high level of absorption of the façade wall. Following the internal insulation, there is a risk that this will no longer be able to dry. The moist part on the surface risks freezing during the first cold periods.



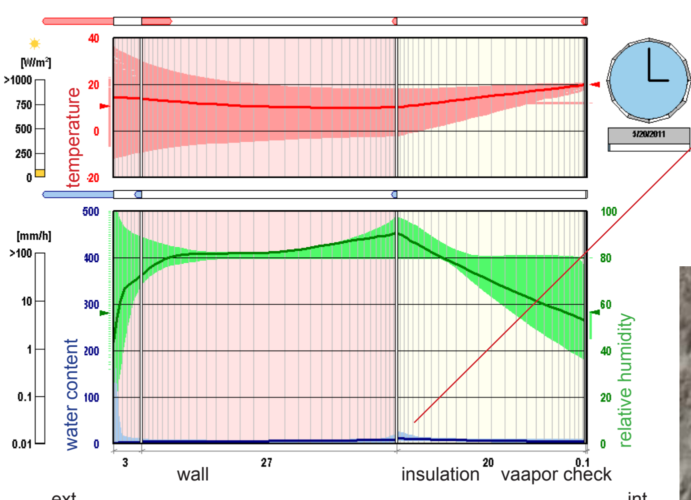
After one year: quantity of water "retained" in the wall between the wall and the insulation…

Simulation of the wall with the insulated interior wall WITH tight but RESPIRING waterproofing treatment



An appropriate water proofing treatment of the façade can make it impermeable and non-water absorbing, while retaining its "respiring" characteristic.

After one year, the wall remains "dry," thanks to the waterproofing of the façade.
"Wetting" test: the water beads on the surface but is not absorbed.




RUE DE LIEGE
LUIKSTRAAT
50
50

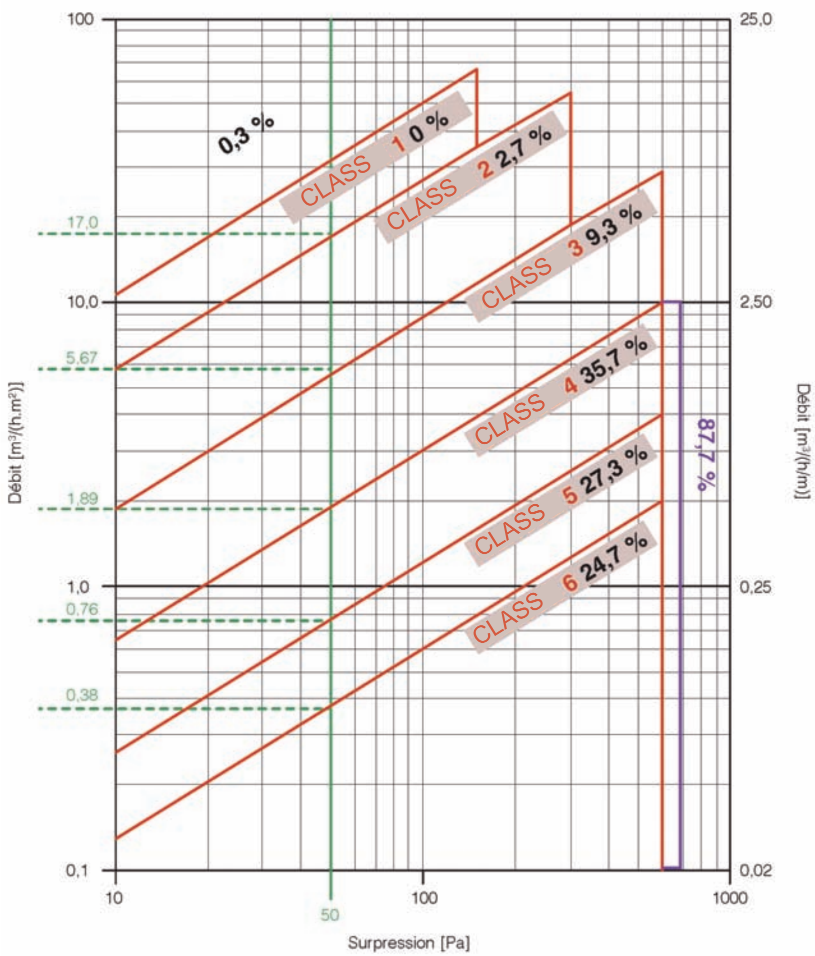
D. D. Specific elements

1) Window frames

Paradoxically, frames are generally more energy-efficient than required by current standards in Belgium! NBN EN 1026 distinguishes between 4 levels of airtightness for the sections of lab-tested frames. There are however two comments to be made here:

- stipulating Level 4 (i.e. the highest level of wind-proofing) is not always sufficient in a project aiming to achieve n50 = 0.6 vol/h;
- the majority of frames available on the Belgian market are much better!

This is why the CSTC has proposed introducing Levels 5 & 6.



Breakdown, by class, of the performance of 300 joinery works tested and proposal to subdivide Class 4 (NBN EN 1026). Source: Magazine CSTC-Contact nr. 33 (2012)

2) Openings in the envelope

There are a number of normal building elements which can be a problem in a passive building. Though solutions are always available, they need to be thought through in advance.

- **Letter box**: These either have to be outside and separate from the building, or they need to have an airtight flap.
- **Wood-burning stove**: open fires are not possible in a passive building, though an airtight wood-burner (with an outside air intake) can be used to quickly heat the building.
- **Extractor hoods**: a simple recirculating system will suffice in a home, whereas in a professional setting a hood with integrated compensation allows the hygienic ventilation system to be halted while cooking. To prevent clogging due to grease, the hood must be absolutely separate from the hygienic ventilation system;
- **Gas cooker**: an input of fresh air must be foreseen;
- **Fuse box:** it is better to install the fuse box within the building as this means that there will only be the mains supply cable traversing the envelope. When the fuse box is outside, a number of holes will be needed for the individual circuits.
- **Recesses for electrical sockets:** to prevent air leakage, the bottom of the recess should be lined with plaster. Another way is to use sealed socket housing.
- **Electrical connections**: all wiring for outside devices (doorbells, outside lights, alarms, awnings) traverses the building's envelope. Specific muffs or flanges may be used here;
- **Manhole/handhole covers:** where these are integrated into the building's envelope, their weight and greasing their edges are enough to prevent air leakage;
- **Primary ventilation of drains**: a priori, siphons are sufficient to prevent leakage through these drains (at most a pressure

difference of 50 Pa will let the water level vary by a few mm);

- **Rainwater downpipes**: the passage of the pipe must be airtight and it is preferable to insulate the pipe to prevent any condensation thereon;
- **Sectional garage doors:** insulated and airtight garage doors are available on the market, though great care has to be exercised when installing them. It is often much easier not to include a garage in the building's protected envelope;
- **Airtight cat-flaps: magnetic cat-flaps** are relatively airtight (even if they constitute a weak point in the envelope's insulation);
- **Airtight fire doors**: airtight inside fire doors are now available on the market; if they were also completely soundproof, they would be absolutely perfect ....

3) Mandatory air vents

On top of what has been discussed above, there are statutory ventilation requirements. It is important to make sure that these various elements are properly positioned during the design phase, as this is when the bounds of the protected volume are determined. Positioning certain service elements inside or outside the protected volume can facilitate or endanger achieving an airtight building.

a. Utility shafts

In the majority of cases, shafts do not need ventilation. The easiest thing to do is to completely incorporate the shaft in the protected volume, i.e. inside the building's airtight envelope. This means that all wiring and plumbing is within the envelope, thus avoiding any airtightness or insulation problems (provided that there is no risk of condensation on the pipes).

Turning to fire prevention, the Royal Decree of 12 July 2012[35] amending the standards for new buildings requires (for low, medium-height and high buildings):

- •either a structural element to be placed in the shaft where it passes from one floor to the next, providing at least the fire resistance required for the floor slab;
- •or the walls of the vertical shafts must have an EI rating of 30 (for low and medium-height buildings) or 60 (for high buildings)[36]. Similarly, all access hatches to these shafts must have a rating of EI 30; vertical shafts need to be compartmentalised via horizontal screens with the following properties:

  - be made of a Class 1 material;

  - seal the whole free space between the pipes;

  - have an EI rating of 30 (for low and medium-height buildings) or 60 (for high buildings)

b. Lifts

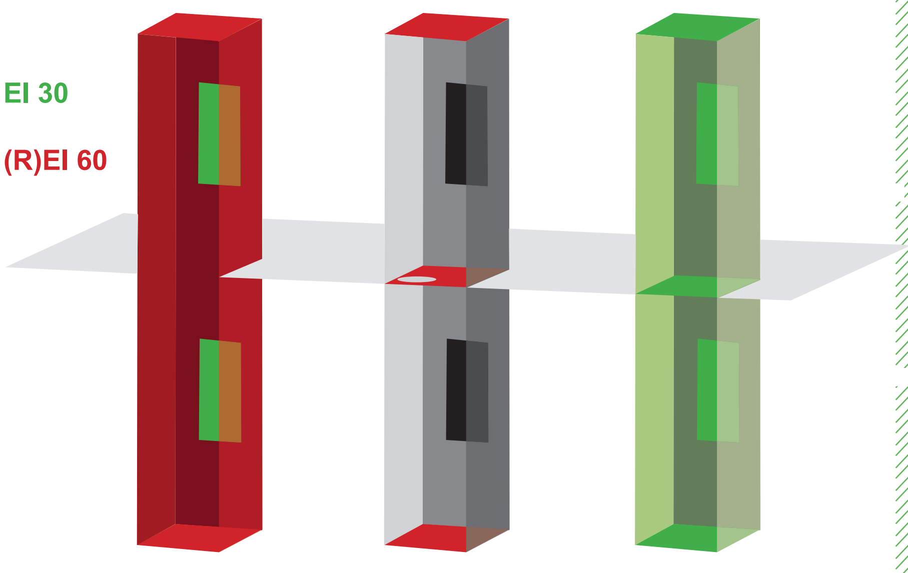
With regard to lift shafts, the Royal Decree solves the contradiction between energy-saving and ventilation requirements, providing a number of solutions only making it necessary to pierce the airtight envelope when all other possibilities have been exhausted.

The whole complex made up of the lift shaft and the machine room or just the lift shaft need to have natural ventilation with an outside air intake. When the shaft and machine room are ventilated separately, each of the ventilation openings must have a minimum section of 1% of the respective horizontal surfaces. Where the complex made up of the lift shaft and machine room are ventilated from the top of the shaft, the ventilation openings must have a minimum section of 4% of the shaft's horizontal surface. The openings can be fitted with motorised dampers controlled in one of the following ways:

- automatically, with a view to providing sufficient air to lift users, even in the case of a prolonged stop;
- automatically in the case of an abnormal increase in the temperature of the machine and/or the control equipment;
- automatically in the case of a fire being detected in the shaft and/or in the

machine room;

- automatically in the case of a fire being detected in the building (where the latter is fitted with an all-round fire detection system);
- automatically in the case of a power cut or a failure of the control system (pro-active safety measure);
- manually via a control located at the emergency exit at a place defined in agreement with the fire department.



mandatory ventilation

No mandatory ventilation (openings in the shaft)

No mandatory ventilation (no openings)

To meet the growing demand for passive buildings, systems ensuring ventilation in such scenarios have already appeared on the market, though their installation previously needed to be approved beforehand by the fire department, and the situation could differ from one local authority to the next. The entry into force of the Royal Decree has put an end to this.

c. Gas meters

Spaces containing gas meters must be ventilated, with at least top and bottom ventilation with a diameter of 125 mm. There are no exemptions allowed, and the easiest thing to do is to place them outside the building's protected envelope.

d. Heating systems

Pursuant to the norms NBN B61-002 and NBN B61-001, rooms containing heating systems must be ventilated. A distinction is made between two types of boiler: an open combustion circuit boiler (type B) and a closed combustion circuit boiler (type C).

However, for a type C boiler with a nominal power rating lower than 70 kW, there is no mandatory requirement to ventilate the room. Where there is no need for such a rating, the boiler can be located within the protected envelope insofar as the room remains normally ventilated and the air intake is properly ensured.

2.1.3. Ventilation

2.1.3.1. Principle

> 1.2.1.1
p. 30

With a passive building by definition very airtight, it is crucial to ventilate for health reasons and to remove moisture. However, even when controlled, incoming and outgoing air flows cause major heat loss.Passive design provides for a substantial proportion of this heat to be recovered through the use of a heat exchanger connected to a comfort ventilation system.

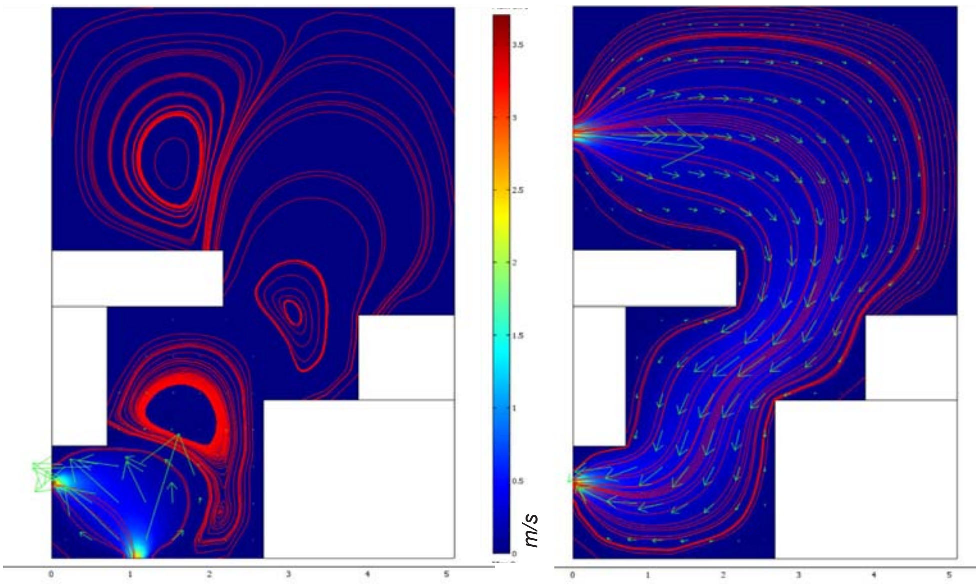
The focus in controlling the complete separation of indoor and outdoor air is not only on avoiding any heat loss, but also on ensuring a healthy and comfortable air exchange via a properly sized and maintained system.

Though the insulation has an impact on the design in terms of the obvious thickness of the envelope, the sheer site of the ventilation system must not be ignored. These two aspects can greatly influence the quality of the rooms and it is necessary to plan for it in advance in order not to end up being forced to make adjustments during construction.

2.1.3.2. Strategy and sizing

It is a "universal truth" that, whatever the shaft or duct, it will always be too narrow for the installer. When constructing a passive building, there are however several points facilitating execution:

- installing the heat exchanger close to the air intake and exhaust ducts: the latter are very bulky and need to be very well insulated in order to traverse the protected volume (the air has outside temperature and has the same effect as a "hole" in the insulation);
- placing all shafts / ducts in the centre of the building (close to a hall or corridor), thereby simplifying and limiting the air distribution network;



Simulation of a room with supply and extraction. The case on the left shows a "short circuit" between supply and extraction. The case on the right shows a solution where the supply is opposite the extraction.

- checking whether the network can be installed without criss-crossing ducts or making sure that the headroom under the ceiling allows ducts to criss-cross[37] (also taking into account the thickness of any insulation);
- checking the path of the air: supply and exhaust vents, even when balanced, may not work properly if the passage is impeded, for instance by doors without a ventilation gap at the bottom.

To avoid pitfalls, it is also important to consider such installations from a long-term perspective: access hatches are for instance needed to allow easy cleaning. It is also necessary to check - during construction - whether the insides of the ducts are properly protected (this is rarely the case) to avoid dust accumulating inside and being subsequently emitted (for years) in the air breathed in by the building's occupants.

> 2.2.2.1 /D
p. 174

Careful positioning of ventilation intakes and outlets can often avoid problems: for instance installing s supply vent above a door ensures that it will never be blocked by furniture (which could have a negative effect on the ventilation system). Conversely, should the shape of the room be unsuitable (e.g. a long entrance corridor), such a provision may cause a short circuit, with the air not able to circulate throughout the space.

> 1.2.3.4
p. 42

> 2.2.3
p. 190

One of the main causes of a malfunctioning domestic ventilation system is bad noise control, which can induce an occupant to simply disconnect his system. It is therefore essential to stipulate a) a ventilation test to check air-flow rates at each vent, and b) a sound test in each room.

2.1.3.3. Building management system (BMS)

Ventilation systems in large buildings are controlled automatically. However, a number of minor measures can simplify life:

- giving occupants a manual "override" facility allowing them to control their personal environment; the opportunity to act pro-actively is psychologically just as important as the actual temperature or moisture level;
- facilitating control of the BMC via clear icons giving simple access to the control parameters;
- saving records of control points to allow a comparison of a subjectively felt situation with the actual (objective) situation and to fine-tune the parameters in line with occupants' needs;
- as a passive building only reacts slowly, parameters may often need more tuning; one needs to plan for at least 2 - 3 full years monitoring the building.

To best manage the monitoring, it is important to have a budget for staff training, spares (e.g. filters for the heat exchanger), the tuning of the building's "operational mode" and also the recording of operating parameters (temperature, power consumption).

The principles governing the sizing and installation of the technical systems are discussed in greater detail in the following section.

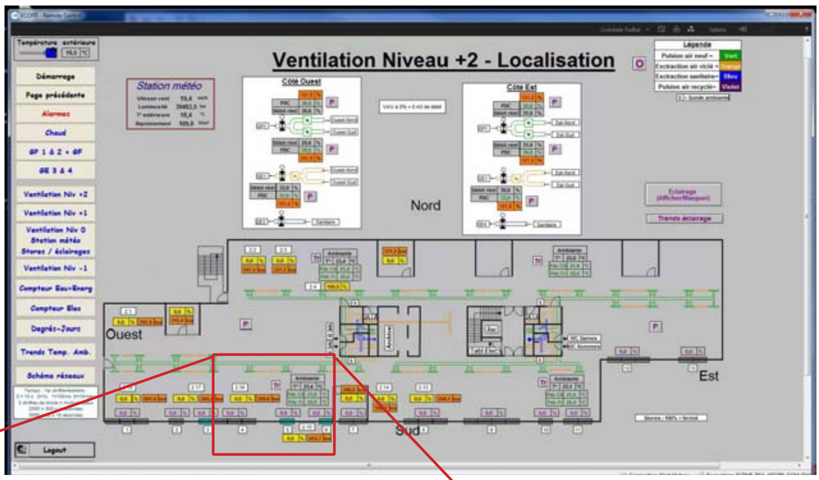
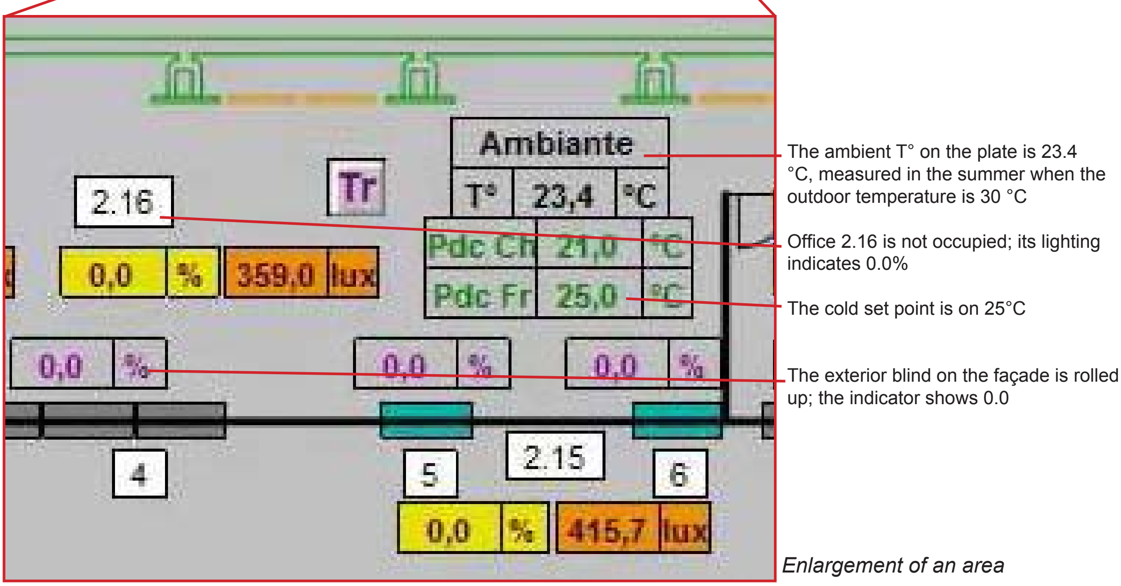


Illustration of the BMS of a typical floor plan of the ECOffice in Nivelles



Enlargement of an area

Holcim HQ | Nivelles | Thomas et Piron | architect A2M

2.1.4. Specifications

> 3.1.4.2
p. 283

An accurate and complete bill of specifications helps let the contractor know exactly what is to be done - i.e. what has been planned and budgeted in the design phase. It is important to check the consistency of the values entered into the PHPP and additionally listed in the bill of specifications:

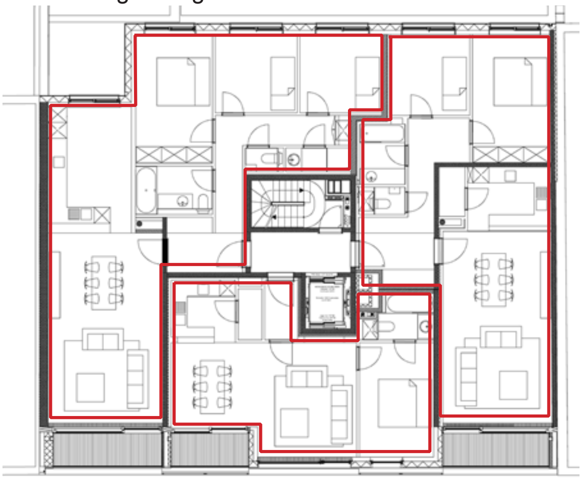
- attach to the bill of specifications a list of U values for the walls and λ values for the insulation material (under passive certification, only ATGs are admissible; datasheets are not accepted);
- make a distinction between the Uf values for the frames and the Ug values for the glazing (a Uw for the whole window is not sufficient);
- list the U values and the required airtightness performance of the outside doors and other openings (outside lamps, etc.);
- provide details of thermal bridge junctions or any other specific point;
- provide details of window frame junctions (insulation and airtightness continuity);
- with regard to airtightness: one item should mention the maximum air infiltration rate and the conditions for measuring such;
- with regard to ventilation: the performance of the heat exchanger listed must be identical to that entered into the PHPP (certificate pursuant to EN 308).

> 3.1.6.2
p. 290

2.1.4.1. Airtightness

As regards airtightness, it is better to create one specific and well-documented item than to have several small and separate items. There are two reasons for this: firstly, doing so highlights this point, and secondly because it is very difficult to specify exactly the quantities of materials needed (metres of tape, dry-lining, etc.). The various junctions (window frames/brickwork, dry-lining/vapour brake, OSB panels, sills, etc.) should be described in detail, as well as any other particular points (electricity, holes through the wall, etc.).

In the documents attached to the call for tenders, it is a good idea to specify the airtight zones, providing specific details and plans covering the building's airtightness.



« Les Courses » housing | Ixelles | Privé | architect: MDW architecture

2.1.4.2. Blower door and thermography tests

To gain certification, only one blower door test is necessary. In practice however, several such tests should be planned[38]: at least one when the building's envelope has been completed, and a further one when all technical systems have been installed. The former test allows possible corrections to be made without having to remove/tamper with any finishing work. It also allows the quality of the junctions to be tested at an early stage. The latter test provides a guarantee that no mistake has been made in the course of the finishing work.

It is recommended to carry out the Blower-Door® test in conjunction with a thermography, as the latter is a great help in identifying any leakages. Though only a minor temperature difference between inside and outside is needed to pinpoint any problems, it is nevertheless advisable to heat the building before the test while at the same time limiting as far as possible the sun's influence.

dnA housing | Asse | D Van Ginderachter & N De Ridder | architect: BLAF architecten

2.2. technical installations

Bram De Meester

2.2.1. The role of engineering consultancies

With passive building design focused on optimising energy performance, the number of technical systems necessary is lower. Moreover the systems involved are less powerful. Nevertheless, it remains important to set forth the expectations they need to fulfil, taking into account:

- legal requirements (energy performance, regulations governing social housing, etc.),
- comfort requirements (criteria for overheating, for regulating heating, etc.) [39]
- financial constraints (initial investment, availability of grants, etc.)

One cannot expect a project owner to have a complete grasp of all technical possibilities and constraints. The role of an engineering consultancy is thus to provide him with advice on the desired performance, to examine with him the consequences of any choices and to translate all this into a consistent list of requirements .

> 3.1.2.1
p. 269

> 1.2.3.4
p. 42

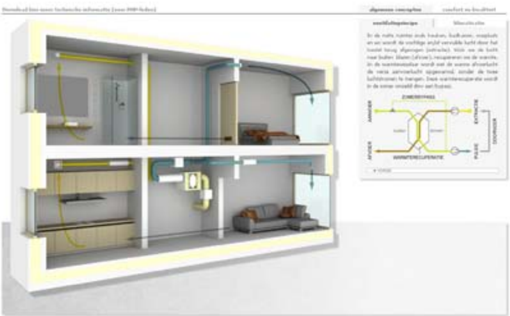
During the design phase, an engineering consultancy should link the technical concepts to be installed with the specific behaviour of a passive building. This goes beyond just selecting the appropriate technologies, as the first step must be to define the best match between envelope and systems. For example, one can choose either a slow or fast emission system based on the foreseeable fluctuations in demand for cooling or heating. Any technological choice will be the result of the priorities assigned to the various design requirements (budget, comfort, flexibility, etc.) and will ultimately be the responsibility of the project owner.

In a similar context, an engineering consultancy contributes greatly to a building's physics, looking for the optimal energy balance right from the start, in consultation with the architect. The bottom line here is that the project owner, the architect and the engineering consultancy share their points of view and knowledge with a view to achieving a technically optimised and integrated overall design[40].

2.2.2. Ventilation, heating and cooling

A passive construction is often compared to a thermos flask which has the task of preserving as much as possible the heat of its contents. We need however to be aware of the fact that minimising heat loss through insulation and airtightness gives rise to a new challenge. The balance between energy gains (heating, inside input and solar power) and energy losses (due to heat transfers, infiltration and ventilation) becomes a lot more complex, requiring an overall vision. This is why the various factors necessary for a healthy and comfortable indoor climate need to be looked at in conjunction with one another.

Taken from 39 combinaisons pour une installation technique (http://www.passiefhuisplatform.be/artikel/installatiewijzer-voor-ventilatie-en-klimatisatie-van-passiefhuizen



Balanced ventilation principle

Climate adjusting possibilities

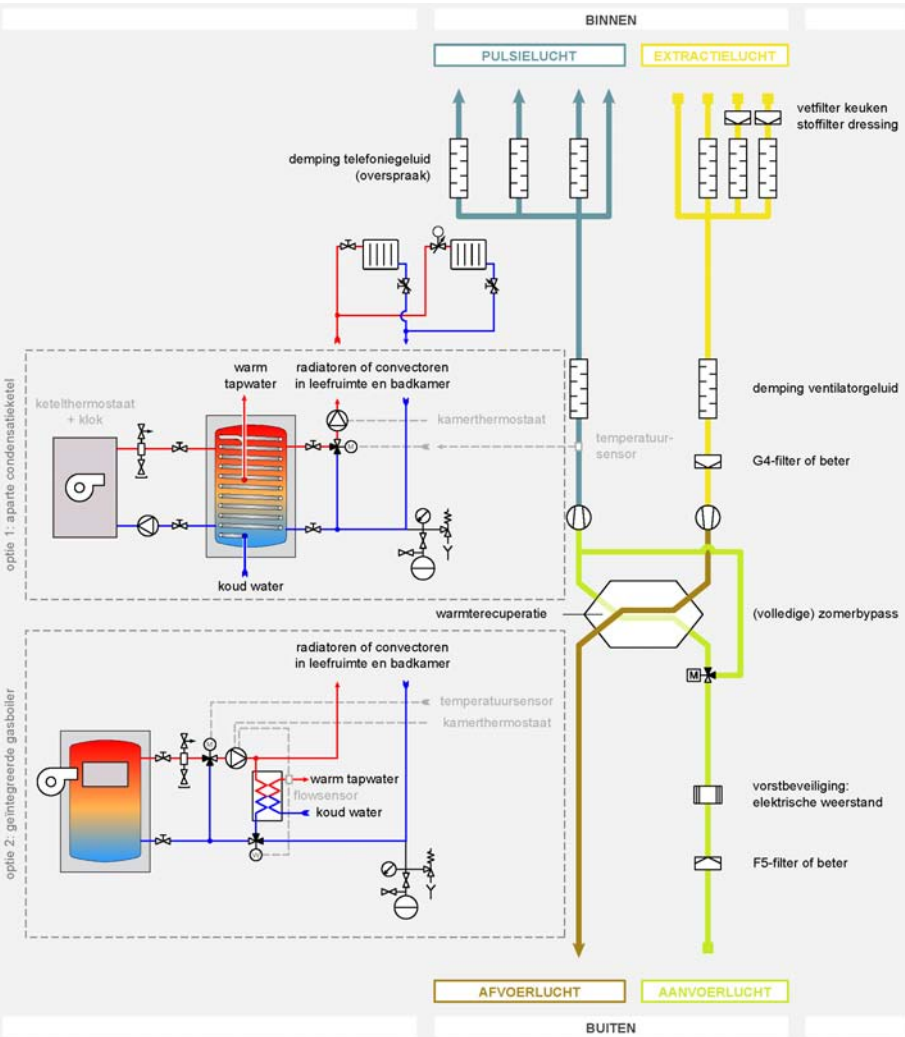
Points requiring attention

Ventilation key

- Air inlet
- Air outlet
- Supply
- Extraction
- Filter
- Fan
- Acoustic muff
- Electric heating element
- Water-air exchanger
- Ground-air exchanger

Hydraulic circuit key

- Refrigerant
- Air outlet
- Cold water
- Hot water
- Pump
- Compressor
- Expansion valve
- Safety unit
  - manometer
  - expansion tank
  - pressure relief valve
- water-water exchanger
- Stop tap
- Adjustable tap
- Thermostatic tap
- Thermostatic mixer tap
- Exchange-mixer tap
- Non-return valve
- Separator


BINNEN
PULSIELUCHT
EXTRACTIELUCHT
vetfilter keuken
stoffilter dressing
demping telefoniegeluid
(overspraak)
optie 1: aparte condensatieketel
ketelthermostaat
+ klok
warm
tapwater
radiatoren of convectoren
in leefruimte en badkamer
kamerthermostaat
temperatuur-
sensor
koud water
demping ventilatorgeluid
G4-filter of beter
warmterecuperatie
(volledige) zomerbypass
optie 2: geïntegreerde gasboiler
radiatoren of convectoren
in leefruimte en badkamer
temperatuursensor
kamerthermostaat
warm tapwater
flowsensor
koud water
vorstbeveiliging:
elektrische weerstand
F5-filter of beter
AFVOERLUCHT
AANVOERLUCHT
BUITEN

2.2.2.1. Ventilation

Proper ventilation is essential and is clearly defined under Belgian law (via the energy performance regulation, EPB). However, proper ventilation requires a large amount of energy, as the air from outside needs first to be warmed, cooled or humidified to meet thermal comfort requirements, without speaking of the energy required for the fans. Mechanical ventilation thus consumes a large amount of electricity, with the result that a lot of effort used to be put into limiting air flows in low-energy buildings. This tendency has however since been reversed as a result of better knowledge of the health effects of proper ventilation, with a number of reference works[41] now recommending higher ventilation flow rates, especially for residential buildings. This does not of course make the problem any easier.

A. Ventilation flow rates in residential buildings

Flow rates are dependent on a building's use. For residential buildings, the norm NBN D50-001 dating back to 1991 still applies. This sets fresh air input flow rates in living areas and output flow rates in wet rooms (bathrooms, kitchens, toilets, etc.). It is obvious that mechanical ventilation (system D) with high-quality heat recovery is best in any passive building. As such a building is also airtight, it is a good idea to do everything to properly balance flow rates, avoiding local over- or underpressure through sufficiently sized transfer openings.

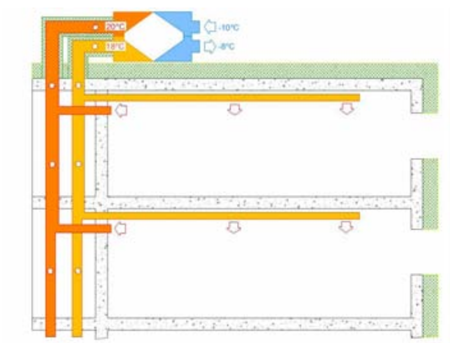
B. Ventilation flow rates in commercial buildings

For non-residential buildings, norm NBN EN 13779 applies. The category "*medium indoor air quality*" (IDA2) is increasingly being given preference over the minimum legal requirements stipulated in the building energy performance (EPB) or working environment (RGPT) regulations. The norm sets a flow rate of 40-45 m³/h per person, thereby limiting the concentration of CO_2 in indoor air to around 400 - 600 ppm above that of outdoor air.
Certain flexi-programmes such as offices delivered in a semi-finished (casco) state may have to cope with varying levels of occupancy during the day (or a year), and it may be a good idea to dimension the system somewhat larger in order for its capacity to keep pace with the developing

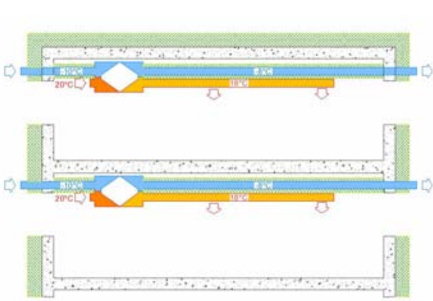
use of the building.

C. Centralised ventilation or not ?

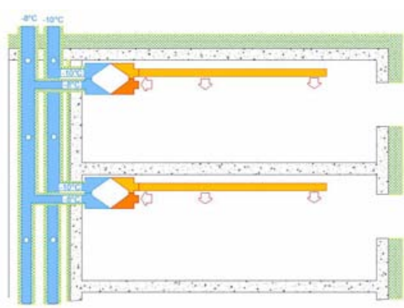
When a new passive building is made up of several individual units (whether used for the same purpose or not), the choice is between a centralised or decentralised heat recovery ventilation system[42]. A centralised system will serve all units within the building, while in a decentralised set-up each unit has its own system.



Centralised ventilation



Decentralised ventilation with intake and exhaust per floor



Decentralised ventilation with central column for intake and exhaust

A centralised system is cheaper to install, is easier to maintain, makes the best use of space and reduces noise pollution. The focus needs to be put on a system which is capable of being regulated locally, i.e. on a flat-by-flat basis in a residential setting or on a zone-by-zone basis in a commercial setting. Each unit must be in a position to individually regulate its comfort, thereby avoiding problems and discontent. Generally speaking, the electricity consumption of a centralised system is higher than the total consumption of all decentralised systems. From an energy design perspective, a centralised system is the best choice as it reduces all related losses (proximity of an outside wall, more effective thermal insulation). Though each case needs to be studied separately, one of the base design principles is not to have a cold duct or shaft within the heated volume.

D. Regulating and maintaining the system

To obtain the desired indoor air quality while limiting energy consumption, it is important to properly regulate air flows and to ensure that all ducts are airtight. Once a system has become operational, maintenance is equally important (replacing filters, cleaning ducts). During the design phase, account needs to be taken of future access requirements to all important parts of the system. Building maintenance must be made as simple as possible, especially in cases where few resources and little knowledge are available (e.g. in social housing, schools, etc.).

> 1.2.3.5
p. 42

It is a good idea to install an on-demand ventilation system where air flows are controlled in line with the building's actual level of occupancy. At a low occupancy level, output air will only be slightly stale or not stale at all and ventilation flow rates can be reduced. In non-residential buildings, CO2 sensors are often used. In a residential setting, humidity is a better indicator, as it is linked to kitchen, bathroom or cleaning activities. A further advantage is that a hygrometer is cheaper and more resistant than a CO2 sensor.

On-demand ventilation is mainly used in buildings or premises with varying rates of occupancy, with potential savings increasing with the flow rates. For this type of ventilation, a minimum flow rate needs to be constantly maintained (for instance 20% of the nominal flow rate, thereby ensuring that all impurities not detected by the sensors (smells, VOC emissions) are systematically emitted. Moreover, the fans and ventilation system must be designed in such a way that they will function properly even at a reduced flow rate. Variable-speed fans are indispensable, as are removable grilles flow regulation valves.

2.2.2.2. Auxiliary heating

Even if a passive building's heating system is smaller, a certain thermal balance must always be maintained. The installed capacity must be sufficient to cope with the thermal bridges as well as a possible stoppage of the heat exchanger in the case of frost. The usual design rules[43] continue to apply, even if the calculation is somewhat more complicated.

A. Inertia and heat emission

The choice of heat emission system is crucial from a time perspective - because inertial effects can play an important role - and from a space one - as the temperature differences in the various rooms need to be well studied.

In order to correctly take the time effects into account, it is essential to know that the thermal balance of a passive building - specifically for reducing losses - can change rapidly from a (minor) demand for heat to an oversupply of heat. Internal (e.g. start of working hours in an office building) and external (e.g. the sun) gains modify the thermal balance. The availability of a thermal mass (a concrete ceiling, heavy walls) only plays a minor beneficial role. Inertia will slow down the rise in temperature and reduce its maximum level, though absorbing any superfluous heat takes a certain amount of time. This all illustrates why fast-acting emission systems are preferable. Underfloor heating or a thermally activated concrete slab reacts so slowly that the target temperature will be exceeded before the system is able react.

ELIA HQ | Brussels | ELIA System Operator | architect: Architectes Associés

B. Regulating the system and distributing heat

Heating a building using ventilation air seems an obvious emission strategy - almost genetically linked to the passive standard. A designer must ask the following question: for which areas of the building does the temperature need to be regulated separately? In the case of a house, regulating heating on a room-by-room basis hardly seems necessary. In the bathroom, a small heated towel rail is enough to provide a higher comfort temperature.

> 5.3
p. 360

The modularity expected by the market from office buildings is more demanding. Various reference works on sustainability recommend installing individual controls as there is proof that these can give users a sense of comfort. It is however impossible to fit each supply grille with its own heating (or individual control). This is why low-powered emission systems (compact thermally active ceilings, convectors) are to be found in passive offices. For other types of building (e.g. hospitals or schools), designers must first correctly assess how the system will be regulated (occupancy times of various areas, variations in the desired temperatures) before opting for a heating system based on the ventilation system.

An air-based heating system distributes the heat through the ventilation unit, meaning that it will run longer. It is also sometimes necessary to increase ventilation flow rates in line with heating power. With such higher flow rates only necessary during peak heating demands, a system allowing flow rates to be flexibly regulated is recommended, even possibly allowing air to be recirculated. Where heating comes from an air-based system and where the ventilation system runs on demand, regulation priority should be given to the heating system. This means that greater importance needs to be attached to defining the parameters for regulating and balancing the ventilation network.

2.2.2.3. Hot water

Demand for hot water is to a great extent dependent on a building's use.

A. Weak demand for hot water

For buildings with only a weak demand for hot water (offices, shops), on-the-spot hot water production is recommended. Where water consumption points are centralised in the building (e.g. kitchen, shower block), preference should be given to using a gas-fired boiler. Where such points are dispersed throughout the building, installation costs can however make it preferable to use electric water heating systems. This option stands up to criticism given that the alternatives (e.g. a hot water circulation network or decentralised water heating systems) often lead to relatively high heat losses. Low consumption levels also curb interest in the use of renewable energy, as the additional investment needed does not provide an adequate return.

B. High demand for hot water

The situation is different for buildings with high demand for hot water (houses, apartment blocks, hotels, sports centres). As heating needs are much lower in passive buildings, hot water production plays an important role, indeed often more important than heating.

Apart from measures aimed at limiting water consumption (showers instead of baths, mixer taps, etc.) and at reducing distribution losses (short distances, insulating pipes well), it is crucial to find the optimal production strategy. In conventional buildings hot water production plays a secondary role; for a house, the central heating boiler will often be fitted with a heat exchanger only using a fraction of its total capacity. For a passive house or apartment, the ratio between peak heating capacity and on-demand hot water production can range from 1 to 8.

Hot water production on a semi on-demand basis - storing a certain proportion of the necessary energy coupled with auxiliary hot water production - is a good compromise between cost (size of the hot water system and the necessary capacity), energy saving (limiting losses when hot water is not

ELIA HQ| Brussels | ELIA System Operator | architect: Architectes Associés

needed) and comfort (sufficient availability of hot water). It is a good idea to group consumption points together, enabling heat storage and hot water production to be centralised and in turn reducing storage losses and overall system capacity.

In apartment blocks, this can be done by equipping each apartment with its own distribution unit (heat exchanger) proving hot water and heating in one circuit. In buildings where combating Legionella is mandatory (care and nursing homes, hospitals, sports centres), a hot water circulation loop will also be necessary. This loop should be as short as possible and have high-quality insulation (this applies also to the brackets, valves and any fittings).

Having a centralised hot water production system opens the door to more efficient technologies using renewable energy. Solar-based hot water systems can provide a substantial share of hot water, and further possibilities include biomass-based systems[44] or (mini) CHP systems. The combination of high demand, storage capabilities and centralised production make these technologies cost-efficient.

2.2.2.4. Overheating

Avoiding overheating is a major challenge, and is difficult for a designer to assess. Experience gained with conventional buildings can act as a guide. For example, in which direction a building faces has a great influence on heating regulation.

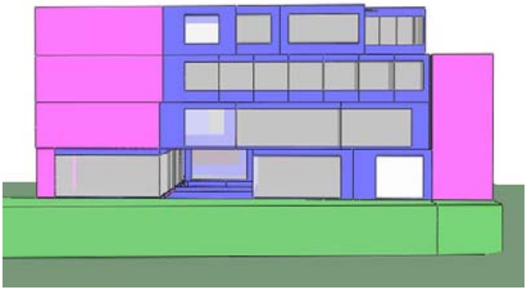
The summer climate needs to be systematically analysed, looking at such items as solar protection, thermal inertia, intensive ventilation and the minimisation of internal gains. In doing so, indoor sources of heat gains need to be checked on a zone-by-zone basis, with priority given to limiting those identified. This can involve using energy-saving lamps, appliances with a high energy efficiency rating and (energy-) efficient office equipment.

A further requirement is to define for each zone the desired level of comfort, using the norm NBN EN 15521 as a basis. Comfort thresholds will vary greatly dependent on a building's use. They may also vary within the same building (e.g. an office, a gym or a hospital room) dependent on the activity exercised there and the clothing worn by the users.

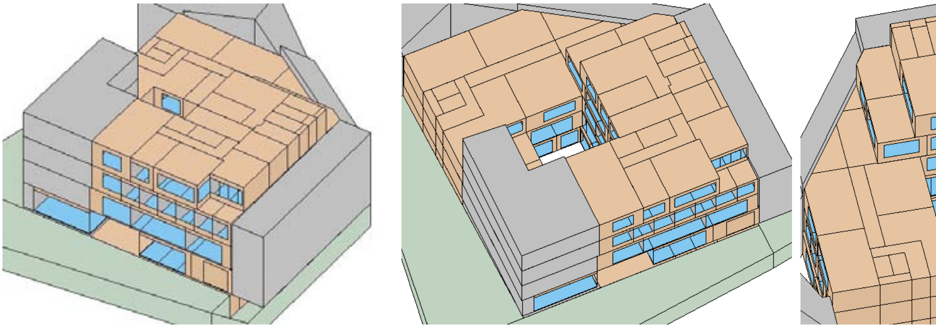
A. Dynamic simulations

Dynamic simulation is by far the best assessment method, enabling users to calculate, on the basis of a reference climate, indoor hour-by-hour temperatures for a whole year. As these values are greatly influenced by the base assumptions, indoor sources of heat as well as ventilation, heating and cooling strategies need to be encoded in detail. Where uncertainty exists with regard to certain parameters, standard values can be used or a worst case scenario assumed. One can also carry out a sensitivity analysis (for instance regarding the relative contribution and timing of indoor sources of heat) with a view to analysing the influence of a problematic parameter. Above all, the simulation must be for a specific area, looking at a minimum at the room for which the ratio between indoor sources of heat / solar input and ground surface is highest. This can often be a small south-or south-west-facing room with a lot of window surface (e.g. a corner office, living room).

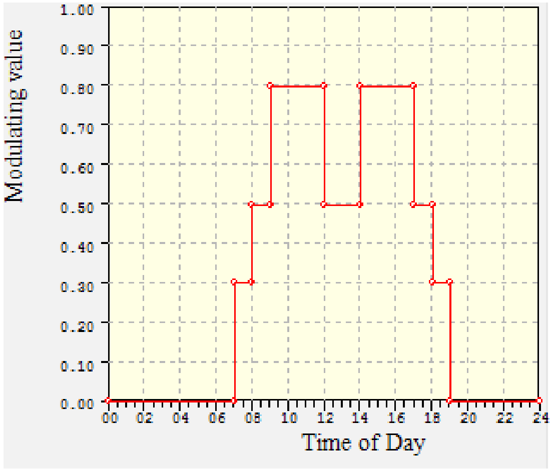
Maison de l'Emploi | Ixelles | Administration communale d'Ixelles | architecte: A2M



Dynamic simulation model (Source CREA-TEC)

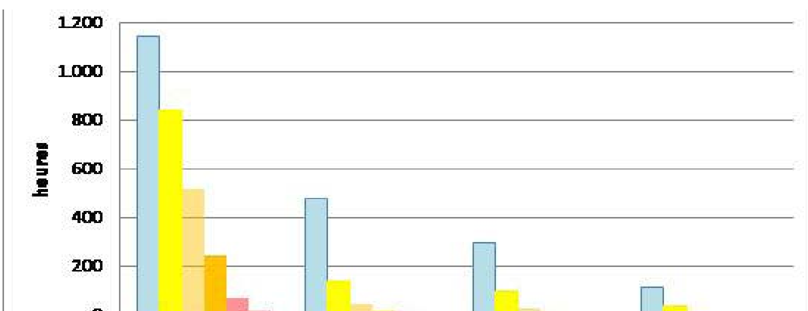


Sunshine June 9:00 12:00 15:00 18:00



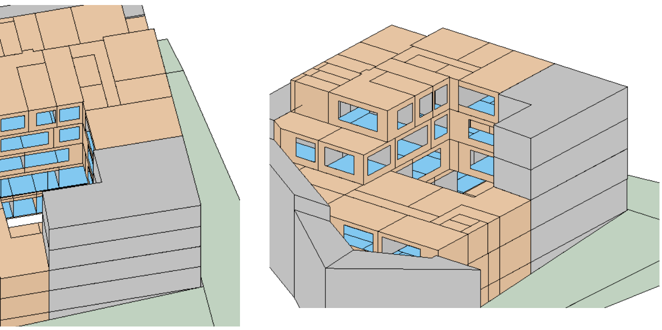
Office occupation profile

> 4.3
p. 313



	Sim0	Sim1	Sim2	Sim3
t°>25	1.142	478	295	114
t°>26	840	140	95	32
t°>27	514	42	26	5
t°>28	245	11	1	0
t°>29	67	5	0	
t°>30	13	0	0	

Result of comfort for a standard floor: number of hours beyond 25°C...



With regard to office buildings, the smallest module (i.e. an individual office) is often the right area. Ignoring how the building is divided up and just simulating larger zones (a whole floor, the entire building) does not make any sense, as it means the thermal loads are distributed evenly, suggesting a uniform temperature throughout the building. This is obviously not the case in reality for individual offices. There is however no problem in simulating such a zone as an open plan office, as long as one is certain that the building's user will not be using any other configuration.

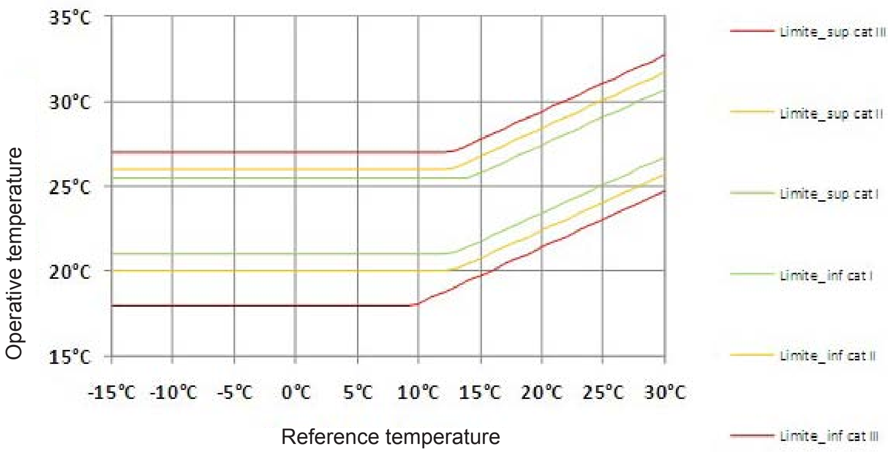
B. Assessing comfort

The hourly indoor temperatures gained through simulation can be checked against the standards for thermal comfort . Various criteria can be used in assessing the temperatures. In this respect, we should forget the idea of a temperature remaining at a predefined comfort level for a certain space of time as this is only relevant in a very few specific cases (e.g. labs, operating theatres). Moreover, such an approach would lead to oversized systems.

Due to its ease of interpretation, a criterion limiting the hours of exceedance is often used. In doing so, we take leave of the principle that a building's users can tolerate temperatures lower or higher than the comfort temperature when these are limited in time. Exceedance values of 3% or 5% per year[45] are often used, as is a twofold limit: 5% exceedance of a temperature threshold deemed as comfortable by 90% of occupants (in a house or office building, this value is around 25°C) and 1% exceedance of a temperature threshold deemed as comfortable by less than 80% of occupants (around 28°C). Another way is to weight the exceedances in accordance with the degree of variation in relation to the desired comfort temperature. The results of this weighted method of measuring temperature exceedances are however a lot more difficult to communicate.

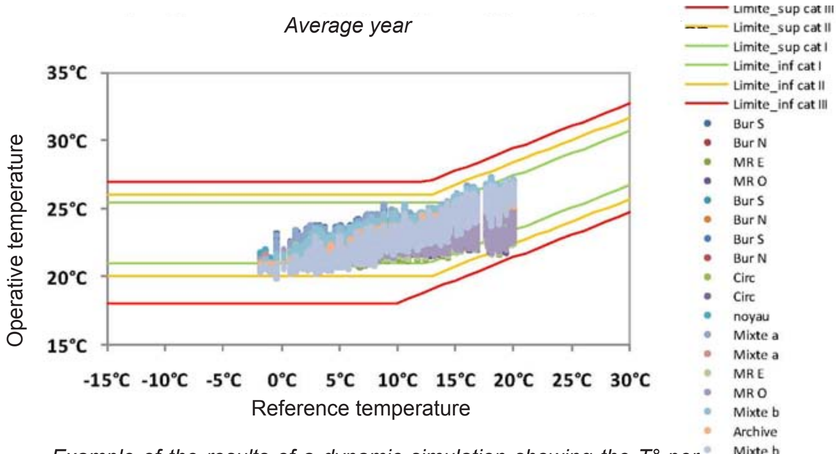
One major disadvantage of the above-mentioned methods is that the threshold values always relate to a reference climate used in the simulation. With actual climate conditions differing from one year to the next, it is impossible to check a posteriori whether the exceedance limits have actually been exceeded.

This can however be achieved using a different method: that of adaptive temperature threshold values[47].

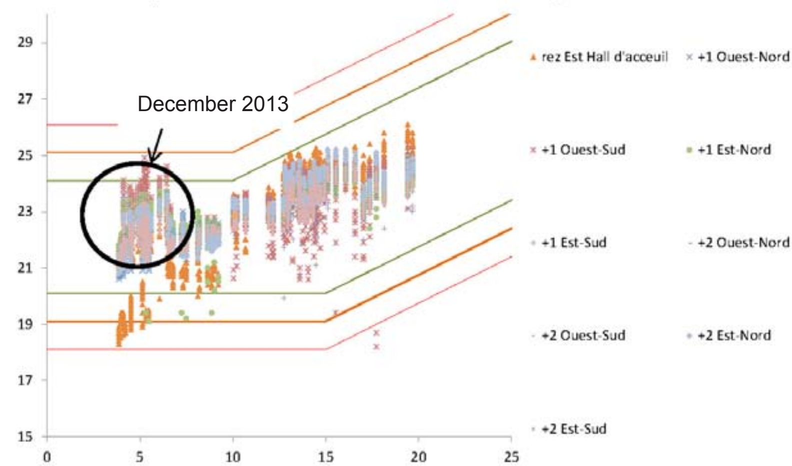


Taken from "Le confort thermique et les exigences de température à l'intérieur des bâtiments" Comfort zone class I to III selon - NBN EN 15251

This method does not allow any exceedance of temperature thresholds, instead adapting them to a dynamic average outside temperature. It is based on study results showing that a building's users adapt to higher outside temperatures behaviourally (wearing appropriate clothing, opening windows), physiologically (body adaptation) and psychologically (perception, expected comfort), enabling them to accept higher temperatures not catered for in conventional comfort theory. This effect is heightened in buildings where users are able to change their environment (opening windows, regulating the heating) and where no strict dress code applies.



Example of the results of a dynamic simulation showing the T° per area for a standard year



Example of the result of monitoring 8 areas of the same office building for a period of 4 months. The temperatures read are compared to the adaptive comfort ranges defined by the NBN EN 15251 standard.

In cases where no dynamic simulation has been carried out in the design phase, there are several simple tools available for identifying risks of overheating. These include for example the PHPP or EPB indicators, though these apply to the whole building and are not in a position to identify risks of overheating in individual rooms. There are several simple simulation tools available (e.g. Alter-Clim[48]), allowing users to gain a feeling for the situation without carrying out an in-depth simulation. Whatever tool used, it is important to always simulate several different architectural or geometrical parameters (the building's orientation, glazing, awnings, sunscreens, etc.) in order to assess their effects. If the risk of overheating cannot be overcome, one will have to look into passive ways of cooling the building.

C. Passive cooling

Any strategy not based on a conventional refrigeration cycle (compression or absorption refrigeration cycle) can be described as a passive cooling method[49] . Examples of passive cooling systems include on the one hand night-purge ventilation, adiabatic cooling, dessicant cooling and air/ground heat exchangers associated with a ventilation system, and on the other hand free chilling on a geothermal or surface water basis or even on a cooling tower basis.

It is important to bear in mind that the strategies mentioned above will always require auxiliary energy, involving higher consumption for the fan or pump. This auxiliary energy requirement is generally not listed in PHPP or EPB calculations, though it is interesting to estimate it in the design phase.

Other cooling techniques are basically independent of the passive concept and detailed descriptions can be found elsewhere.

> 1.1.2.3
p. 22

Basically speaking, passive cooling systems are not that powerful, with the result that combinations of different strategies are often found. It also needs to be understood that a cooling system will not have much effect in a passive building - precisely due to the presence of other measures such as sunscreens, thermal inertia and limiting indoor sources of heat , making it all the more difficult to achieve any degree of cost-efficiency. A simple solution is often the right solution, insofar as it meets overheating norms.

Brussels Environnement HQ | Bruxelles | Project T&T | architect: Cepezed

02 design

2.2.3. Commissioning

Sebastian Moreno-Vacca

2.2.3.1. Current status

In *commissioning* a building, the aim is to get it functioning as planned by its designers. However, the majority of buildings, either in their construction or their use, differ from the original project.

Commissioning practices have been the subject of an international study financed by the International Energy Agency (IEA) and conducted between 2005 and 2010. Some 40 partners were involved. The publication of the study results should help a number of countries to make progress towards achieving greater standardisation of the commissioning process. Commissioning as a separate activity is already to be found in the Belgian Sustainable Building Guidelines (*Référentiel Bâtiment durable*) and in the BREEAM certification guidelines, where it is listed as a specific item of attention and pricing.

> 5.3
p. 360

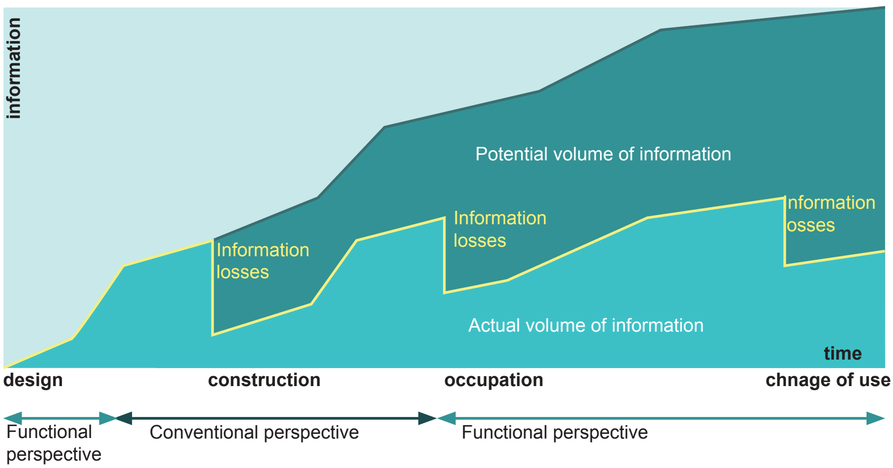
In the period before the IEA study, methodology was confined to conventional technical systems, in many cases ignoring the improved systems, or worse still, component-system interactions. However, any successful design of a passive building (or any other building) requires a large degree of interaction between the project's design and construction teams – what one might call "*integrated interdisciplinarity*"[51]. The IEA work has helped extend existing methods and tools to now cover low-energy buildings, taking account of the design data and systems specific to such buildings.

Indeed, commissioning has returned to the agenda on account of the emergence of passive buildings, reminding designers that their projects are not just design projects, but also real lived-in projects once they have been commissioned. Passive projects have been the subject of particular attention, but also of often high expectations with regard to levels of comfort, energy consumption, environmental benefits, etc.

It is also true that a building that has not gone through commissioning and where there are deficits in its maintenance consumes considerably more energy than planned, while at the same time offering an appreciably second-rate working or living environment. Once completed, many projects suffer similarly from inadequate commissioning due to a lack of clarity regarding who is responsible for what.

Although rarely in a position to supervise commissioning, design team members are ideally placed to contribute to the process, improving the quality of the information to make the process relevant, robust and efficient. In projects involving greater complexity, it can be a good idea to designate a “commissioning officer” with the responsibility of making sure that all systems interact as planned, avoiding unnecessary system conflicts resulting from bad installation and wrong parameter settings.

Once a building is occupied, regular commissioning is a way of fine-tuning operating parameters with a view to providing optimal living and working conditions. According to the IEA, optimising buildings on the basis of their actual utilisation and occupation parameters (instead of merely using the data given to the designer) has the potential to reduce energy consumption by 5 - 10%.



Project phases (Source: Annexe 47 de l'AIE)

2.2.3.2. Keeping track of all information

In any project, the successive involvement of different players often leads to a loss of information which could be of use in later phases.

This is why it can be a good idea to try and recover information lost during the course of the project, in particular when moving from one phase to the next. There are so many design and engineering firms which have carried out the dynamic simulations needed to have a passive building certified, only for these to end up at the bottom of a drawer the moment the next project members get the plans to start work on planning project execution, without even knowing that such a study exists. Worse still, they will sometimes even repeat the calculations, using the simplified programmes at their disposal. The result is that the work actually performed on-site has absolutely nothing to do with the assumptions used in the simulation. Once completed, it becomes very difficult to operate such a building ...

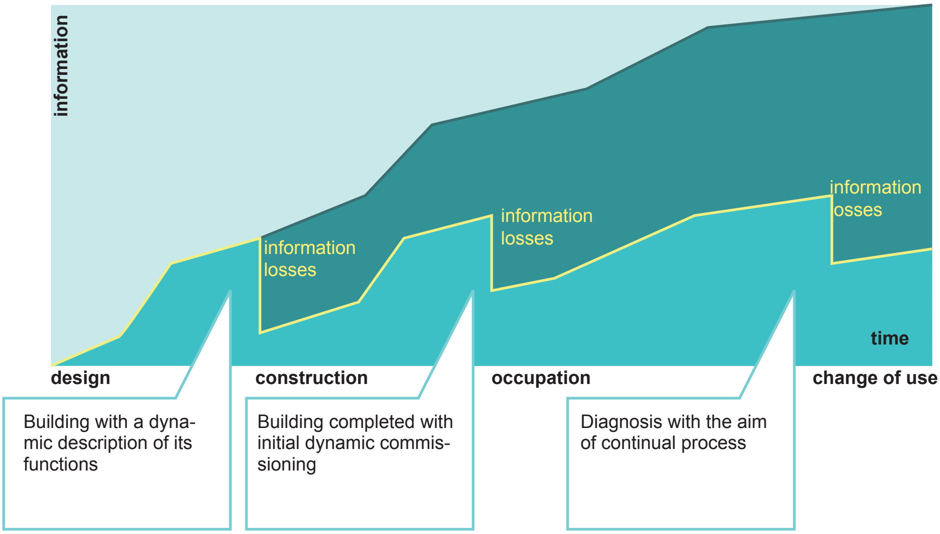
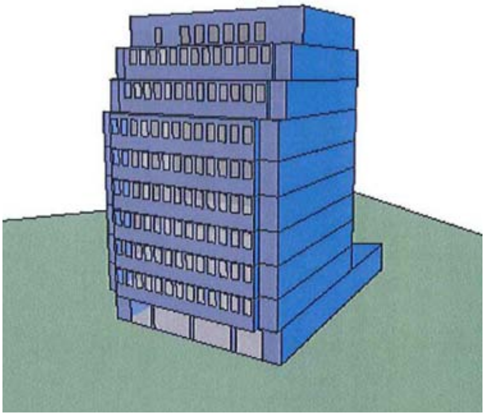


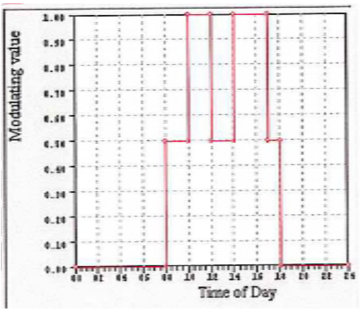
Diagram showing the post-completion problems of a project without commissioning

A. A case in point: no commissioning

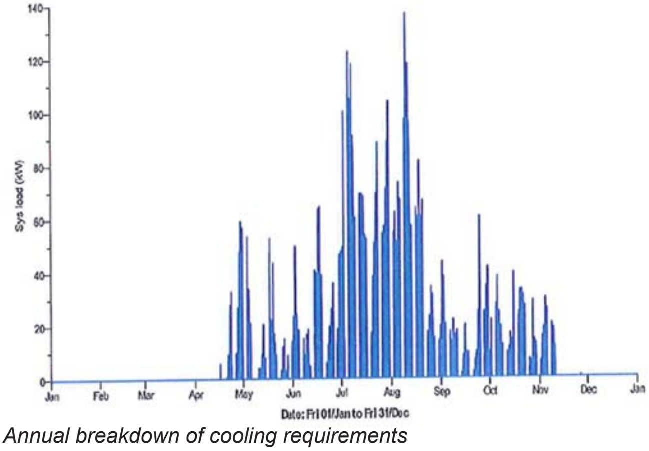
The building in question is a ten-storey office block in Brussels refurbished for an advertising company under the passive standard and with a Very good BREEAM certification.



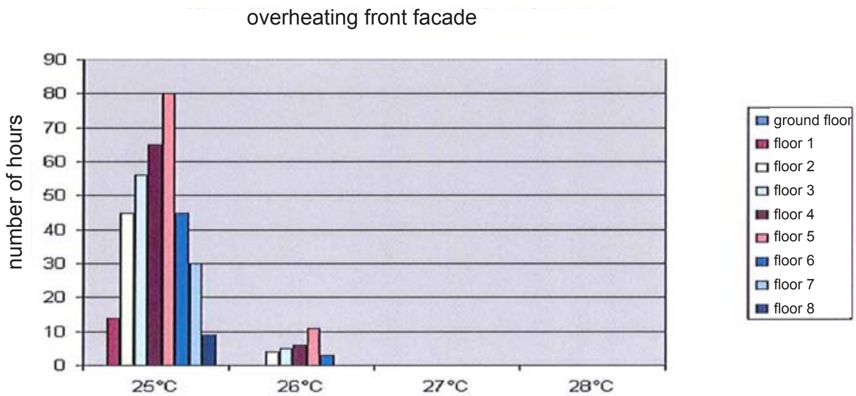
Simulation model (Source: CES)



Building occupancy profile



Annual breakdown of cooling requirements



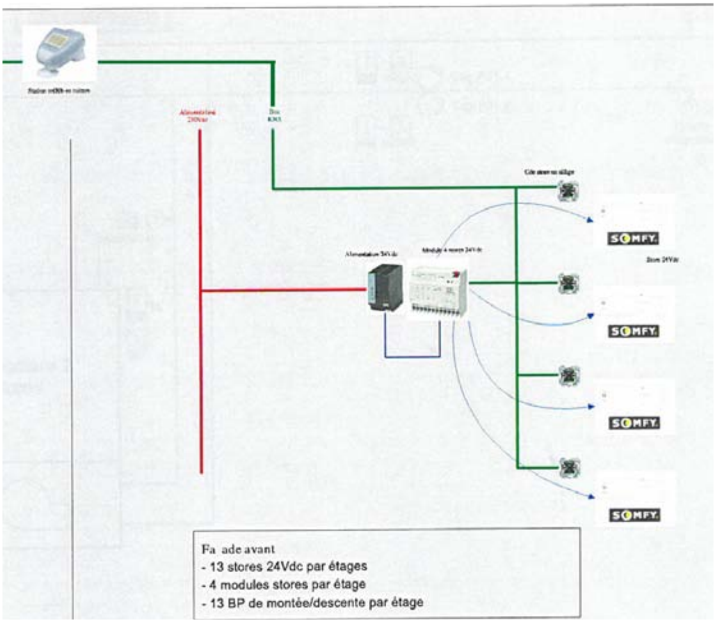
	floor								
	ground floor	1	2	3	4	5	6	7	8
Temp. sup à									
25°C	0	3	24	37	42	44	36	34	8
26°C	0	0	0	0	1	3	0	0	0
27°C	0	0	0	0	0	0	0	0	0
28°C	0	0	0	0	0	0	0	0	0

Number of overheating hours per year

Once the execution plans were completed, the simulation report was simply put aside. Other more "qualified" firms took up the plans for the construction phase and described in the bill of specifications for the work on the special passive technologies an operating mode completely foreign to the assumptions used in the initial dynamic simulations.

For example, the management for the front façade sunscreens was described as being controlled by a sun sensor controlling the whole façade, i.e. all 10 floors, even though the dynamic simulation had been based on floor-by-floor controls also taking account of inside conditions. It would make little sense to lower the sunscreens on all floors if only the bottom floor was subject to overheating.

The building was accepted without *commissioning*, thus making it more difficult to manage. The company responsible for maintaining the building has only a base mandate and it is difficult for it to adjust BMS[52] parameters not incorporated in the design and execution process.



The extract from the sunscreen management diagram shows that there is just one sun sensor controlling the sunscreens on each facade. No account is taken of the indoor temperatures on each floor.

> 5.3
p. 360

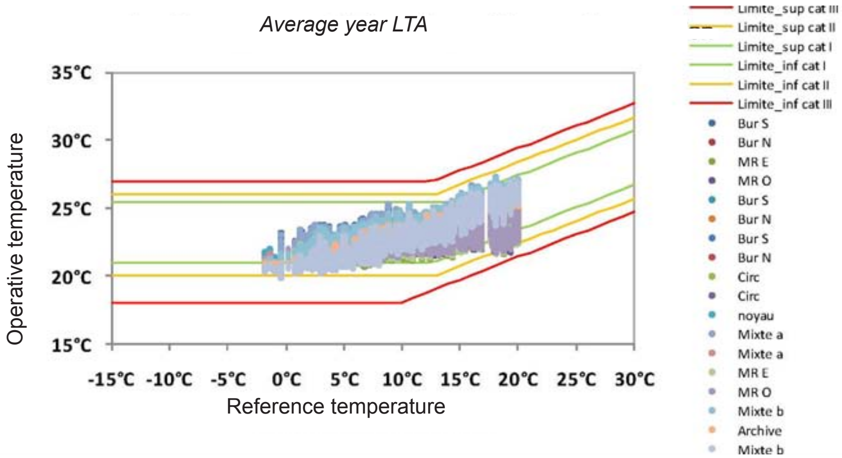
B. A second case in point: light" commissioning

The building in question has been built in Nivelles to promote passive offices and has a Very Good BREEAM certification[54].

The design and engineering firms involved attached the dynamic simulations to the bill of specifications for the work, and the installation and programming work was carried out in accordance with these parameters. After a few months of operation, the building started showing a number of disparities with the simulated results. Over a 4-month period, the occupant increased the heating setting from 21°C to 23°C . This led to a post-acceptance fine-tuning period during which settings have been slightly modified. The monitoring also revealed further relevant information, such as the possibility of losses in the heating network, the imminent failure of one of the post-heating units, etc.

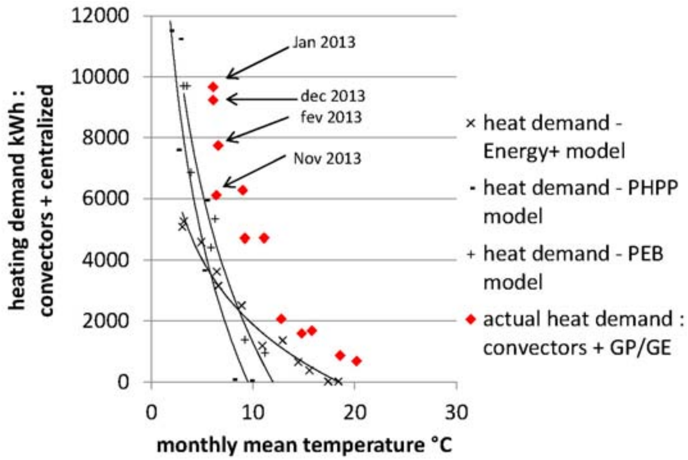
The designers are continuing to monitor the building's performance, and could possibly remain on-site for a total of two years. The readings and the feedback from the occupants are now being regularly checked against the simulation results, thereby helping the maintenance team to fine-tune the building management system. Should the occupant make any significant change to how he uses the building, the maintenance team, associated with the project right from the start, is now able to adapt the building's behaviour accordingly. This commissioning, although only in a "light" version, shows that a building that has been optimised in line with its real-life use and its occupants is able to meet the energy efficiency and comfort targets defined

Dynamic simulation model (Source: Matriciel et Architecture et Climat)



Behaviour of zones in analysing comfort under summer conditions pursuant to EN 15 251) Dynamic simulation results (Source: Architecture et Climat)

Statement for one month of monitoring for 9 work areas. The building is found to be "comfortable" according to NBN EN 15 251.



Cross-checking readings and simulation results (PHPP and dynamic) for heating requirements (Source: Architecture et Climat)

Over a period of 4 months, the occupant asked for the heating set point to be raised to 23°C from 21°C.
The specific heating need calculated initially by PHPP for 20°C is 10.9 kWh/m²/year and 7.5 kWh/m²/year with EnergyPlus (dynamic simulator).
With the set point increased to 23°C, the monitoring showed a slight increase of the specific heating need between 18.1 kWh/m²/year and 19.1 kWh/m²/year.
If this set point is modified in the PHPP we obtain … 18 kWh/m²/year!

2.2.3.3. And now?

It remains astonishing that commissioning is still questioned - or even completely ignored - by the construction sector, although it is a well-established practice in industrial engineering. When a machine tool is delivered to a factory, those installing it are held responsible for it functioning properly. In projects where the process is of fundamental importance, the commitment of the designers is greater than that binding them to the project owner until the final acceptance of the project. Such aspects are often not recognised or only understood in a problem resolution context once a problem has been encountered. Should a designer's responsibility not end with project acceptance, but carry on to cover the correct functioning of the project, it would be wise to provide for an additional fee scale or to revise the breakdown of fees in line with project phases.

The effect of such a development would be to give greater responsibility to designers. Commissioning could act as a stimulus to (re-)structure this process. The consequence would be that designers would have to come to grips with having part of their work taking place at a later date, in the form of "support" in the "post-operational" or "post-acceptance" phase of the building's life cycle.

Holcim HQ| Nivelles | Thomas et Piron | architect A2M

Dubrucq street housing | Molenbeek-Saint-Jean | Municipality of Molenbeek-Saint-Jean | architect: B-architecten

2.3. Structural stability

Benoit Meersseman

2.3.1. New buildings

L'architecture passive implique une désolidarisation complète et absolue entre la structure et l'enveloppe du bâtiment. Cette coupure rassemble la quasi-totalité des difficultés structurelles qui lui sont propres.

2.3.1.1. Foundations

A. Deep foundations

These are used when the subsoil has a very low load-bearing capacity or when the weight of the planned building is significant and concentrated. It is virtually impossible to separate these foundations from the structures they will be carrying, with contact needing to be maintained between the pile pads and the piles, as well as between the stabiliser beams and the pads. This means that it is impossible to insert any thermal barrier at this point, with the barrier needing instead to be located higher up, between the floor slab and the screed, i.e. at the foot of the load-bearing structure.

B. Shallow foundations

In contrast to deep foundations, shallow foundations mean that the load of the building is evenly distributed across a foundation slab. This method is used when the subsoil has sufficient load-bearing capability, when structural loads are evenly distributed and when the risk of subsidence is controllable. The separation between inside and outside can be made below or above the slab.

When insulating the bottom side of the slab, care needs to be taken that the insulating material has a maximum compression rate above that of the ground on which the slab sits. The material must also be extremely durable, unaffected by damp and rodent-proof, as any change in its physical properties can lead to subsidence, a general weakening of the structure and structural cracks. It is therefore vital to have the insulation producer issue a 100% guarantee in this respect. Finally when insulating underneath the slab, any surrounding frost protection beams also need to be insulated.

When deciding to add insulation between the slab and the screed, the work must be done at the foot of the load-bearing structure as described above.

C. Insulated foundations

When the subsoil has sufficient load-bearing capability or when structural loads are low and evenly distributed, a system of insulated (strip) footing is used. Requirements and solutions are the same as for slab-based shallow foundations.

2.3.1.2. The feet of load-bearing structures

Load-bearing structures above the foundations can be either linear (i.e. walls, shells) or non-linear (i.e. columns). When the insulation is positioned above the floor slab, the load-bearing structures must be able to pass on their weight to the foundations, while at the same time allowing a thermal barrier. This involves specific mechanisms.

A. Thermal barriers at the bottom of a wall or shell

Linear loads are traditionally separated from the foundations via the insertion of an insulating material. Three categories of material are available: cellular concrete, cellular glass and special products[55].

Great care should be exercised when using cellular concrete, and it is basically only feasible in cases where loads are low and evenly distributed. Its compression resistance is low and it is unable to support any non-linear load.

Cellular glass is therefore used when loads are higher. Before use, it is a good idea to check, via a detailed load distribution calculation, whether the insulating material's compression resistance meets the loading requirements. During execution, great attention needs to be paid to the fact that the insulation materials used actually have the properties defined in the design phase.

When loading becomes too heavy or too concentrated, the compression resistance of conventional insulating materials may become insufficient. This has resulted in certain composite products appearing on the market, linking small high-resistant cylindrical or rectangular concrete elements to a rigid insulation material, with load distribution provided by the concrete. Though such materials have very interesting mechanical properties, they are very heavy. These insulation blocks must therefore be laid on the concrete foundation slab or on a surface capable of handling such a concentrated load. The same applies to elements laid on top of these blocks. Where the walls are to be built of bricks, the bottom layers must be built with solid blocks.

Where the walls are separated from the foundations by a thermal barrier and where they are subject to horizontal pressure (as in the case of earth pressing against a wall), some form of anchoring going through the insulation must be used. The number and dimensions of such anchors need to be determined by an engineering firm.

B. Thermal barriers below columns

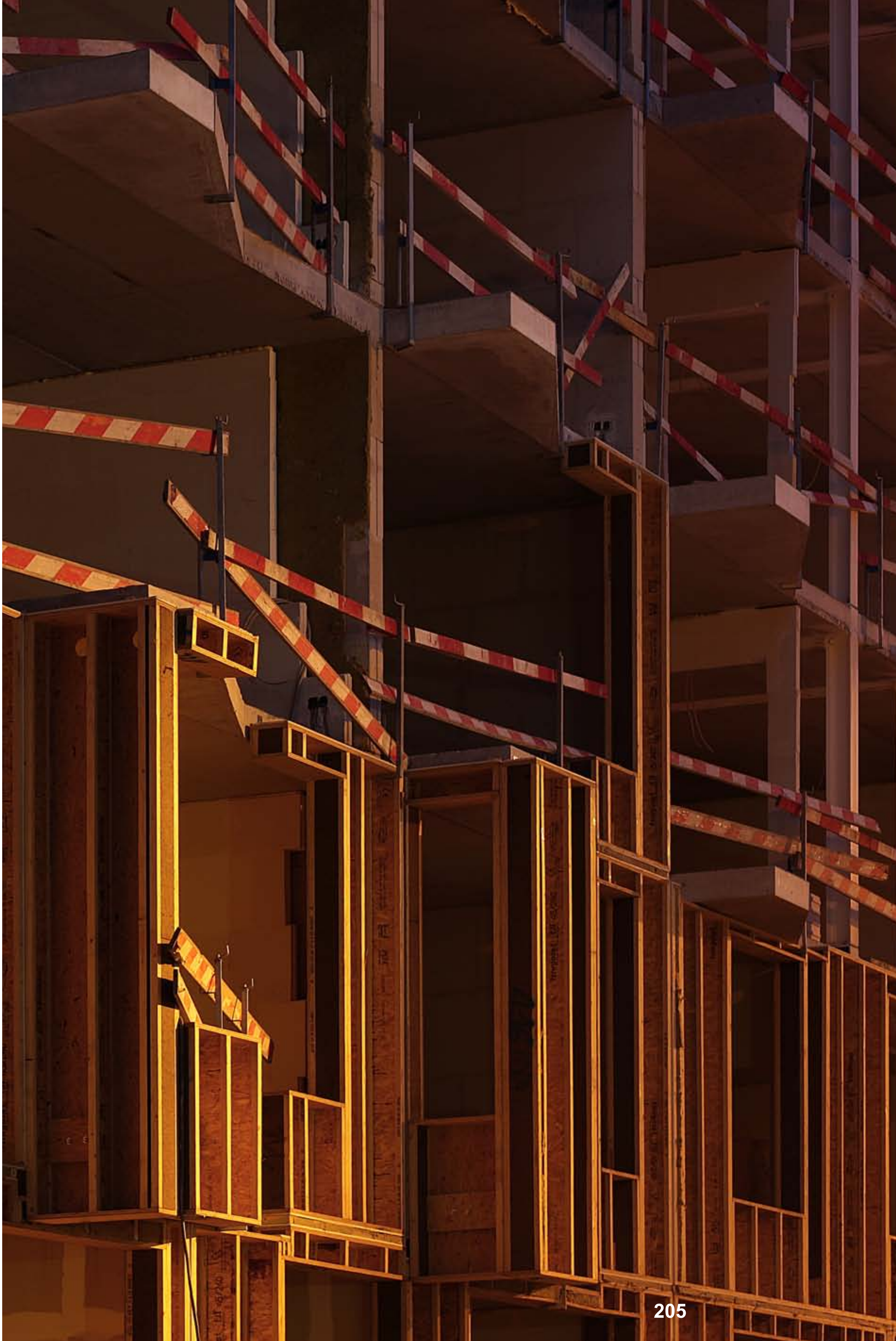
Because the columns need an absolutely solid base and because loads are highly concentrated, it is impossible to completely separate the column from the foundations. Certain manufacturers are currently developing separation systems, the principles of which resemble to a certain extent the thermal barriers used for balconies. Now available for different types of column (concrete, steel), they are however still in an experimental stage and therefore still quite rare.

2.3.1.3. Stability requirements associated with different construction methods

In Belgium at least three different construction methods are currently in use:

- “Heavy” construction (brickwork, column and beam concrete shells) with heavy facing;
- “Heavy” construction (as above), but with lightweight facing (rendering covering a layer of insulation or cladding);
- Lightweight construction (load-bearing walls or a skeleton frame), generally with lightweight (rendering covering a layer of insulation or cladding) or heavy facing (bricks).

Midi-Suède housing | Saint-Gilles | Citydev | architect: Urban Platform



All these different construction methods must however respond to similar questions, with responses specific to each method.

Each individual building (or part thereof) must be stable in its own right and braced. When two parts of a building need to be kept separate, for example an insulated part and a non-insulated one, care must be taken to the fact that each part must be able to function completely independently. This may involve duplicating certain structures, installing additional bracing or providing anchoring through the thermal barrier to link up the different parts of the building.

Any element to be fixed to the façade needs to be studied in detail:

- One should avoid attaching heavy items to a lightweight structure or fragile items to a flexible structure. Taken in the project's design phase, this precaution will help avoid excessive deformation and subsequent cracking.
- Any anchors used in load-bearing structures should always match the structure: anchors with chemical sealants for concrete structures and solid elements, sleeved anchors for hollow bricks, bolted anchors or structural screws for lightweight structures. Particular attention is required for anchors in lightweight structures made of STEICI or TJI wood beams, as it is dangerous to anchor anything in the heads of such beams. The manufacturer's instructions must be scrupulously followed in this respect.
- Window frames, generally with triple glazing in any passive building, have become very heavy, and the way they are anchored needs to be looked at carefully. Their weight can be included in the load distribution calculation, with structural elements being sized accordingly.
- The anchoring systems used for any heavy cladding (traditionally prefabricated corner irons) must be reconsidered, as the thickness of the insulation material is such that standard systems are no longer sufficient.
- When anchoring a balcony, a thermal barrier needs to be fitted. Frequently seen on heavy structures, balconies on light weight structures are rare and expensive, and building contractors have little experience in installing them. They will therefore remain the exception, and when required, they

need to be installed with great care.

- Awnings, external staircases and any other item to be fixed to a facade need to be anchored in the load-bearing structure, i.e. through the insulation layer. Under no circumstances may they be fixed to the cladding. Any mounting brackets should therefore be installed before any insulation, rendering or cladding is installed.
- Where the project involves a flat roof surrounded by non-insulated parapet walls, the latter need to be kept isolated from the roof structure. Such parapet walls must however be able to withstand horizontal pressure (i.e. providing anti-fall protection), meaning that it is vital to foresee a double row of anchoring through the thermal barrier in order to absorb any momentum at the foot of the wall.
- Where solar or PV panels are to be fitted to the roof, they need to be able to withstand wind loading. They therefore need to be fitted with horizontal blocking systems as well as vertical anchoring systems. Such systems must be designed with great care so as not to interrupt the continuity of the insulation and not to impair the roof's waterproofing.

2.3.1.4. Environmental constraints

When the project requires the demolition of an existing building with a joint wall to a neighbouring building (a party wall), the stability of this wall needs to be guaranteed. This is rarely a problem when construction work is in progress, as temporary shoring provisions - needling or underpinning the wall - can generally be used. Once construction has been completed, it will generally be the floors of the new building locking onto the party wall. Where thermal reasons dictate that the new building needs to be separate from this adjacent building, provisions need to be taken to guarantee the stability of the latter. Replacing the insulation parallel to the floors by non-compressible insulation material glued to the wall is one possible solution. It needs however to be checked that the admissible compressibility rates of the insulation material are sufficient and that it will remain in place alongside the floor without slipping down into the gap, thereby losing all its effectiveness.

The points listed above are the main considerations taken into account


DEMOCO
DEMOCO
DEMOCO

Bellevue Brewery | Molen-beek-Saint-Jean | Molen-beek-Saint-Jean | architect: Escaut and MS-a

by an engineering firm when asked to design a new passive building. Nevertheless, on account of the specific circumstances of any project, other questions may also arise, even possibly leading to a significant modification of the planned project and/or having a major financial impact. To guarantee project success, it is desirable to involve a design / engineering firm in the initial design phase.

2.3.2. Building refurbishment

The question of isolating the structure from the envelope is particularly relevant when refurbishing a building, as existing buildings have rarely been designed from an energy efficiency perspective. Where the building can be completely insulated on the outside, the majority of thermal bridges can be quickly removed. The one more complicated aspect is what to do with the foundations.

Where by contrast it is impossible to completely insulate the building from the outside, a large number of questions arise. Inside insulation is basically inevitable and priority must be given to eliminating thermal bridges.

It is impossible to raise all questions here and to deal in detail with all junctions. As each case has its own particular circumstances, individual studies are required. Nevertheless there are a number of basic principles applicable to all projects. The aim of the following section is to provide an understanding of the difficulties involved in any such project, as well as the caution needing to be shown from the outset. It is vital to bring all players (project owner, architect, (structural) engineers) together to successfully complete this type of refurbishment.

2.3.2.1. Checking the foundations

The existing foundations need to be looked at in detail, on the one hand because the loads bearing down on them could be significantly changed (for example through adding a new skin to the facade) and on the other hand because it is sometimes necessary to lower the levels of existing floors in order to install under-slab insulation.

A complete review of the foundations is required, looking at their dimensions, depth and nature. Once this review has been completed, a new load distribution calculation can be made to determine whether any strengthening will be necessary. Dependent on the depth of the foundations, they may also need to be underpinned, insofar as this is feasible.

2.3.2.2. Checking the existing structures

Once the project has been defined, a detailed load distribution calculation for the new situation needs to be made, on the basis of which all existing structures need to be checked. The roof requires particular attention, as the loads it will be subjected to on account of the refurbishment will obviously be much higher: insulation material, triple-glazed windows and possibly solar or PV panels. The precautions mentioned above for a new building naturally also apply to a refurbishment project. .

> 2.3.1.3
p. 204

2.3.2.3. Eliminating thermal bridges by cutting through floors and interior walls

In order to achieve insulation continuity, it may be worthwhile - when using inside insulation - to completely isolate the facade from the inside structures (floors and interior walls). This can however have numerous consequences.

The stability of the facade itself must be ensured: it needs to be anchored through the new insulation layer into the load-bearing structures. What sort of anchoring is used is dependent on the type of structure:

- Where the anchoring is into concrete structures (columns, beams, floors in precast slabs or poured in situ, chemical anchor systems will be required. If the concrete is already very old or in a bad state, it is wise to carry out tensile tests to determine the pull-out resistance of any anchor. Dependent on the results, the number, diameter and installation of the anchors can be determined by a structural engineer.
- Where the anchoring is into floors consisting of hollow core slabs (in French: hourdis), it is desirable to partially uncover the slabs around the anchoring points and cut notches in them, into which the anchor rods are

then installed before being sealed with concrete. It is vital to ensure that the slabs are interlinked by reinforced compression slabs, forming a rigid diaphragm.

- Where the anchoring is into floors made of reinforced concrete beams with intermediate hollow slabs (in French: poutrains et claveaux), it is vital to partially uncover the slabs around the anchoring points and cut notches in them, before proceeding as above.

- Where the anchoring is into a wooden floor, this will be done through pinning through the facade's brickwork, with a distribution plate on the outside and mechanical fixing to the floor's joisting. When using this type of pinning, the floor needs to be checked to make sure that it is sufficiently rigid to act as a diaphragm.

- Where the anchoring is into brickwork, it is vital to carry out tensile tests to determine the pull-out resistance of any anchor. Old brick walls were very often built using lime mortar or cement-lime mortar, which has very poor mechanical properties. Dependent on the results of these tests, the number, diameter and location of such anchors need to be determined by an engineering firm.

All anchors, whatever their type, must be installed in such a way that they will only function only in traction and never in flexion. This requires them to be perfectly gripped between the structures needing to be pinned. In old buildings it is quite common for the facades to support the floors, meaning that isolating them from each other involves inserting a new structure duplicating the facade. To avoid any subsidence, this new structure needs to be designed in such a way that the load distribution on the foundations remains as close as possible to its initial value. Where this is not possible, a whole new set of foundations will have to be calculated and installed.

The facades of old buildings very frequently played a major role in their overall bracing. Isolating the facade thus involves a complete review of the building's bracing and the possible installation of a completely new bracing system.









design 02

CPAS de Forest | Forest | Municipality of Forest | architect : A2M

2.4. Cost efficiency and cost managment

Bernard Deprez

Construction costs can be disturbingly high. Since 1975, the average price of a house has risen more than 10 times, while the general price index has only increased 3.5 times[56]. Between 2004 and 2013, the construction cost index has risen 33% in France[57] and 25% in Belgium[58].

The sector has experienced a major hike in the costs of certain materials and energy[59], without speaking of land prices and the length of time required to process planning applications. On the other hand, the improvement in a building's energy efficiency, health quality and acoustics are also factors contributing to this rise in costs.

The whole concept of cost is in itself a very complex subject, with the "true" price not just involving the construction costs, but also the cost of operating a building over years. Using this "total cost of ownership" (TCO) concept covering the building's whole life cycle allows us to distinguish between pure expenditure items and those leading to savings (in particular energy-related ones) and usage benefits.

In the absence of any scientific field study on this subject, **be.passive** has devoted several articles to the cost of sustainable projects: a US study on the financial and non-financial benefits of sustainable buildings, the calculations of the *Centrum Duurzaam Bouwen* on when the break-even point is achieved and those of Test-Achat on the financing of passive buildings through energy savings (certain banks are beginning to take account of such), or the model of the property developer Urbani based on the same principle but adapted to renting situations[60].

There is also debate on the economics of passive building. There are a number of completed projects showing that it is possible to construct passive buildings at a price above or below that of a conventional building. On the other hand, conventional financial tools show that the passive standard is still not the cost optimum on the market, calling for patience.

This is hardly surprising, as passive construction is an emerging practice. Yet this caution leads us to neglect a fundamental aspect: when current-day projects ignore the climate and energy agendas in their energy-related dimension - i.e. when they are unable to achieve a nearly-zero energy status (nZEB) - they will at some stage in time either have to be upgraded at considerable expense or demolished. The ongoing energy transition demands that such half-measures be avoided. In the absence of a general rule (each project has its own specific characteristics), this chapter provides a few thoughts on budget control.

2.4.1. Cost optimum or irrevocability?

In setting its nZEB target, the EU was fully aware that this would shake up the construction sector. Though leaving it up to Member States to define their own nZEB standards, it also imposed controls to check whether these standards would also lead to a TCO close to the cost optimum for the building's life cycle (30 years).

What does this involve? Using certain assumptions on the future development of certain financial indices (inflation, discount rates, energy costs, etc., excl. subsidies) and construction costs, the calculation of the optimal level identifies in theory the most profitable options from an energy and financial perspective. Total investment costs, operating and maintenance costs are considered for various types of buildings characteristic of the building stock. These studies are thus comprehensive, though conditional on both their assumptions (uncertainty) and calculation methods (margin of error).

The calculation method identifies, among all possible configurations, those close to optimal cost. Each energy-related construction element or technical system has a systemic impact on a building's overall performance, and only this can be optimised. There are a large number of technical combinations available for achieving this optimal level.

Studies were conducted in the Brussels-Capital Region in 2007, 2008 and 2013 on the basis of 4 typologies (houses, apartment blocks, schools and offices) and a number of technical configurations. Using the most recent version of the energy performance (EPB) calculation software, we find that the time needed to achieve break-even is still more than 20 years[61] and that gap remains below 15% between the cost-optimal level, 2012 energy performance requirements (EPB 2012) and those of 2015[62].

We should however be aware of the fact that, while EPB 2012 requirements currently correspond to the cost optimal level, this was not the case in 2007. This is because prices have come down in line with the market situation. It is safe to say that the passive standard is getting closer to the cost optimal level, i.e. closing in on nZEB requirements.

This financial approach often leads designers to await the next defined cost optimal level - like commuters waiting for the next train. Though proven in industry[63], it however divides economists when applied to buildings, as these have much longer life cycles than consumer durables. One risk involved in the cost optimum approach is that it can produce buildings where, to achieve an optimum today, any a posteriori enhancement risks no longer being cost-effective. Achieving a cost optimum at today's level would lock the building into an energy configuration without a future. This *lock-in* phenomenon is frequently found and can lead to a property dropping in value.

> 2.2.3.2 /B
p. 196

More than a numbers game, we are seeing here a methodological debate, with the cost optimum approach leading to wrong decisions[64] as it ignores two fundamental aspects: future uncertainty and the irrevocability of building. In the view of economics professor Aviel Verbruggen (Antwerp), this irrevocability particularly impacts the definition of a building's energy performance: "*Knowing that the energy performance of his house cannot be* *improved if he opts for a standard solution, any potential home-builder opting for the passive standard is making the smartest choice from a purely financial perspective, as opting for a non-passive building will in the long run mean high running and maintenance costs. Opting for a passive building, one is always on the safe side, secure in the knowledge that one's investment will pay off*."[65]

A financial analysis used for taking decisions takes account of uncertainty and irrevocability. In particular when a choice cannot be postponed, as is the case in respect of energy performance, this methodology demonstrates that a decision can be optimised by quitting a usual wait and see stance and adopting a choose or lose position. "Go without hesitating for the highest returns when they concern characteristics or elements that are by nature irreversible. Otherwise you will lose out in the future. A building's energy performance is determined on the drawing board - afterwards it's too late [to make any improvements]…"[66]

There are a lot of property developers relying on irrevocability, providing an explanation for why, despite all theories and uncertainty, people are so enthusiastic about the passive standard. The Foundation for Future Generations[67] awards its BLUE HOUSE prize to the Belgian home construction or refurbishment project best exemplifying the twin aspects of sustainability and financial feasibility. For two years, this prize has gone to ... passive buildings[68].

Major social housing companies are building new homes to the passive standard with a view to helping their tenants to reduce their rental costs. In Frankfurt[69], the additional investment (for insulation, airtightness, heat exchanger, triple glazing, etc.) is limited to 5 - 7%. Such budget control is the result of an optimisation process, similar to the one set up by the partners in the Écoffice office development project[70] in Nivelles with its aim of achieving a construction price of €1,000/m². The aim of the European Buildtog research project[71] is to optimise the process of constructing passive buildings in France, Germany and Sweden. A first apartment block was recently completely in Darmstadt (Germany), at an additional cost of just 1%.

What needs to be done to boost the reputation of the passive standard and reformulate the question of costs: what factors allow passive buildings to be built at no great expense, what factors make them excessively expensive?


ELUX
Wienerberger
.be

BLUE HOUSE
awards 2013

Sebastian Moreno-Vacca

2.4.2. The cost of a passive building "on the ground"

Certain people claim that building to the passive standard costs at least 25% more than conventional construction. They are certainly right! This is because the passive standard involves thicker insulation, better airtightness and possibly even a comfort ventilation system (instead of a simple one), and all this obviously costs more. Nevertheless, an increasing number of passive building projects are now achieving overall costs similar to or even lower than those of conventional projects, leading certain people to announce that building to the passive standard is no dearer than building conventionally. And they are right!

However, if everybody is right, where does the truth lie?

A large number of economic methodologies are against partial visions, reducing for instance the passive standard to "all you need is a bit more insulation!" As shown by more than 900,000 m² of passive buildings completed or in the course of construction in Brussels in 2014, reality is showing that things are not that simple. Day-to-day experience on the ground reveals that building to the passive standard involves a lot more than just a few additional centimetres of insulation. There are a lot of factors influencing the final cost that need to be taken into account. In the course of its design, each project is constantly reviewed to make sure it stays within a budget acceptable to all concerned.

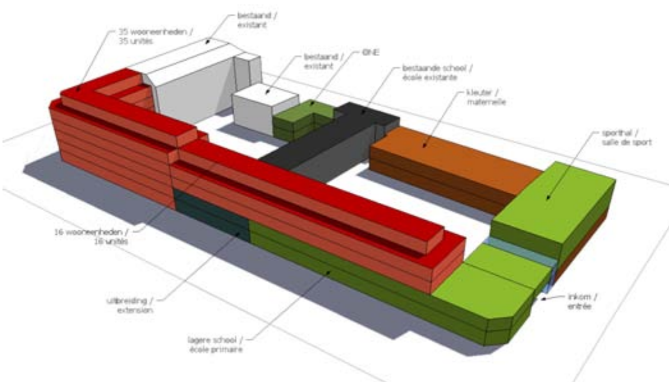
Though there are no hard-and fast rules regarding the cost of passive construction, there are certain factors with a positive influence – meaning that a passive building can end up with a price tag similar to that of a conventional building – and ones with the opposite effect.

Example of construction cost of passive building in Brussels

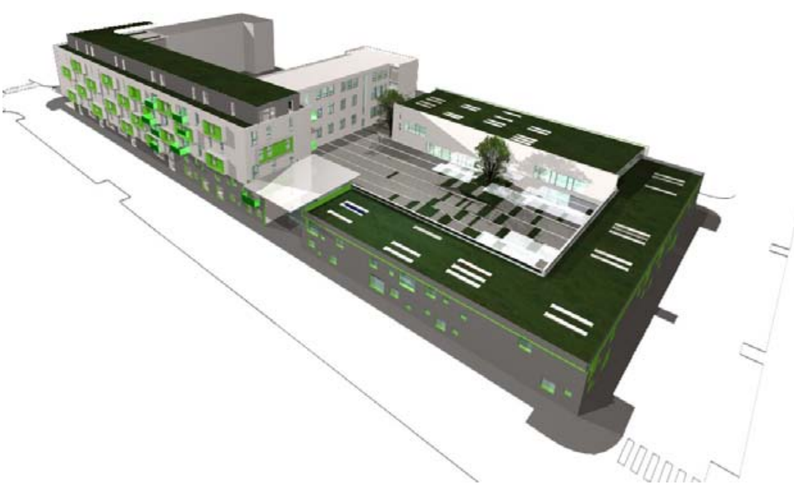
IPFC | Nivelles | Province du Brabant wallon | architecte: A2M

In 2005, the architectural firm A2M was surprised to find that, in response to a call for tenders for its first passive building project[72], 7 of the 9 tenders were lower than the estimated cost. This project ended up being completed at a cost equivalent to 90% of the planned budget by the company which had put in the cheapest bid. After acceptance and the final settlement of all accounts, the project ended with a price tag 5% below that usual for a comparable project.

In 2012, the firm put in a bid for a Design, Build & Finance call for tenders for a 13,000 m² complex consisting of a school, housing and offices issued by the City of Brussels Property Agency, the Régie Foncière de la Ville de Bruxelles.



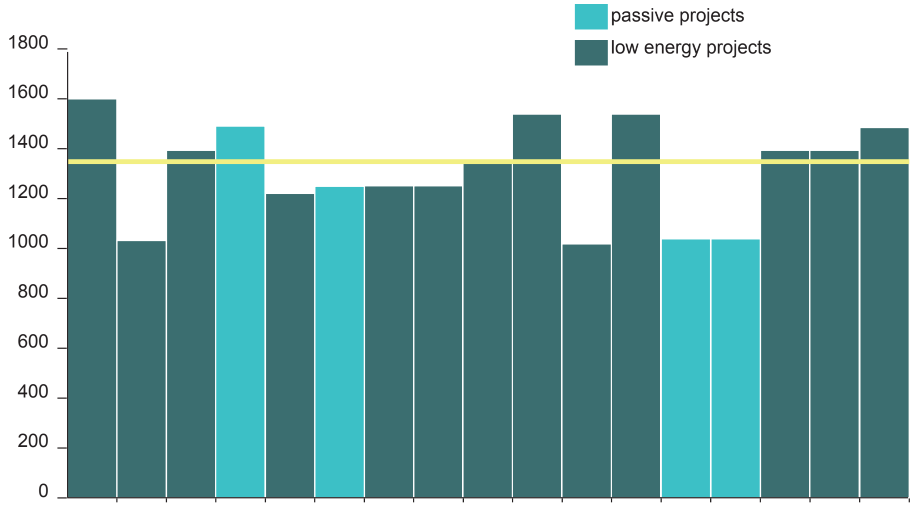
The Particular Land Use Plan, and the project selected below



Simons-Anvers street housing, school and kindergarden | Brussels | VCiti of Brussels – Régie Foncière | architect: A2M

Bids ranged from 12.7 to 19.4 m€ (ex. VAT). Of the 17 bids received, 4 were for a passive building (in light bleu in the chart page 226), while the rest were for a low-energy building (in dark blue). Though the least expensive bid (1,053 €/m² ex. VAT) was for a low-energy building, the next two were for a passive building (1,087 €/m²). Their projected cost was quite a bit less than

the average (1,339 €/m²) and much less than the most expensive bid (1,606 €/m²) – for a low-energy building. The project was naturally awarded to the lowest-price company offering the passive building.



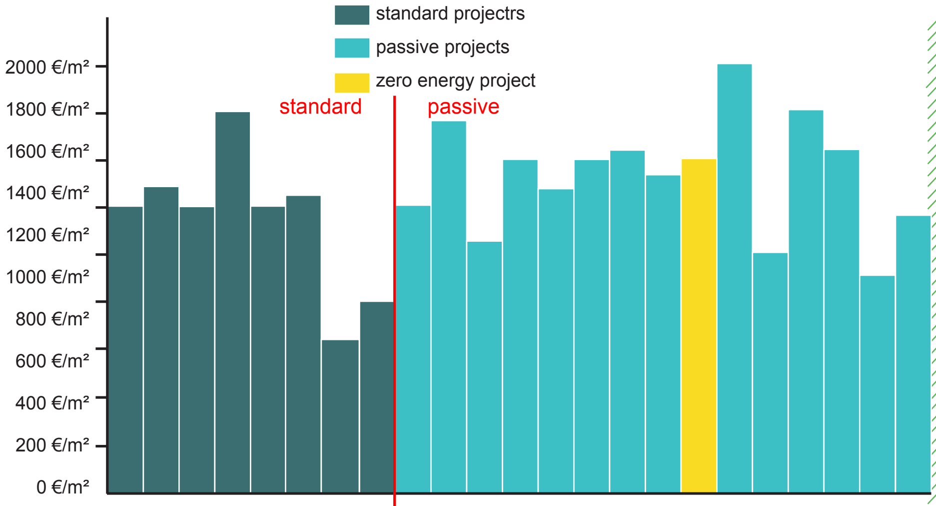
Price per m² exclusive of VAT of offers submitted in Bouwteam or Design & Build.

Other similar experiences, taken from the impressive stock of passive building projects currently running in the Brussels-Capital Region, permit the identification of recurring factors allowing passive buildings to be constructed at prices equivalent to those of conventional buildings. Two recent studies corroborate these experiences.

2.4.2.1. The "Fast" study :

In 2013, the Fast think tank conducted a study[73] on the cost of large-sized passive office buildings, looking at 25 office buildings built either to the passive standard or conventionally. All had been built or refurbished between 2005 and 2013, and most were in Brussels. Average floorspace was 44,033 m². A number of them had gained BREEAM certification.

15 of the buildings were certified as passive (2013 criteria), with one even achieving zero-energy status. 5 projects (3 of which were passive ones) involved refurbishment (showing, by the way, that it is possible to refurbish an office building to the passive standard), with the rest being new buildings.



Price per m² exclusive of VAT for large-scale office buildings in Brussels and the surrounding area

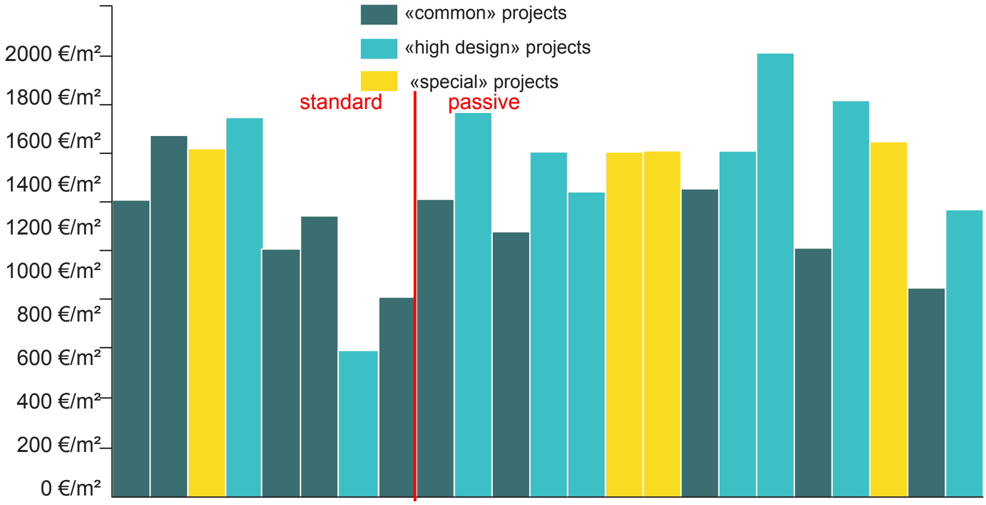
The costs analysed in the report are the actual construction costs, excluding design and planning costs. The conclusion of the study was that there was little difference in the investment costs between the passive and conventional buildings. The sample used even ended up suggesting that the cost of a passive building (on average 1,266 €/m² ex. VAT) was lower than that of a conventional building (on average 1,324 €/m² ex. VAT).

There are several factors explaining this situation: :

- The sample was only small and not representative;
- The conventional projects were more expensive because they were generally more advanced, meaning that the costs given probably incorporated additional features;
- 6 projects (all of them passive ones) were currently in the process of gaining BREEAM certification, with very ambitious targets (2 Very

Good, 3 Excellent and 1 Outstanding). This similarly confirms that a high energy performance is fully in line with increased environmental expectations;

- the high energy performance of these recent projects is becoming increasingly well-known and market prices are becoming fairer;



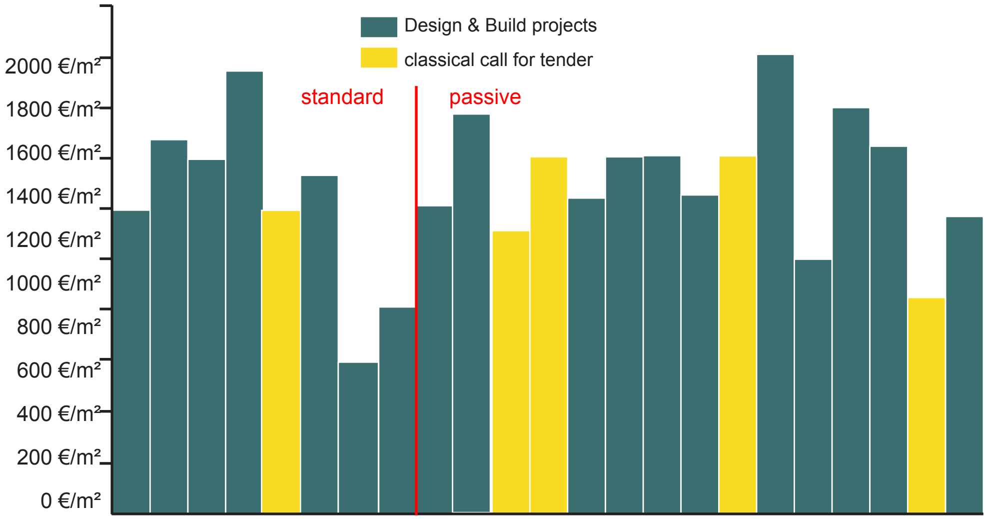
Price per m² exclusive of VAT for large-scale office buildings in Brussels and the surrounding area

- the most expensive projects are those with a very high design value or with specific features (an atrium, zero energy, etc.). As an example, the estimate for the project designed by the architects Baumschlager & Eberle + Styffhals for the new headquarters of BNP Paribas (95,000 m²) is for 1,800 €/m² ex. VAT. A high design conventional building, the court building designed by the architects J. MAYER, A2O and Len°ass (24,808 m²) has an estimated cost of 1,752 €/m² ex. VAT.

BNP Paribas Fortis Bank Headquarter | Brussels | BNP Paribas Fortis | architect: Baumschlager & Eberle et Styfhals & partners

Court Building of Hasselt | Hasselt | n.v. SOHA | architect: J. MAYER H. Architects, A2O-architecten, Lens°ass architecten

- The Design & Build projects built to the passive standard (5) often cost less than the conventional ones (1); for example, the passive refurbishment of an office building on the Avenue Louise by architects A2M (3,708 m²) cost 890 €/m² ex. VAT).

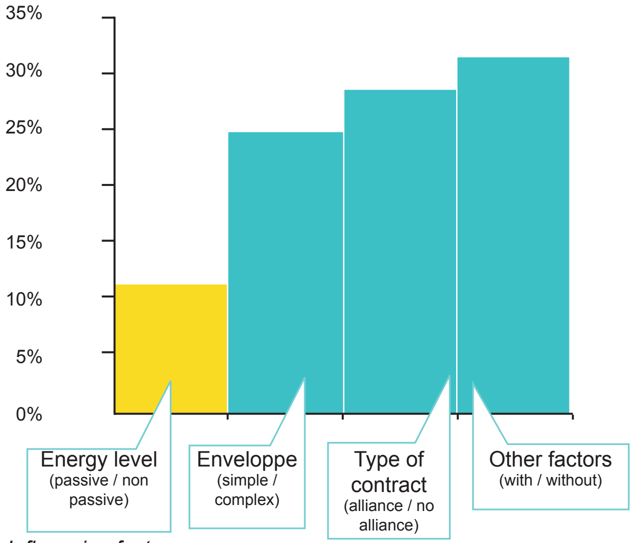


Price per m² exclusive of VAT for large-scale office buildings in Brussels and the surrounding area

2.4.2.2. The pmp study

The non-profit organisation, pmp conducted a study in 2014 on the cost of constructing passive social housing in the Brussels-Capital Region. The first phase reviewed a limited sample of 12 buildings constructed between 2008 and 2013, 5 of which were built to the passive standard (2013 criteria), 3 as low-energy buildings and 4 as conventional buildings. Floorspace varied from 3,284 m² to 30,548 m².

The costs presented in this report are the actual construction costs, without design or planning costs. Looking at this sample, the pmp finding is that on average the gap between the cost of a passive building and a conventional one is 11.5%. Prices varied a lot, whether for passive buildings (from 950 to 1,468 €/m² ex. VAT) or for the other ones (from 860 to 1,371 €/m² ex. VAT).



Influencing factors

As with the "FAST" study for the office sector, pmp notes that the choice of a more complex architecture can significantly push up construction costs (whatever the energy standard used), with a complex envelope costing up to 25% more. Recourse to Design & Build and Design, Build & Finance schemes is a great help in keeping a project's budget under control and preventing cost overruns. Other criteria, especially ones relevant to a building's architecture, have a much greater impact on costs, with the most critical (+31%) being related to the specific features of a site, to stability, to additional technical systems, to the choice of certain materials, to innovative systems, etc.

Paradoxically, cost overruns associated with the energy standard are seldom, with these costs being kept best under control.

2.4.2.3. Conclusion

These two studies show that, though the construction cost of a passive building is higher than that of a conventional one, the difference is the least important in comparison with other criteria such as the choice of architecture, the type of project delivery system used or the cost overruns appearing during actual construction. Experience shows that it is more difficult to keep prices stable in small projects with floorspace lower than 1,000 m².

Moreover, those construction companies able to limit cost overruns for passive buildings (thereby providing a building at the same cost as a conventional building) are the ones more likely to have success in avoiding cost overruns in other areas.

Province of Antwerpen HQ | Antwerpen | Province of Antwerpen | architect: XDGA

Abdennour Aananaz

2.4.3. Determining factors

There would seem to be several factors determining prices:

- •**Project size:** as in any market, economies of scale often play a determining role.
- •**Building typology:**
    - Refurbishment projects are always one-off projects, requiring a project-specific approach and specific systems, all of which push up the price (especially when heritage conservation aspects play a role);
    - The structure of the building (whether "heavy" or lightweight) further determines the level of competition on the market, with the current situation in Belgium being that the market for "heavy" construction is much larger (and more competitive) than that for timber-framed construction;
    - Where a building incorporates special features (overhangs, innovatory systems, etc.), it will be more expensive, regardless of whether it is a passive or conventional building.
- **Finishings** are also a key factor, and it is often possible to find finishings at a lower price.
- **Compactness**: where buildings are relatively compact, it is generally easier to achieve the required energy performance; this also makes it possible to reduce insulation thickness or even to revert to double glazing.
- The targeted **energy performance**: in the case of a building exceeding the passive standard, energy-saving technologies often represent a significant budget factor.
- The **project delivery system**: Design & build delivery systems allow all players involved in a project to be brought together right from the design phase. This helps in finding comprehensive solutions encompassing all aspects of the project (architecture, functionality, cost, etc.).

Last but not least, the proper use of software tools (PHPP, calculation of thermal bridges, etc.) often allows a project to be analysed from a thermal point of view, playing with different parameters to optimise their financial impacts.

2.4.4. Comparing prices and materials

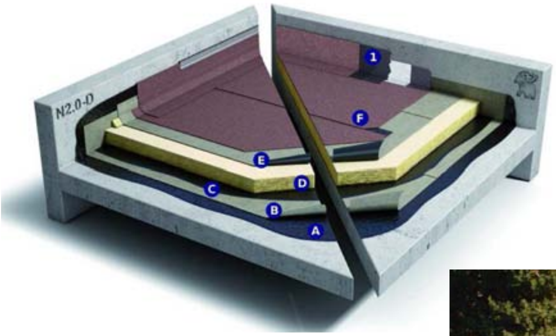
With insulation, airtightness and ventilation being aspects that may be somewhat abstract for certain readers, it is a good idea to look at a few orders of magnitude regarding market prices in relation to the specific properties of these products.

Starting with insulation, having an overview of overall heat losses can help find the best way of allocating insulation. An interesting proposition is to use thicker insulation where insulating costs less (i.e. the roof) and to reduce the energy performance of elements that are more expensive (e.g. window frames).

This similarly applies to the thermal bridges, the impact of which on the overall energy footprint must be calculated with great care. If the project has been designed with a certain leeway (+/- a few kWh/m² p.a.), it might be possible to ignore certain thermal bridges that are too difficult or too expensive to eliminate (insofar as they do not present a health risk), concentrating one's efforts instead on ones with a greater impact (for instance through investing in better facade insulation).

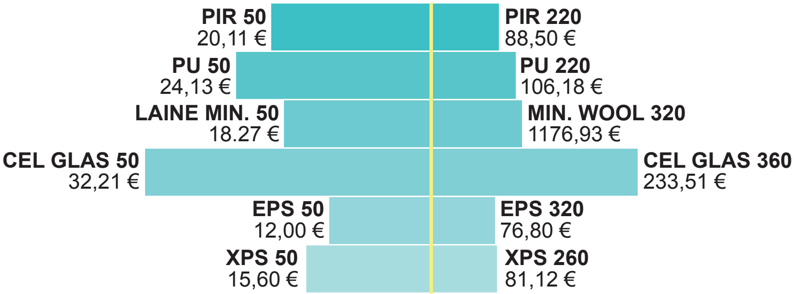
The tables below compare several types of insulation material, showing the average price for the same thickness or the same performance[74].

Flat roof

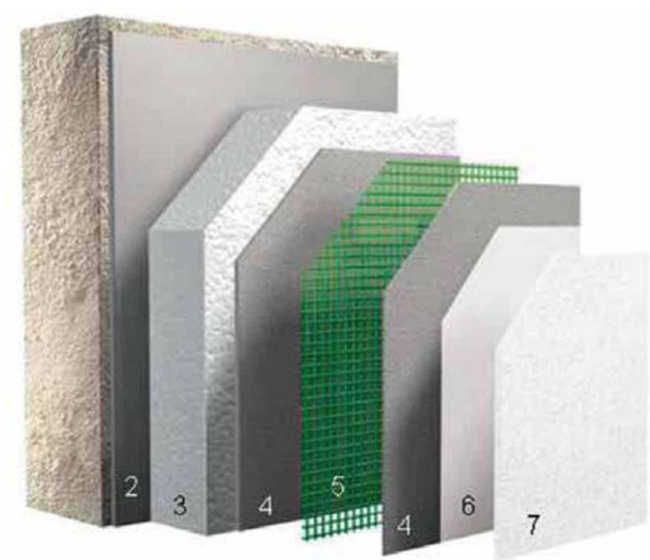


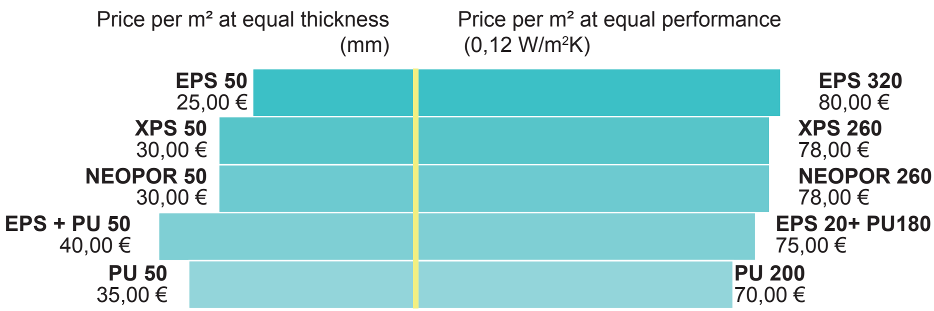
Price per m² at equal thickness (mm)

Price per m² at equal performance (0,12 W/m²K)

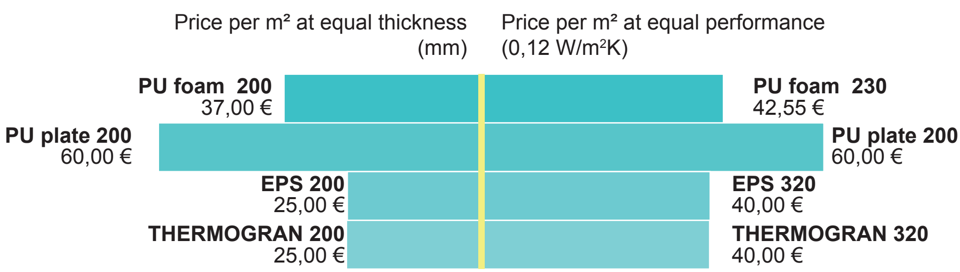


Facade (brick-built)





Ground slab



Price per m² at equal thickness (mm)
Price per m² at equal performance (0,12 W/m²K)
PU foam 200
37,00 €
PU plate 200
60,00 €
EPS 200
25,00 €
THERMOGRAN 200
25,00 €
PU foam 230
42,55 €
PU plate 200
60,00 €
EPS 320
40,00 €
THERMOGRAN 320
40,00 €

A comparison based on an equivalent performance is obviously a lot more interesting when choices have to be made during the design phase. Nevertheless, one needs to take account of all parameters: where thicker insulation has to be used to achieve the same performance, this can have other financial consequences:

- **Roofs and floor slabs**: to maintain compliance with internal dimensions, this extra thickness means that the walls will be higher. The additional metres of wall (parapet walls, etc.) thus need to be taken into account.

- **Outside walls**: total floorspace may be reduced as a result of using thicker insulation, meaning that the overall cost per m2 will increase. In large projects, this can often have quite a significant financial impact.

- **Window frames:** it would seem that a frame's material (and not its energy performance) often determines the price. Again, it is interesting to take all factors into account: U_f, U_g, glazed surface, etc. For example, aluminium window frames with a lower U_f may end up with an overall result just as interesting as other types of frame with better insulating properties, as aluminium frame cross-sections are generally thinner, allowing greater glazed surfaces and thus letting in more sun. Finding the optimal solution is obviously dependent on the specific features of each project.

  Wood-aluminium: +/- €580/m²
  Wood: +/- €560 /m²
  Aluminium: +/- €480 /m²
  pvc: +/- €400 /m²

- **Airtightness**: it is vital to define the right method or the right product in line with the way the building is built. In addition to the price of materials, the time it takes to install them and their ease of use are determining factors. Achieving airtightness through the use of dry-lining is probably the best known method in Belgium and the easiest to implement compared with other more demanding and newer methods involving membranes and adhesive tape. Proper site planning, the right implementation and blower door tests help minimise airtightness problems.

- **Ventilation** : the positioning and overall length of the ventilation network play a decisive role. A compact, centralised ventilation network limits the amount of ducts and false ceilings (or any other finishing) needed. Carefully selecting where the ventilation unit is to be placed also cuts down insulation requirements for pipes leading to the outside.

2.4.5. Variants

In any detailed analysis of outside walls, certain synergies between components can be leveraged. For example, a prefabricated concrete facade may at first glance seem expensive, but as it means that there is no need to apply an additional airtight layer (dry-lining, for instance), it may be interesting from a financial perspective.

The time needed for construction is also an important factor, and gaining a few days vis-à-vis the site schedule can be a worthwhile proposition.

Finally, certain long-term questions can play a decisive role (especially under a *Design, Build, Finance & Maintain* delivery system: what warranties do the products have? Will the products still be available in a few years' time?

Each project needs to be looked at individually, and a large number of pragmatic and cost-efficient solutions can be the result.

Saint-François kindergarden| Schaerbeek | Municipality of Schaerbeek | architect: O2 architects


MIDDAGLIJN
34
1-BJV-192

2.5. On-site control

Daniel De Vroey

2.5.1. Blower-door tests

2.5.1.1. Principle

The blower-door® test is used to measure a building's airtightness.

A device equipped with a fan measures the air flow blown into or sucked out of the airtight volume, together with the pressures outside and inside the building, quantifying the volume of air needed to maintain a given pressure difference between inside and outside. This test allows us to identify uncontrolled air flows traversing the outside walls, leaving aside ventilation systems and other closable openings.

The test first pressurises the building by blowing in air, and then depressurises it by reversing the fan to suck air out through the envelope. Measurements are taken at different pressures, generally between 10 and 100 Pa. Pressure-related flows are entered into a chart, providing a linear distribution. The straight line represents the leakage rate at 50 Pa.

> 1.3.1
p. 44

The test can be performed either to check the proper installation of various elements (method B) or for an official certification (method A). In the latter case, both the norm and the additional test requirements need to be complied with. It is very much recommended to perform one or more initial tests, insofar as the airtightness plan is available, before proceeding with the official test.

Such tests allow (a) the proper installation of the various elements to be checked, and (b) a fine-tuning of the installation. It is a good idea to check outside walls which are to be clad at a later date, especially when the execution method is unusual and when inexperienced people are at work. These preliminary tests can be performed once the building's envelope has been sealed, whereby temporary openings can be taken into account.

It is not uncommon for the blower-door expert to take part in remedying leakages, keeping the building at reduced pressure to identify and correct leakages. It is vital to check and possible correct all still accessible junctions.

2.5.1.2. Calculating air leakage rates

The official test measures the average air leakage rate, which is then used to determine a range of values:

- **V_{50}** [m³/h]: the average leakage rate through the building's envelope at a pressure difference of 50 Pa. This represents the total of all leakages through the building's envelope
- **v_{50} (ou q_{50})** [m³/h.m²]: the envelope's permeability at a pressure difference of 50 Pa. The air leakage rate V50 is put in relation to the envelope's outside surface.

  $v_{50} = V_{50}/A_{test}$ where A_{test} is the envelope's total air loss.
- **n_{50}** [vol/h or h-1]: the rate of air renewal. The air leakage rate V50 is put in relation to the building's volume of inside air. This value is used in the context of passive building certification, and must be lower than 0.6 vol/h.

  $n_{50} = V_{50} / V_i$ where V_i is the building' inside volume, determined in accordance with the norm but also specified in the vade-mecum[79].

Thus::

$$V_{50} = n_{50} * V_i = v_{50} * A_{test}$$

As a rule of the thumb[78] , given that compactness $C=V_e/A_e$ one can determine the following relationships between n_{50} and v_{50} :

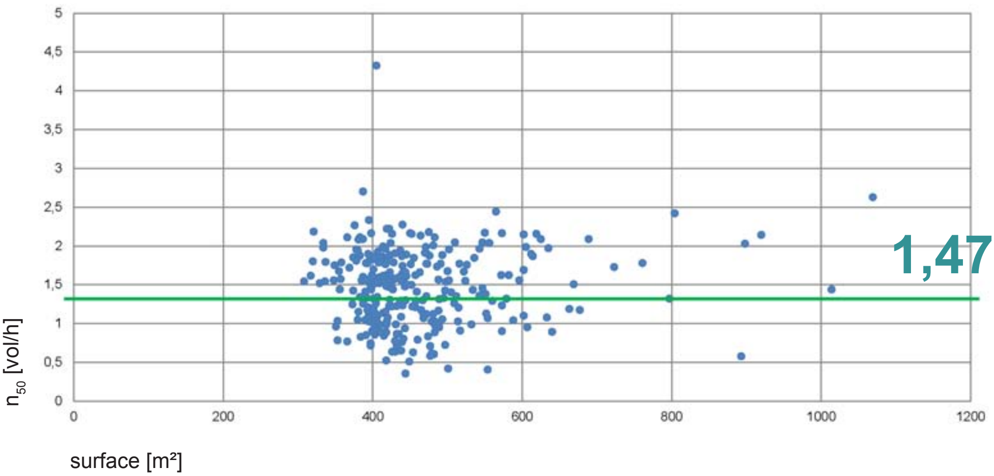
$$n_{50} = \frac{v_{50}}{C} \text{ et } v_{50} = n_{50} * C$$

In Belgium, the resultant values n_{50} and v_{50} are currently in use.

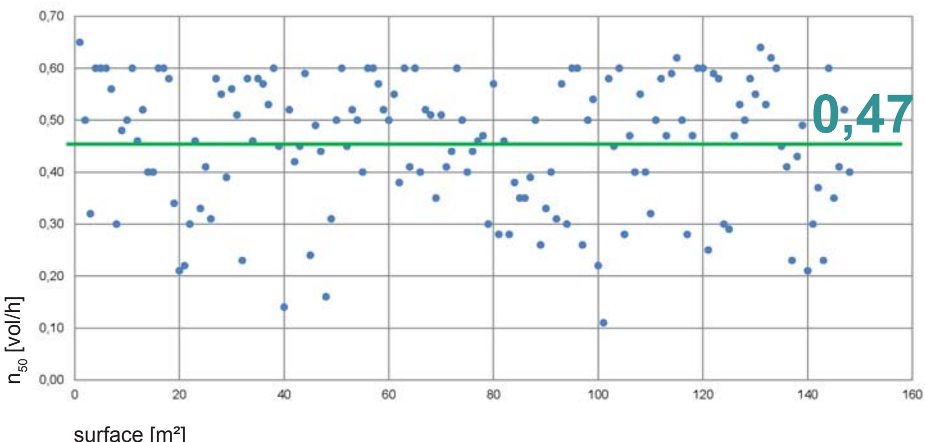
2.5.1.3. A realistic target in Belgium

Though this airtightness criterion of 0.6 vol/h (at ΔP=50 Pa) may at first glance seem strict[79], quite a few new conventional buildings achieve very good airtightness levels simply through making use of improved components and technologies (e.g. better window frames).

With regard to conventional new buildings, the company Hoffman et Dupont has published[80] the results of a number of airtightness tests on all types of building. These reveal an average n50 value of 1.47 vol/h.



Experience gained in certifying buildings shows that the success rate of the n50 test is around 95% for buildings wanting to gain passive standard certification. The average vale achieved is 0.47 vol/h[81] :



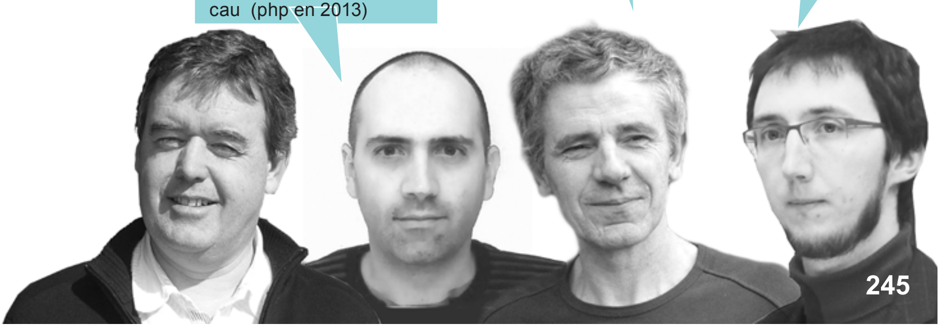
In Wallonia, the non-passive new construction is already running on average around n_{50} of 1.47 vol/h. Not bad at all!
Roger Hoffman (Hoffman et Dupont)

3.996 Blower Door ®

With all these housing certification projects, the PHP manages an average of 0.43 vol/h at n_{50}!
Christophe Marrecau (php en 2013)

The average n_{50} in passive construction is 0.50 vol/h. Not bad either.
Paul Eyckens (Isoproc)

In passive certification, the pmp notes that the average n_{50} is equal to 0.4 vol/h with less than 5% failure!
Benoit Quevrin (pmp)



The 0.6 vol/h target is thus realistic, given the current construction context in Belgium where a number of favourable factor are present, such as a tradition of dry-lining. Efforts are currently under way to raise awareness for these issues and to provide appropriate training to the sector.

2.5.1.4. Certification test

The final certification test (method A) takes place once the airtight envelope has been completed (including all planned openings). Though there is at present no official certification requirement in Belgium[82] requiring such tests to be carried out and a report compiled, the official test does lay down certain conditions for it to be valid.

First of all, the zone to be tested must be prepared in accordance with strict specifications regarding openings (under which conditions can they be opened)[83] and the placement of the blower-door equipment. Though it is tempting to install the equipment in the least tight opening, the reference documents say that an opening with the greatest airtightness should be chosen a priori , with its position and description being recorded in the report.

The test must be carried out with the building in both a pressurised and depressurised state, with the final value corresponding to the arithmetical average of the airflows. The building will be subjected to different pressures, ranging from 10 to 100 Pa, thereby providing results relatively independent of "natural" pressure effects. The normal pressure the building is subject to is measured at the start and end of each test (pressurised and depressurised), with this value expected to be less than 5 Pa. The location of the capillary as well as the building's exposure thus have a major influence.

2.5.1.5. Interpreting the results

Pressure of 50 Pa corresponds to a 30 km/h wind blowing against the whole building. In Belgium, an air infiltration rate of 1 - 2 Pa is considered to be average. To gain this rate, the n50 is divided by 10, 20 or 30 dependent on the degree to which the building is exposed to the wind (very much / average / little exposure).

2.5.1.6. In practice

When testing a residential building, a test usually takes about two hours, not including getting the envelope ready for testing and looking for leakages. It can often take up to a whole day to rectify junctions and to carry out further tests to get the leakage rate down.

As air is invisible, smoke is used to visualise airflows. Thermal cameras round off the equipment. In many cases tactile perception is sufficient, though common sense can sometimes be misleading, and not all weak points are intuitively identifiable. A heavy block is not always airtight, a wall made of chipboard panels will let through a small amount of air, and a membrane might be porous. Screed may at first sight seem good, but pour a bucket of water over it, and you might see the water percolate through it straight away. If water can get through, air can get through as well.

Air infiltrates and then spreads out. Plasterboard stuck to a wall with plaster adhesive "dabs" are very good at letting air through, while by contrast you can get a "funnel" effect when a wall made of various materials without any cavities extends the orifice of a well-sealed outside door.

Air passes through gaps between bricks and joints, and one will often find leakages behind stair stringers: as the side facing the wall is not dry-lined, air can get through the junctions with the wall and spread out through the airtight envelope, in this case via the bricks. At 50 Pa, a 1 cm² hole can cause air to flow through at a rate of 2 m³/h.

2.5.1.7. Additional information

In addition to the official report, the blower-door test highlights air leakages causing other problems. Passing through an insulated wall in winter, hot and humid inside air brings damp into the structure, and consequently a risk of condensation. Air passing between two heated rooms can similarly cause acoustic problems or smells. The faulty installation of a window frame can cause heat losses and noise problems. The faulty installation of a fireproof duct can lead to a risk of fire and smoke spreading.

The importance of such leakages for a building's overall effectiveness requires that they be anticipated in the design phase, i.e. with the building being designed right from the start as being completely airtight. All holes/ openings and junctions need to be looked at in detail. Ducts, wiring holes, the choice of materials, the location of technical systems (e.g. the heating system, fuse boxes) all have a major influence, as does the choice of the volume to be tested and its problem features (stairwells, lifts, landing doors, etc.).

The test also allows certain specific elements to be analysed. In association with depressurising a building, screens can be used to carry out measurements for a particular zone. The most common case involves installing a screen in a window recess to measure the window's leakage rate. Covering up certain parts of the frame also allows a more in-depth comparison of selected items. The use of a 'mock up" can also be interesting[84].

The outside joinery must comply with airtightness norms regarding the actual frame and not its connection to the envelope. Studies show that a badly constructed window can cause such a leakage rate that the class of air permeability has to be corrected downwards. The effort put into achieving airtightness is also a sine qua non for the window's durability[85].

Where a building has several doors, pressurising the adjacent spaces allows an analysis of the leakages via these.

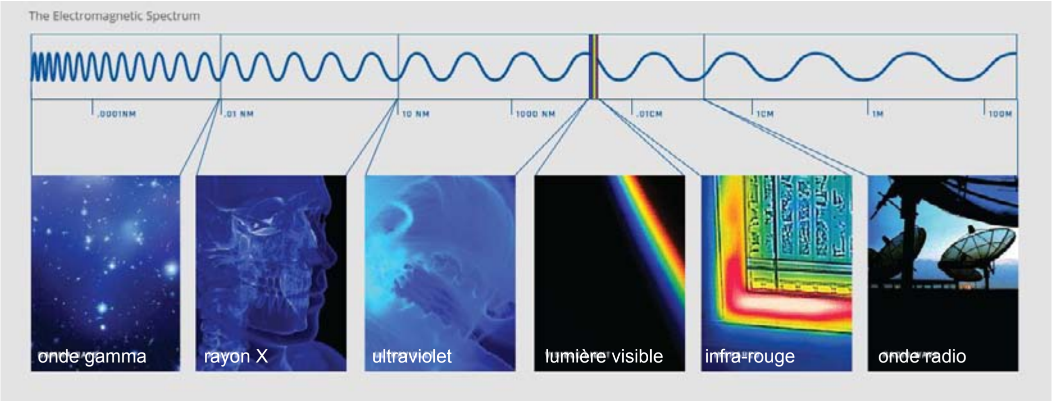
.

2.5.2. Thermography

Sebastian Moreno-Vacca

The use of an infra-red camera is a non-destructive way of checking exactly where a building is losing heat.

Put more precisely, an infra-red camera does not actually "see" temperatures, instead recording infra-red radiation. This radiation is captured in the form of a "thermograph", using different shades of grey or different colours to show the heat losses.



Electromagnetic spectrum. Source: FLIR©

2.5.2.1. Theory

The human eye is blind to the infra-red spectrum. As electromagnetic radiation is linked to temperature, a camera can calculate a surface's temperature from the radiation it emits. An infra-red check allows us to:

• visualise energy losses,

• detect faults in the insulation (or places without any insulation),

• detect air leakages,

• detect moisture in the insulation, the roof and walls, both inside and outside,

The FLIR ONE Source: FLIR©

• detect mould and badly-insulated zones,

• identify thermal bridges,

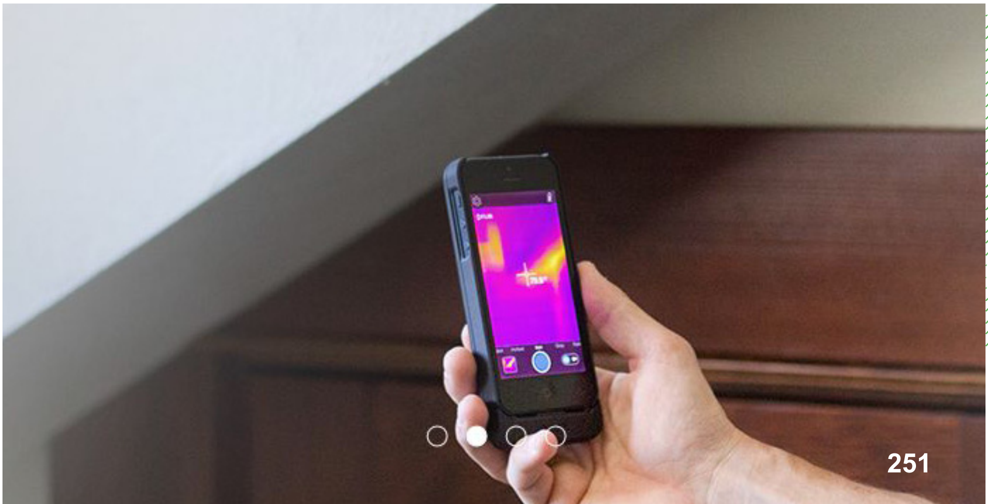
• detect a leakage in a flat roof,

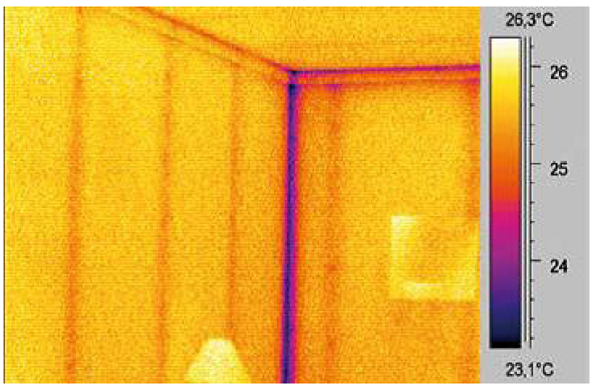
• visualise construction mistakes,

• visualise other faults or the state of a building's component (in particular technical systems).

Though an infra-red camera is an exceptionally useful device, the interpretation of the images produced requires an understanding of the conditions under which the image was taken, a knowledge of the building and the laws of physics.

For example, materials like concrete are slow to change temperature, while others do so much quicker. To correctly interpret the results, the user must know whether any major change in temperature has occurred shortly before the image was taken, whether inside or outside the building, which could affect the temperature data. An outside wall may feature an air space between the façade and the rest of its components, with the result that an external check will be inappropriate. Within a wall, a skeleton frame will seem colder when looked at from inside (assumed to be heated), while the opposite is true when looked at from the outside (assumed to be cold).





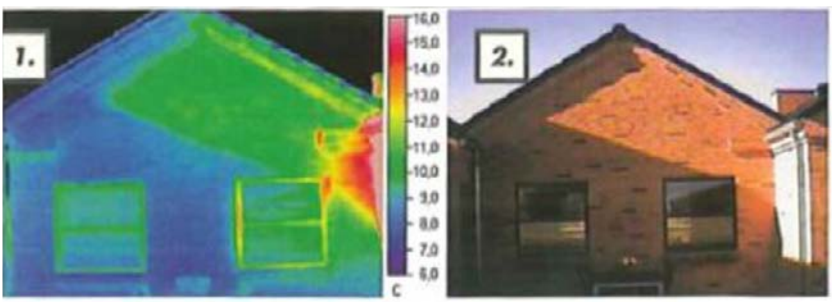
IR image taken from inside. The skeleton frame is visible, as well as the screws fixing the panelling to the frame. The corner is much colder, though such "corner effects" are normal. Source: FLIR©

2.5.2.2. Points of attention and advice

The reference norm for thermography is EN 13187 (ISO 6781:1993), *Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method*.

The majority of infra-red cameras currently on the market work on the basis of a stable 10°C difference between inside and outside temperatures. However, a user should know whether any major change in temperature has taken place within the last 24 hours.

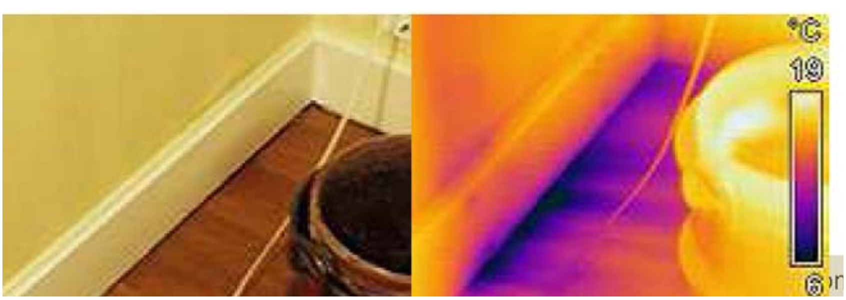
Outside conditions can influence infra-red measurements. Sunshine and shade can create various motifs on a surface which will remain visible as an infra-red image several hours after the sun has stopped shining. The duration of this phenomenon is dependent on the construction materials (for example, bricks change temperature much quicker than wood). Rainfall makes a surface colder, and evaporation when drying will lead to further cooling of the surface, possibly producing a misleading motif.



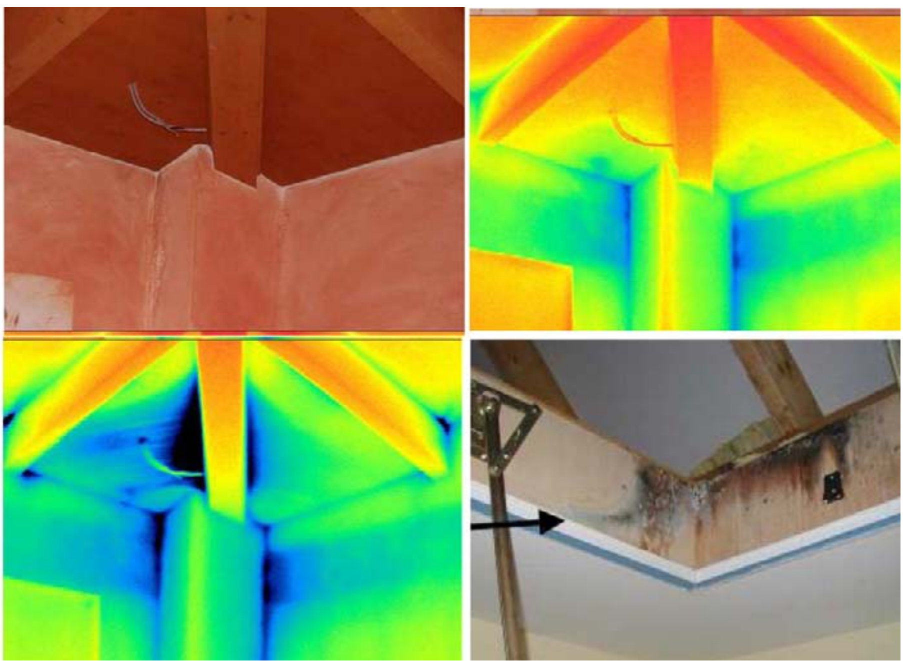
The difference in T°C needs to be considered. On a surface warmed by the sun, the different colour of the bricks is a sign of a difference in their emissivity and not a loss.

The best cameras generally provide a resolution between 320 × 240 and 640 × 480 pixels, whereby their sensitivity will be lower or equal to 0.07°C at 30°C.

Combining an infra-red check with a blower-door® test allows any faults to be pinpointed even more exactly, whereby the infra-red camera does not "see" the air itself, but allows zones cooled by the airflow to be seen. Characteristic smears (see below) can be seen on the image, allowing conclusions to be drawn.



Thermography coupled with a blower-door® test: the image shows air leakages at the bottom of the inside walls



1- Photo of a ceiling

2- Infra-red image showing faults in the corner of the walls

3- Combined IR and blower-door images additionally revealing problems associated with the roof's airtightness.

4- Photo showing the risk of mould around the woodwork.

A key success factor in passive-standard construction and refurbishment involves frequent on-site controls during execution using an infra-red camera. It is recommended to carry out checks at different stages during construction: once the structural work has been completed, once the technical systems have been installed and once all work has been completed.

Top-quality infra-red cameras are now available on the market at a very reasonable price - and there is even a smartphone version.

Neerstalle street housing | Forest | Municipality of Forest |architect: B612 associates


155

References:
1 **be.passive 08**, p.82; 13, p.68; 14, p.86; 15, p.84; 17, p.78
2 **be.passive 04**, p.70; 07, p.74
3 **be.passive 08**, p.62.
4 **be.passive 03**, p.30.
5 **be.passive 05**, p.60; 06, p.72.
6 Other factors (e.g. relative humidity, the type of surface, risk situations) play an important role in the development of mould.
7 Pursuant to NIT 153 published by CTSC, UYTTENBROECK, CARPENTIER, 1984.
8 **Ytong**, Hebel, Foamglass, etc.
9 www.schock-belgique.be
10 www.etanco.be
11 **CSTC, contact 2013/01**.
12 Dealing with water vapour involves an understanding of various physical principles. These cannot be explained in detail here. See www.energieplus-lesite.be
13 For more information, see *inter alia Isolation thermique par l'intérieur des murs existants en briques pleines* by Arnaud Evrard, Aline Branders and André De Herde (**Architecture et Climat**, 2010). Available at: www.energie.wallonie.be
14 **be.passive 04**, p.53.
15 **be.passive 03**, p.80.
16 Germany (DIN 4108-3:2001), UK (BS 5250:2002).
17 **CTSC contact 2013/01**.
18 **be.passive 08**, p.73.
19 Downloadable from www.energieplus-lesite.be > Calculs > L'enveloppe du bâtiment > La condensation interne d'une paroi; this allows an analysis of wall with up to five different layers.
20 The ISOLIN tool is available at: http://energie.wallonie.be/fr/isolation-thermique-par-l-interieur-des-murs-existants-en-briques-pleines.html?IDC=6099&IDD=41922
21 Please note: a cement layer is not airtight.
22 According to the CSTC tests in compliance with NBN EN 12 114.
23 For example: Airgard (STO).
24 For example: M330 (Illbruck).
25 **CSTC contact 2013/4,** pp10-11.
26 **CSTC Contact 41**, *Enduits extérieurs sur isolant : nouveaux points d'attention*, January 2014, p. 21.
27 **be.passive 03**, p.70.
28 **CSTC, Contact 2013/01**
29 **be.passive 08**, p.86; **CSTC dossiers 2012/2.6**.
30 **be.passive 02**, p.70.
31 **be.passive 12,** p.56.
32 For example: **Durelis** (**Spanotech**).
33 For more details: *Isolation thermique par l'intérieur des murs existants en briques pleines*, op. citum.

34 **be.passive 08**, p.67.
35 www.ejustice.just.fgov.be/mopdf/2012/09/21_1.pdf#Page2 (in particular Point 5.1.5.1 : Gaines verticales); **be.passive 15**, p.30.
36 European fire resistance classification system for building components, referring to the component's level of fire resistance (i.e. how long it can withstand fire). EI 30, for instance, means that it will withstand fire for 30 minutes.
37 Where criss-crossing cannot be avoided, it is nevertheless still possible to use flat connections with a rectangular section.
38 **be.passive 16**, p.86.
39 **be.passive 02**, p.52.
40 **be.passive 12**, p.58; 18, p.20.
41 Manuals: **BREEAM** (www.breeam.org); Waardering van kantoorgebouwen. Op weg naar een duurzame huisvesting voor de Vlaamse overheid (www.lne.be).
42 **be.passive 05**, p.74.
43 NBN B 62-003 (1986): Calculating a building's heat losses, partially replaced by EN 12831 (2014), Heating systems in buildings. Method calculation of the design heat load
44 The primary energy conversion factor of biomass is set on a regional basis under Belgium's building energy performance (EPB) regulation. In Flanders and Wallonia, the applicable value is Fp=1; while in the Brussels-Capital Region it is 0.32. Biomass is less highly subsidised than other renewables as its (sustainable) production is limited in a regional and national context.
45 For example, the norm NBN EN ISO 13790:2008 can act as a starting point (aspects relevant to the detailed simulation method, references to applicable norms), as well as the slightly outdated ISSO-32, Principles for thermal simulation calculations (1994).
46 An approach adopted by the Vade-Mecum for office buildings (Vade-Mecum tertiaire).
47 Dutch thermal comfort guidelines: from weighted temperature exceeding hours towards adaptive temperature limits, Publication 74, ISSO, Rotterdam, March 2004.
48 http://app.bruxellesenvironnement.be/alter_clim; more information at www.cuepe.ch/html/plea2006/Vol1/PLEA2006_PAPER205.pdf
49 **be.passive 03**, p.54.
50 International Energy Agency, www.iea-annex47.org
51 **be.passive 12**, p.58; 18, p.20.
52 Building Management System
53 **be.passive 09**, p.56; www.ecoffice-building.be; www.febelcem.be/fileadmin/user_upload/dossiers-ciment-2008/fr/A6-FR-beton-passif-internet.pdf
54 The specific heat requirement initially calculated by PHPP for 20°C is 10.9 kWh/m² p.a. and 7.5 kWh/m² p.a. by the EnergyPlus dynamic simulator. This new directive brings the heat requirement to respectively 18.1 kWh/m² p.a. and 19.1 kWh/m² p.a. The PHPP comes up with a result of 18 kWh/m² p.a. Not bad!
55 **MARMOX**, etc.
56 http://statbel.fgov.be/fr/binaries/A5_FR_batibouw%202013_tcm326-213556.pdf
57 Institut national de la statistique, www.insee.fr/fr/themes/conjoncture/indice_icc.asp
58 Belgian National Bank website, www.nbb.be/belgostat/Pr

esentationLinker?TableId=410000014&Lang=F
59 **Le Journal de l'architecte, no. 279**, February 2014.
60 **be.passive 09**, pp.48-56; 16, p.56.
61 Technum, Étude du cost-optimum pour Bruxelles Environnement, 2013, p.56.
62 ibidem, p.67.
63 Although it leads to programmed obsolescence
64 Dixit, A. K., & Pindyck, R. S. (1994). Investment under uncertainty, Princeton: Princeton University Press (quoted by Verbruggen, Financial appraisal of efficiency investments: why the good may be the worst enemy of the best, Energy Efficiency (2012) 5:571–582
65 **be.passive 07**, p.88.
66 Jan **Hoffman**, Aviel **Verbruggen** : *Il est toujours payant d'investir dans un concept passif,* **Energymag 16**, 28.01.11.
67 www.fgf.be
68 **L'Espoir** (2012, **be.passive 05**, p.60; 06, p.72; 11, p.12; 14, p.32), **Brutopia** in (2013, **be.passive 08**, p.42; 17, p.28; 18, p.38).
69 **be.passive 16**, p.31.
70 **be.passive 09**, p.56; www.ecoffice-building.be
71 From the English "Building together", www.buildtog.eu
72 **IPFC** School (Nivelles), **be.passive 03**, p.29.
73 Study for Brussels
74 These prices are provided as a guide and represent averages ascertained from a number of projects completed in 2013 by the **Democo** construction company.
75 The base document for the measurements is EN 13829:2001, Thermal Performance of buildings - Determination of air permeability of buildings - Fan pressurisation method' (iso 9972:1996, amended). In the context of the Belgian building energy performance (EPB) regulation, requirements set by each of the country's three regions apply (see "Spécifications supplémentaires sur la mesure de l'étanchéité à l'air des bâtiments dans le cadre de la règlementation EPB", version 3 of 28 May 2013.
76 This value is used in the EPB regulation, whereby the default value is 12 $m^3/h.m^2$.
77 Soon to appear: STS 71-3-P, Étanchéité à l'air des bâtiments – Essai de pressurisation (a French-language guide to testing airtightness).
78 To be precise, there is a slight difference between the external volume and the internal volume calculated under n50. The exact formula is n50=(v50*Ve)/(C*Vi) and v50=n50*C*Vi/Ve
79 **be.passive 12**, p.82.
80 **be.passive 15**, p.90.
81 Ibidem.
82 Soon to appear (2015): Un cadre de qualité et d'une certification des mesureurs (Quality and certification guidelines for measurers).

83 www.epbd.be/go/mesure-etancheite, Spécifications supplémentaires sur la mesure de l'étanchéité à l'air des bâtiments dans le cadre de la règlementation EPB, version 3 of 28 May 2013.
84 **be.passive 12**, p.67.
85 **be.passive 18**, p.60.


BPC

PoliceHQ in Charleroi | Charleroi | City of Charleroi/groupe CFE | architect: Atelier Jean Nouvel and MDW architecture

legal issues

legal

03

3.1. From the legal perspective

Frédéric Loumaye

In this chapter we expand the main focal points outlined in the "angle droit" column of the **be.passive** magazine. For lack of space, we refer on certain subjects to the original articles. In particular, see p. 281 + p. 295.

3.1.1. The end of the state of grace period ?

The days of the first passive projects driven by a pioneering spirit and shared goodwill among all players are now gone and past. Customers will be less and less ready to tolerate the trial and error attendant on the innovative nature of such constructions.

The growth and success of the passive standard will inevitably put an end to the honeymoon between customers, architects and contractors. In particular, the political choice of imposing the passive standard (or equivalent) on all new construction means that this standard will lose its uniqueness, with the corollary that most building owners will apply it by obligation, with neither passion nor tolerance.

Developers, contractors, architects and consultants, all will be affected. Some will probably attempt to bend the philosophy of passive building to their logic of profitability and tight deadlines without really taking on board the methodology that is essential for "successful" passive building. But all too easily the system can break down, if one of the players in the triangle {designer, project owner, contractor} is not animated by the same good will, passion and competence as the others.

Lurking in the background here stands the best friend/worst enemy of the building's designers and the contractor, namely the lawyer, and his corollary, the courts ... Therefore, when facing the technical challenge of passive building it is vital that professionals be aware that the adventure can also be a source of dispute and invoking of liability at every stage of a project. Each stage of a passive

3.1.1.1. Innovation: the driver of architecture

Our era is experiencing significant and exciting developments in construction techniques and materials. However, the spirit of the times that seeks to find someone onto whom to pin liability for every problem may result in stagnation and lead designers to avoid any potential risks.

Caution invites them to remain with tried and tested technology and avoid the risks involved in innovation. In addition to its unattractiveness from a creative and intellectual viewpoint, this position conflicts with the political will to impose the use of passive building. This involves “newness” and therefore change, with their share of uncertainty and additional risks ...

The newness of passive building is, however, relative. In Germany in particular, passive building has been going on since 1991. The knowledge and technical experience necessary to erect a passive building are therefore readily available and do not constitute in themselves a novelty.

The only real innovation is the legal imposition of the passive standard to all new and assimilated construction. Unfortunately, when change is imposed and unwanted, the risk of things going wrong and of professional errors is always greater. Builders therefore have a vested interest in really taking on board the “newness” of passive building, whether to comply with the requirements of the “PEB 2015” in Brussels or to obtain certification. In case of failure, any “putting right” can have serious financial consequences in terms of legal liability, including dismantling of what has already been constructed, delays, and loss of tax benefits and other grants.

Whatever one’s views on passive building, its regulatory nature leaves no alternative but to fully engage with it.

EcoPuur HQ | Nevelle | EcoPuur | architect: denc !-studio

> 1.3.1.1
Juridique
Comment fair
la réception

3.1.1.2. Who should bear the additional risk arising from the use of new technologies?

Some case law[1] considers that innovations have the effect of increasing the legal liability of those responsible for designing the building and subsequent intervening parties. Other authors, on the contrary consider that "*the project owner alone should bear the consequences of the use of novel technology where it has been duly informed beforehand of the risks and nevertheless decided to incur them*"[2]. Designers therefore have an interest in drawing project owner's attention in advance and in writing to the potential risks incumbent on the use of innovative techniques.

> 2.2.1
p. 168

The radical difference is these opinions represent a source of uncertainty in terms of legal liability. The differences of opinion regarding innovation clearly leave the door open to the invoking of the liability of the professional, whose only possible line of defence is to try and protect himself by arguments that make the project owner bear the risks arising from innovation.

However, it is to be feared that the latter reasoning will not apply to sites where new technologies are required to be used for legal reasons, as is the case for "Passive 2015", where innovations are implemented not because the owner has knowingly requested them, but because they are required by law. This legal requirement necessarily implies an obligation on the part of builders to take the necessary measures to erect passive buildings that comply with the rules of the art.

The use of innovative technology in response to government regulation has the unfortunate consequence for construction professionals of making them bear sole responsibility in the event of dispute. They will therefore be well advised to exercise the greatest possible caution and in particular not hesitate to avail of the expertise of consulting firms, of facilitating services set up by the government[3] or of passive platforms. The latter can help builders with the benefit of their experience, in particular by making them aware of the relative nature of the novelty of passive building. What is innovative is not passive building as such, but recourse to it in a regulatory and generalized way.

3.1.2. The pre-project

A building's designers have a duty to provide advice to the project owner, throughout the building process, right from the pre-project stage and the first choices made.

3.1.2.1. Consultants, subcontracting and insurance

In the case of a passive building, the risk of being taken to court for a breach of the duty to advise weighs not only on the architect, but also on the special technologies consultancies and on the energy advisory companies.

The peculiarities of passive building often involve the intervention of consultants for energy design, either at the initiative of the project owner, or on the advice of the architect, and especially for passive building under the PEB regulations.

Special technology consultants have long since known that in the event of any litigation relating to their areas of intervention, they inevitably risk being dragged into the judicial proceedings. Energy design consultants, often involved only at the project stage, and before the site gets under way, have the mistaken impression that their liability cannot be invoked. However, if a dispute should occur involving the passive characteristics of a project, these consultants cannot stay out of the conflict. It is therefore vital that they be covered by professional liability insurance.

It is the architect's task to check here and demand documentary proof that the consultants have insurance coverage extending to the project in question, given that the logic of judicial litigation is to suck into a dispute any professional involved near or far in the project. The fact is that every party will seek to shift responsibility to the others for any errors and the possible financial consequences thereof.

Energy design consultants are not immune to this dispute mechanism. The other builders will take refuge behind the study and any errors of the energy design consultants in trying to escape the consequences of issues leading to litigation.

Serpentin street housing | Ixelles | M H Grondel and Mme C Allan | architect: atelier d'architecture FORMA

The architect, in general, has an interest in having the project owner conclude contracts with special technology, stability and energy design consultants directly and with no subcontracting relationships.

Some project owners, in particular public ones, require the architect to bring in these consultants as subcontractors. This means that if these fail to perform, the architect will find himself in the front line, with the task of seeking recourse against his subcontractor, and exposing him to the risk of total subcontractor failure, in particular following a bankruptcy. As part of his responsibilities towards the project owner as well as in his own interest, the architect therefore needs to ensure that these consultancies have insurance cover.

The existence of professional liability insurance, including for energy design, normally serves to mitigate the consequences of a bankruptcy or insolvency of such consultancies.

3.1.2.2. Specifics of passive construction

The architect needs to draw the project owner's attention to the specific features of a passive construction. The project owner needs to be aware, at this stage, of the particularities of such a project, with its ensuing advantages and constraints. The architect will take care to maintain written records to corroborate his execution of this duty to advise.

Passive building is not only revolutionary in terms of technology, it also affects lifestyle, aesthetic choices, and even the selection of plants in the garden ... The architect must draw the project owner's attention to the fact that passive design will also have implications for DIY and repair work in the future, and even the interior decoration. Indeed, a single hole drilled in a strategic location could have unfortunate consequences for the sustainability and efficiency of the building.

The project owner's liability is rarely invoked in the context of a traditional building. The situation is very different when it comes to a passive building. The owner will need to use the building in accordance with the instructions for use and maintenance. It is likely that, in the event of a dispute following acceptance of the building, he will find himself potentially liable.

The general lack of public knowledge of how passive buildings work and the at times serious consequences of failing to respect their specificities require the architect to be particularly careful in his duty of advice towards the project owner. He will remind the latter that regular maintenance of the building is vital (including replacement of certain elements, such as sealants), as is the maintenance of the systems necessary for the proper functioning of the passive building. He will define the frequency of these interventions, which must be undertaken, in certain cases, by accredited bodies. The architect will try here to be as exhaustive as possible, while keeping written evidence of advice given.

3.1.2.3. Budget, grants and tax benefits

The architect will both attract the customer's attention to the potential increased cost attendant on the passive design of the building, both for construction and for maintenance, which differs from traditional buildings (filters, heat exchangers, etc.), and will provide information on the grants and benefits that exist for this type of property.

3.1.2.4. Differences between theoretical and real savings

> 2.1.3.2
p. 158

Designers need to draw the project owner's attention to the margin that exists between the theoretical calculations of savings generated by this type of building and the actual savings that can be expected during use. They must remember that the former is only an estimate and not a firm commitment to achieve the calculated consumption, which, depending on the lifestyle of future residents, can in fact be equal to, above or below the theoretical calculation.

3.1.2.5. Final destination of the building and renting

A. Habitability of the building and compliance with legal standards for leases

Passive buildings require their occupants to comply with certain rules of everyday life and to be vigilant with regard to the required maintenance. Failure to follow the necessary rules to ensure proper operation and maintenance of the building may have relatively serious consequences.

A poorly motivated and careless occupant may, through DIY jobs or lack of maintenance, undermine the passive operation of his building or even cause health problems resulting from poor ventilation of the building.

At the same time the law of 20 February 1991 and various regional provisions require the lessor to rent out only premises that are free of all problems of habitability and salubrity. Failure of the ventilation system in particular could mean that the building no longer meets these provisions. In this case, the regions generally provide the possibility of prohibiting the rental of the property and imposing extremely heavy fines on the lessor. It follows that if a passive building is intended for the lease market, there is a need for reinforced mechanisms concerning safety, maintenance and servicing.

The classic case is for example to provide air vents that cannot be blocked by the occupants, either intentionally or by negligence (e.g. by furniture or other objects).

B. Lease contract

The architect must draw the owner’s attention to the need to have specially adapted contracts that specify the passive character of the building and the intervention of third parties to perform maintenance of the ventilation equipment.


12

Les courses housing | Ixelles | private | architect: MDW architects

The tenant should be provided with precise plans indicating where drilling is and is not permitted. It is recommended to attach the building's maintenance manual to the lease contract, specifying that it forms an integral part of the latter, and to have it initialled by tenants. The contract should include clauses that call tenants' attention to their responsibility for the consequences of non-compliance with the maintenance manual.

C. Inventory on entry and leaving

The expert brought in to conduct the inventory on tenant entry or departure needs to be familiar with the specifics of passive buildings in order to identify and quantify the rental damage ensuing on the failure to respect their specificities. For example, simple holes in the wall of a traditional building could require compensation of a few euros, while in a passive building they can have serious (and expensive) consequences in terms of insulation. An expert conducting a departure inventory who fails to take into account the passive features of the building runs the risk of being held liable by an owner confronted by significant costs not covered by the compensation fixed by the former.

3.1.3. The project design

3.1.3.1. Renovation of an existing building

The passive renovation of a traditional building usually involves heavy and expensive interventions which, even if justified in terms of insulation, may affect the structure of the building. It is vital that these choices be validated by the competent stability consultancy and be shared with the special technologies consultancy.

As part of his duty to advise, the architect must ensure that the project owner is in a position to take his decisions in full possession of the facts. He must keep evidence that he has clearly warned his client as to the budgetary impact of his choices and has anticipated the specific problems of such a construction, especially with regard to the potential return on investment in terms of energy saving. The architect must be aware that some older buildings cannot be reasonably transformed into passive buildings, given the technical and financial constraints, and for aesthetic reasons, not to mention the issue of listed buildings. If, for reasons of principle, the project owner decides to renovate a passive regardless of economic considerations, the architect will never be too careful in covering himself in writing.

3.1.3.2. Consideration of neighbouring buildings

The architect will naturally have the reflex of taking into account the neighbouring buildings in designing his project. The design of a passive building is obviously not the same if it is detached or has a party wall. Where a passive building adjoins existing buildings, the project owner's attention should be drawn to the fact that the neighbouring buildings and their possible evolution could directly impact his own project.

These buildings may well be demolished without being replaced immediately, for example pending the outcome of a long and complicated building project; they could also be reconstructed differently. The demolition or a possible change of neighbouring buildings can definitely impact the performance of the passive building.

The structure itself of neighbouring buildings or their inhabitants' lifestyle may also have implications even in the absence of any conversion or demolition. Thus, for example, the presence of an unheated stairwell next to the party wall will inevitably impact the energy performance of the proposed project, as will adjoining offices that are heated by definition during daytime and not during evenings and weekends. The same applies for adjoining buildings left wholly or partly uninhabited or unheated for various reasons specific to the owners or occupants.

The project owner could deem the architect to have failed in his duty by not anticipating such problems. The architect therefore has every interest to protect himself by drawing the project owner's attention in writing to the choices to be made in such cases. The project owner must therefore be confronted with the choice: going for safety and covering the uncertainties with the resulting added expense, or taking the risk of situations he does not control.

3.1.3.3. Siting of the exterior walls of the new building

When the proposed passive construction project is not already surrounded by adjoining buildings, or only partially, the question arises as to the siting of the future walls of this building. Article 663 of the Civil Code and especially the surrounding jurisprudence regulate this particular issue of the siting of said walls.

In an urban environment the future wall can be sited on either side of the property boundary line, with the neighbour being unable to oppose the "invasion" of his property.

The principles established by Article 663 aim to establish a party wall situation "in waiting". Jurisprudence here has clearly favoured the interests of the property as such over the momentary opinion of a current owner-neighbour. The latter may not use the fact that he does not intend for the time being to use said wall to prevent the siting of this wall astride his land. The neighbouring landowner may later change his mind ...

At a subsequent date, his heirs or other future owners might have other

Mixed destination building in Mortsel | Mortsel | Régie autonome de Mortsel | architect: Abscis architecten

projects requiring the use of this party wall "in waiting". The aim is also to avoid costly and disproportionate property transfers if and when the owner of the neighbouring property uses the new walls. This system makes it possible to have to repurchase only the cost of construction without requiring a notarial deed for a strip of land about 15 cm wide.

These principles also ensure the continuity of adjoining buildings without leaving gaps between buildings, for obvious reasons of aesthetics and public hygiene. By introducing these mechanisms, jurisprudence has clearly favoured a pragmatic solution in the interests of the property and of the public good.

Not to put too fine a point on it, most architects place the separation wall straddling the two properties automatically without even knowing why they are allowed to invade the neighbouring property.

We have seen that this encroachment is permitted only if this wall, by its structure, can be eventually be used at a later date by the owner of the neighbouring land. This "invasion" of the neighbouring land (often resented in practice) is based on a presumption of future usefulness of the wall.

But in passive buildings, it is recommended to provide an at least 25 to 35 cm layer of insulation. The architect, in particular for reasons of cost and efficiency in terms of continuity will be inclined to have this layer placed on the outside of the future wall. In the case of a new wall built straddling two properties, this will ultimately be located on the neighbouring property. This "invasion" of 15 cm (accepted by the courts and commentators) serves in the case of a passive building for placing the insulation.

While this placing of the insulation on the outside of the building is entirely consistent from an economic and technical viewpoint, it is unfortunately legally unworkable. This is because the owner of the neighbouring land has no use, either present or future, for this insulation.

On the contrary, if one day the owner of the neighbouring land himself needs to erect a structure, he will either have to remove this insulation or build next to it, losing in this way the 15 cm used by his neighbour for the construction of the latter's passive building. This invasion of the neighbour's property is of no use to the latter. The same problem arises in the context of a wooden building which, in the event of an "invasion" also does not present

any future interest to the neighbouring owner.

It follows that the architect must be extremely careful in positioning the wall of his new building.

If, following traditional practice, he plans to site the wall straddling the two sites, he needs to be aware that he can do so only if this construction can potentially be used by the neighbour. This is not the case if insulation is placed over it and in the case of a timber construction.

But if this wall built straddling the two sides cannot technically be used by the owner of neighbouring land in the event of his own construction owing to the insulating layer or the use of wood, we cannot take advantage of the reasoning established by case law and doctrine on the presumption of future usefulness.

If the wall of the new building is not of potential utility to the neighbouring property from a technical point of view, it must then imperatively be sited exclusively on the site of the passive building. This means that, in making his decision to site the wall on the border of the two plots, the architect must ensure either that, in this project, the wall has a utility for the neighbouring plot, or else place it exclusively on his client's plot.

Indeed, in the unfortunate event that a wall having no use for the adjoining building is placed straddling the two plots, the project owner cannot take advantage of section 663 and the jurisprudential and doctrinal construction deriving from it.

The neighbouring owner can then bring legal proceedings to prohibit the continuation of the work and if necessary seek the demolition of building work already erected subject to the doctrine of abuse of rights. The consequences can therefore be extremely heavy, with liability falling on the architect, who must bear the consequences. The architect must therefore be extremely careful and attentive to the issue of the location of the future wall.

3.1.4. The tender

3.1.4.1. Selecting companies

The specific nature of the technologies required for erecting a passive building means that the architect must be especially careful in the final choice of companies to be involved in this building project.

The architect must take as many precautions and obtain as many guarantees as possible with respect to the abilities of the contractors. However, the final say in the selection of the contractors lies of course with the project owner, with the architect having only an advisory role at this stage. The project owner could, for various reasons, end up bringing in a company that lacks the requisite skills to carry out such a project. Faced with such a situation, the architect will have to be extremely careful and sound the alarm bell as quickly as possible, with written proof, where problems are observed at the execution stage.

Moreover, however much information is gathered, the project owner and the architect will never be totally protected from a contractor which sends in a bad team or calls in an incompetent subcontractor. Such problems may be exacerbated in the case of 'subcontractor cascading', as sometimes observed, with each subcontracting layer working at a low price so as to leave a margin to the layer higher up the line, often leading to catastrophic situations. The question of the transmission of information un the event of multiple sub-contractors also raises a serious issue with potential dire consequences in the context of a passive building (e.g. permitted intervention areas, zones that can undermine the sealing, etc.).

Moreover, in some markets, including government contracts, neither the architect nor the project owners have real control in the selection of the companies to whom the contract is finally awarded.

The hype currently surrounding passive building and the new regulatory requirements mean that we are unfortunately faced with companies that are keen to take advantage of this new "niche" without having either the requisite real skills or the willingness to adapt and take into account the specifics of this kind of project. Whether we like it or not, the first circle of insiders, the true pioneers in the industry, has expanded inevitably to include other undertakings that do not always have the skills required, with the attendant danger of a string of litigation and often dramatic situations for the project owners.

This vigilance must be extended not only to the contractors implementing the techniques required in passive houses but also towards other intervening parties. Indeed, all the professionals involved in this type of building may, by misguided interventions, undermine the effectiveness of the passive building. The architect will have to make sure, even after the structural work is finished, that all intervening parties know exactly where in the building they can intervene (e.g. drilling holes). By way of example, an electrician, plumber or even an interior decorator could, by misguided interventions, seriously undermine the effectiveness of the system.

In addition, given the habit of carrying out certification testing at the end of the structural work, one can end up with a duly certified passive building which in reality no longer has the required efficacy following the subsequent intervention of finishing trades or even a misguided repair job by the project owner. The architect must therefore ensure that all the trades involved in this project are aware of the risks of misguided interventions for the effectiveness of this building.

He should also be aware that the proliferation of intervening parties may make it difficult to determine liability in case of damage to the sealing and the other specifics of a passive building. In this way one could be faced with a site where certification is withheld owing to a series of minor errors which, while individually benign, together result in a more than problematic situation. Each of these professionals has itself only committed a small fault, but taken together, these can produce a catastrophe. The division of responsibilities could well prove problematic in such a case. The same can happen in the case of potentially more serious errors where many participants may each play a part in the incident (separate trades, general contractor and subcontractors).

In such a confused situation, there is a danger of the legal expert and the court eventually ending up holding all these professionals responsible with, as a corollary, with the risk of a joint and several conviction.

3.1.4.2. Specifications

It goes without saying that the building's specifications may not be the classic document as applicable to other buildings. These must of course be adapted, right the way through, to the specificities of passive building. Nor must we be blind here to the fact that many architects, for simplicity's sake, provide copy-pasted specifications for both the technical and the general clauses.

If for a conventional building project the specifications are already an important document, they are even more vital for a passive project. The architect must therefore be particularly vigilant both in preparing specifications and ensuring that these are respected by contractors at the execution stage. When in doubt, we can only recommend to architects and consultants that they turn to the platforms to benefit from their experience.

The architect will therefore need to be careful in controlling the site to ensure strict compliance with the specifications by contractors. Finally, if overly general specifications are to be criticized, the same applies to overly precise ones, detached from reality and representing no more than a statement of unrealistic wishful thinking.

3.1.4.3. Technical consultancies

Passive building promises a heyday for consultants and engineers. Faced with the multiplication of technical constraints and the specifics of this type of building, the architect will legitimately turn, as he was already doing for questions of stability, to specialized consulting firms.

It is thus appropriate that the architect involve a special technologies and/or energy design consultancy, especially for ventilation and thermal issues, while prudently making provision for distinct, direct contracts between the project owner and the latter. From a legal viewpoint, in questions of liability, it is always easier not to be in a subcontracting relationship with any intervening party in a real estate project.

The use of special technology, energy design or stability consultants does not, however, release the architect from liability if something goes wrong. The latter, especially given his “orchestra conductor” role, and despite the intervention of specialist consultants, must exercise the utmost vigilance and fully play his coordinating role. Indeed, it is not possible that each of the players and designers work in his area without worrying about any interfacing and overlaps. By way of example, in a renovation project, the requirements in terms of thermal insulation can have serious consequences for the stability of the building.

The architect therefore, in his conductor role, needs to ensure the perfect coordination of what has been dreamed up by the special technologies and/or energy design consultants with the studies provided by the stability consultants, so that together they produce a project that is feasible from all points of view, without losing sight of the financial aspects.

Judicial experience shows that the architect rarely emerges unscathed when something goes seriously wrong, even if liability can be pinned on the consultants selected. The courts consider him as retaining a portion of responsibility. The architect must therefore be even more careful, in a passive project, to ensure that the various special technology, stability and energy design consultancies together produce a project that is viable both technically and financially.

3.1.5. Inspection and control

3.1.5.1. The architect’s role: orchestra conductor or supervisor?

The architect is required to exercise a control mission at the site. His job is not, though, to act as a supervisor living almost permanently on the site. Indeed, the duty of control is unambiguously defined by case law and doctrine. Specifically: “*The control undertaken by the architect serves to verify the compliance of the work performed by the contractor with the contract documents, the rules of the art, and the safety regulations and requirements. It must allow for verification of works during execution, especially when these do not lend themselves to later examination, so that any faults observed can be remedied immediately.* “

According to Y. Hannequart, the architect must "*be present on site periodically to discover shortcomings and defects and remedy them in good time, so as to safeguard the good final execution on time; react preventively where he observes faulty organization or implementation by the contractor, or a defect in the materials, and be present at the key execution phases, especially as a function of the contractor's ability to resolve the difficulties he is normally called to meet.*"[4]

Following in particular this conception of the duty of control, it is considered that the architect does not obviously have to be present on site at all times. Applying this definition of the duty of control to a so-called passive building, we can only conclude that the architect needs to be much more present on site than with a traditional type project, given the much greater frequency than in traditional building of delicate phases that, if not properly carried out, can undermine the proper functioning of the passive house.

The architect obviously cannot continuously monitor workers to ensure, for example, that the membranes providing the sealing between partitions are placed on a clean support, free of all dust and other waste and flat and homogeneous. Such a requirement would be both unreasonable and unattainable. Where there are several different workers at work on a construction site, it is not possible to have an architect standing behind each one of them! The problem is that, as the project evolves, certain elements that are extremely important for ensuring the airtightness of the construction will be hidden by walls and other coverings rendering any problems undetectable.

In the case of damage resulting from poor implementation or the incorrect intervention by a particular trade, it is to be feared that the project owner will blame the architect for failing in his duty to control by not being present or not having detected the problem. Prudence therefore requires a much greater presence of the architect in such a project. This caution is not without consequences, as what we are seeing is a shift from the role of orchestra conductor to that of supervisor. The fact is that, following extensive doctrinal and jurisprudential controversies, the overwhelming majority opinion is that this supervisor role is not incumbent on the architect.

The architect must therefore be aware of this problem, including increasing his fees if necessary to account for a much greater presence on

Bockstael school | Brussels | City of Brussels | architect: Nimptsch Thüngen Architekten site for this type of project, or advising the prime contractor to bring in another professional to exercise this supervisory function. In such a case, it is again important to avoid any subcontracting relationship between the architect and this site supervisor, while naturally checking the competence of the latter for undertaking such a mission.

3.1.5.2. Instructions

The architect also needs to provide extremely clear execution details, while keeping proof of their transmission to the trades involved and ensuring that their interventions are properly supervised to avoid any unintentional damage to the elements that are essential for the proper functioning of the passive house.

The architect and engineering firms need to ensure that no information is lost at each level of intervening parties and in particular for the different steps. More than ever this kind of project has to be conceived as part of an overall vision, avoiding any loss of information, both during construction and at the end of it, by both project owners and future owners.

3.1.6. Acceptance and certification

3.1.6.1. General comments

Common practice in Belgium is for the acceptance of building work to be divided into two phases (even though the Civil Code provides for one only), namely provisional acceptance, followed, usually a year later, by final acceptance. Provisional acceptance consists, put simply, of recognizing the completion of the work and noting any non-completion and defects warranting further intervention by the contractor. After a trial period, the parties proceed to final acceptance of the works. Final acceptance (and in some cases, depending on the contracts signed with the project owners, provisional acceptance) forms the starting point for the decennial liability. The consequences of acceptance are extremely important and numerous. The architect of a passive building will of course be extremely vigilant with regard to the specifics of this type of construction at the acceptance stages.

3.1.6.2. Passive certification

The project owner will legitimately wish to verify the effectiveness of the passive building, in particular to see if the objectives being pursued have indeed been achieved. Today regional and/or municipal grants are available for passive building in Belgium. Allocation of such grants is generally subject to certification by the passive platforms. In other words, a “passive building” certificate issued by these passive platforms is essential to qualify for grants, the certificate being issued where the building passes the blower door test[5] and meets a series of other criteria.

It is clear that project owners will want to take advantage of these benefits for their passive buildings. As a result, these will be systematically subject to the tests and verification calculations required for “passive building” certification. The project owner will naturally demand that the building obtain its certificate. This will require architects to devote a certain amount of time to these tests and the issuance of the certificate. Such services can be considered as not falling within the traditional mission of the architect and the fees applicable thereto. It is therefore logical that the architect be entitled to request additional fees for his services related to the issuance of the certificate. It is therefore wise to include in the contract a mention that this service is an additional one and to indicate clearly the method of calculating these fees (fixed amount or hourly rate).

Even if in fact certification and the intervention of the passive platforms have been introduced for other reasons (subsidies and, previously, tax deductibility), they will inevitably affect the problem of the acceptance of the building. Although created for other purposes, certification becomes, in the eyes of the project owner, the criterion for whether or not to accept the building, by confirming that the objectives have been achieved. The project owner will expect the professional involved in his project to undertake the necessary steps to successfully pass this step. In this way both architect and contractor of the passive building are faced with an obligation of result. This requirement is, to say the least, restrictive, and increases the risk of the professionals involved ending up in court.

Usage has it that the certification process takes place once the structural work is complete. If airtightness issues are identified at this stage, it may be necessary to dismantle what has already been built in an attempt to address the problems, and try to retake the tests successfully. It is probably wise, if frequently confronted with passive buildings, to plan to acquire equipment with which to perform a whole series of preventive checks without waiting for the certification test proper. Such pre-emptive testing and ensuing action can avoid the need for destructive and often expensive measures often leading to substantial delays in construction.

3.1.7. Decennial liability

Articles 1792 and 2270 of the Belgian Civil Code provide for the so-called decennial liability of building professionals – that is, concretely architects, contractors and consulting firms – in respect of all serious defects likely to impair the strength or stability of the building (structure). This responsibility, as its usual name states, lasts for ten years and starts, unless otherwise agreed, from final acceptance.

Some case law in the past attempted to extend the decennial liability to everything that made the building unfit for its intended use. This jurisprudence has, however, been abandoned. Our courts have returned to a strict definition, limiting this 10-year liability to impairments of the strength or stability of the building due to serious defects. Indeed, the Supreme Court, in its famous judgment of 15 December 1995 (the so-called "chocolate" judgment) held that Article 1792 of the Civil Code applies only in the presence of faulty design or workmanship. This explains why we no longer speak of ten-year guarantee but of ten-year liability. Under the conditions set out above, decennial liability applies without distinction as to whether the defects are visible or hidden.

Decennial liability applied to passive housing does not have a particular specificity. Indeed, the problems of thermal insulation and ventilation do not normally involve problems of strength or stability and therefore fall outside the decennial liability. However, construction professionals should not rejoice too soon. Indeed, such problems fall easily into a definition of minor (or in legal language: "venial") hidden defects.

3.1.7.1. Minor hidden defects

Jurisprudence has consecrated the theory of liability for minor hidden defects, which probably explains the abandonment of legal theories giving an extended definition of decennial liability. As their name suggests, minor hidden defects do not have to be detectable at the time of acceptance. The designers of the building can be held liable in terms of duty of advice if, against all probability, they advised the project owner to accept the building when there were detectable defects that had gone undetected by themselves.

This liability, to be effective, implies that the defects are hidden. It is subject to a limitation period of ten years from the date of acceptance. Legal action should also be introduced in "good time" following the discovery of the defect by the project owner. This ten-year deadline of course poses a problem for a passive building bearing in mind that we do not have long enough to verify the effectiveness over time of certain materials used to secure the insulation. By definition, these problems of thermal insulation are generally not apparent.

This warranty for hidden defects does not involve the concept of seriousness, which is a necessary condition for the decennial liability. This means that the emergence over time of thermal insulation defects due to a lack of durability of the materials used may inevitably lead to the invoking of the liability of the professionals intervening in the construction process. Fortunately, the courts generally consider that the faultiness of the professional needs to be analysed according to the scientific knowledge prevailing at the time. However, there exists a certain body of case law which considers that builders are liable once they were in the position to detect said vices, even if this meant having to undertake costly research.

This responsibility for minor hidden defects represents therefore a Damocles sword hanging over the heads of construction professionals. These therefore have an interest in lobbying government and other certifying bodies so as to be able to deliver products which benefit from a certain warranty, which could be invoked to exonerate themselves of any wrongdoing.

Lambermont housing | Schaerbeek | Municipality of Schaerbeek | architect: MS-a and V+

3.1.7.2. The duty of advice at the end of the project

Architects are recommended to create user manuals for passive buildings and keep a record of the transmission of such documents to the owners. It is also wise to hand over the as-built plans, again with proof of transmission. These plans should clearly state the areas where one can, for example, drill or intervene to perform maintenance or repairs. It is wise to draw the project owner's attention, again in writing, to the importance of transmitting these as-built plans and the owner's manual to future potential owners.

It would be wise to join this user manual and these as-built plans to the subsequent intervention dossier that the seller is required, at sale, to pass on to the buyer. It is a good idea to use this legal constraint to ensure that a whole range of information critical for the functioning of a passive building, and for any interventions or extensions, can be communicated to all subsequent purchasers of the property.

By including all such information and documents in the subsequent intervention file (with an inventory to prevent any loss), the architect will make it possible not only to keep the record of the transmission of this information but also to save the "memory" of the building that it is important not to lose for this type of construction.

It is also extremely important to remind the project owner of the vital importance of servicing and maintaining the systems which make the passive house work. This maintenance needs to be done by accredited organizations. It is also appropriate to specify in writing the frequency of such maintenance. Those involved in the design process must draw the project owner's attention to the fact that the former are released from their liability in the unlikely event that maintenance and repairs are not executed. Such a discharge clause is probably not 100% effective but is at least a sensible precaution on the part of the professionals who have intervened in this project.

The project owner's attention should also be drawn to elements requiring maintenance or even replacement (sealants for frames, etc.) at regular intervals. The discharge clause should also target these maintenance and replacement obligations, seeking of course to be as comprehensive as possible.

Finally, the project owner will need to be made aware that his own lifestyle could affect the performance of the passive house, especially in relation to the choice of domestic and other appliances.

Divercity | Forest | Municipality of Forest | architecte: V+ and MS-a legal

03

3.2. Fire safety

be.passive [147]

3.2.1. The fire problem

In Belgium, the total building stock exceeds 4,000,000 items. Of these, some 10,000 catch fire each year, or about 0.2% of the stock. The current "scarcity" of passive housing stock indicates that the probability of a fire in a passive building is very low.

When it comes to risks, we must distinguish the situation of the occupants from that of the emergency services. While the occupants are present in the building at the outset of the fire, the emergency services come onto the scene later, once the fire has already developed.

Occupants may be exposed to a flow of heat, to irritating and poisonous gases, and have their visibility reduced by smoke. Firefighters can face violent, transient phenomena, including rapid spreading of the fire, the best known being flashover and backdraft, an explosive phenomenon caused by the sudden inflow of oxygen into a closed space filled with smoke laden with unburned gas. It is this latter phenomenon in particular that is of concern to firefighters.

be.passive has regularly followed this issue, while the Integrated Safety Policy department of the General Directorate for Safety and Prevention of the Belgian Federal Home Affairs Ministry has funded a study[7] on the issue of fire risk and passive houses.

The study was primarily designed to assess the impact of a passive mode of construction on the development of a fire. For this, simulations were conducted using fire engineering tools. The idea was to compare a passive house and a "traditional" one based on a given scenario (couch fire).

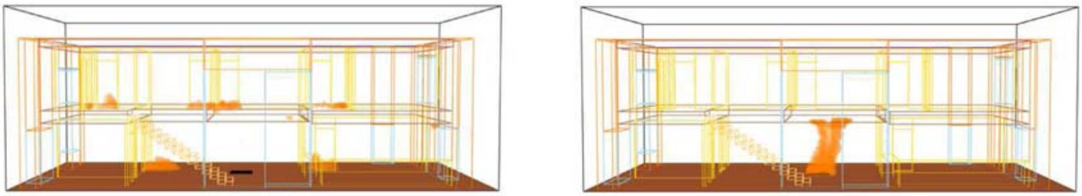
We must first point out here that a passive house is defined solely in terms of energy performance, with freedom therefore left as to the choices of building materials. On the other hand, there is no precise definition of a "traditional" home. An existing passive house was therefore chosen, and the "traditional" house was created by taking the same passive house and converting it to make it non-passive: same structure, but less well insulated, less airtight and without mechanical ventilation.

It appears from the study that, for the simulated dwelling, with the same interior wall covering, there is no significant difference between the passive house and a "traditional" house in terms of time available for evacuation. "*For the same inner wall covering (e.g. plaster walls) and the same type of furniture, the insulation and initial air renewal rates have little influence on the temperature of the fumes and the concentrations of CO and HCN during the development phase of the fire (as long as oxygen concentration does not become the limiting factor). Similar evacuation times are therefore for the occupants of passive houses and traditional houses.*"

If in the first few minutes there is no significant difference in the development of the fire in the two houses, different regimes are then observed with, for example, increased production of unburned material in the passive house. *"During the pseudo-regime phase, higher CO and unburned materials concentrations and lower fume temperatures are obtained for the passive house, owing to the suffocation of the fire. The risk of occurrence of a backdraft during the intervention of firefighters in a passive house should not be overlooked. Opening a fume escape outlet in the upper part of the house (roof) does not seem necessarily to be a sufficient solution to ensure the safety of firefighters in an intervention.*"

"*With the fire taking place in a living room, the smoke will tend to go up the air supply system with which passive houses are fitted. Nevertheless, it appears that the material flowing up the ventilation system will remain relatively low compared to the flow of smoke under the doors (except in the event of a short circuit disabling the fans)*."

Be all this at it may, given the relative newness of the passive sector and the large number of possible architectural configurations, vigilance is called for.



Fire simulation in a passive house model. Source: Brohez S., Cornil N., Fourneau C., Breulet H., Desmet S.: "Passive House and fire = Inferno?"

3.2.2. On fire regulations

Stéphane Desmet

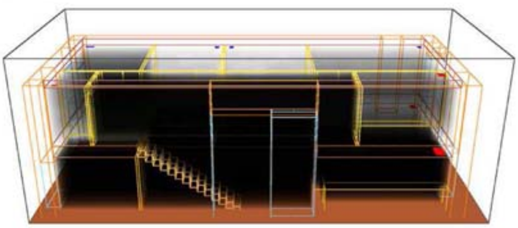
In Belgium, following the law of 30 July 1979 on the prevention of fires and explosions, a legal framework has been defined. This framework establishes a set of minimum fire safety conditions which buildings must meet, with the exception of single-family homes and buildings with a maximum of two levels and a total floor area of no more than 100 square metres. These “basic standards”[8] are based on decades of experience and are only prescriptive. In 2012, they were been adapted to European regulations, including, among other modifications, provisions for the ventilation of lift shafts in “low energy” buildings.

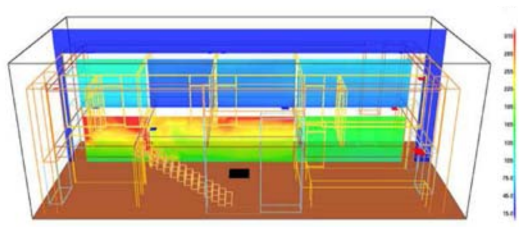
To these minimum conditions, the regional authorities may possibly add additional requirements for buildings falling within their competence (nursing homes, hotels, student rooms). Each region has issued its own legislation.

Currently in Belgium, single family homes represent the vast majority of passive constructions, i.e. buildings that fall outside the “basic standards”. The only rules for this type of building concern fire detection, where each region has issued a regulation.

Since 1 July 2013, Regulation 305/2011 EUR[9] has applied. This is a European regulation, that is to say a legal framework that is binding on Member States and which must be fully implemented throughout the European Union. This regulation contains seven basic requirements that construction works must meet, particularly the requirement no. 2: Safety in case of fire. The Belgian Federal Economics Ministry has published a brochure explaining the implications of this regulation.

Taken together, the full range of texts to be complied with may seem very restrictive and leave little room for innovation. However, where an innovative solution exists that is better adapted to the reality on the ground, but falls outside the prescriptive framework, it is always possible to request a waiver from the Derogation Commission[10] of the Federal Home Affairs Ministry.





3.2.3. Recommandations of the Federal Home Affairs Ministry

In their brochure for the Federal Home Affairs Ministry, researchers UMons-ISSeP recommend the following actions[11]:

- Having at least one detector per room, interconnected or connected to a central point; with a detector in each bedroom (crucial rooms because people remain in them for a long periods in a state of sleep), but not the very small rooms in which people stay for only short times (toilets, showers).
- Giving preference to external insulation.
- Avoiding the use of insulating inner facing in home improvement; this insulation should be “concealed “ behind a topcoat such as plaster.
- Emphasizing the importance of having another exit other than the front door for buildings not governed by the standards of basic buildings. Thus, at least a window which can be opened easily and which is sufficiently large to permit the easy passage of an individual.
- Inserting non-return values in the air supply lines to prevent fumes returning up the ventilation network.
- An emphasis during firefighter training on the recognition of precursory signs of sudden fire development and on the adoption of intervention strategies in such situations.

Caserne de pompiers de Heildelberg | Heidelberg (AU) | Gesellschaft für Grund- und Hausbesitz mbH Heidelberg | Prof. Peter Kulka, Henryk Urbanietz Architekten >

References:

1 D. **Tomasin**, *Innovations en responsabilité des constructeurs*, rev. Dr. Immob., 1990, p.281 ; Liège 16 May 1988, jlmb, 1990, p.441.

2 A. **Delvaux** et D. **Dessard**, *Le contrat d'entreprise de construction*, répertoire notarial, 1990. p.201.

3 See for example the site of Bruxelles Environnement, Accueil > Professionnels > Guichet Nos conseillers (facilitateurs)

4 A. **Delvaux** et D. **Dessard**, *Le contrat d'entreprise de construction*, répertoire notarial, 1991, page 140; see here Y. HANNEQUART, La responsabilité de l'architecte, Liège, 1985, p.57 ; P. RIGAUX, L'architecte, Brussels, 1975, p.332.

5 **be.passive 16**, p.86.

6 **be.passive 04**, p.30 ; 07, p.86 ; 10, p.72 ; 15, p.30.

7 **Brohez** S., **Cornil** N., **Fourneau** C., **Breulet** H., **Desmet** S., *Passive House and fire = Inferno?*, Rapport final UMons / ISSeP, février 2011

8 Laid down in the Royal Decree of 7 July 1994, as amended by the Royal Decrees of 19 December 1997, 4 April 2003, 6 June 2006, 13 June 2007, 1 March 2009 and 12 July 2012. The texts are available on the website of the Federal Justice Ministry www.ejustice.just.fgov.be/cgi/welcome.pl

9 This Regulation repeals the Construction Products Directive (CPD - 89/106/EC). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:088:0005:0043:EN:PDF

10 www.ibz.be/download/QFP_Commission_derogation_fr_2009.pdf

11 **be.passive 10**, p.72.

passive building - test results

reality

04

4.1.
Installation and coordination

Bernard Deprez

>2.2.3
p. 190

A passive building is an energy conservation thoroughbred, and like every thoroughbred needs to be properly broken in. The technology is ready and waiting, but cultural references need to change.[1] The work done by the Bonnevie non-profit association with the residents of L'Espoir, a passive building in Molenbeek, has demonstrated that such change is possible. This work also led to the publication of a "user manual" and a study of the first two years of the residents' learning process.[2]

Moving into a new building is never easy, and especially so where the building is innovative, passive and publicly owned. Not having been involved in the conception process, occupants can be caught off guard. In 2013, Brussels Environment commissioned the 3E consultancy to examine five energy-efficient buildings occupied by low income tenants and where moving in had produced difficulties.[3]

The study found that these problems were not systematically related to energy efficiency or to the passive nature of the buildings. With the standard aimed at producing certain results, users are often very attentive to the building, with the slightest malfunction a potential source of protest.

Many intervening parties (project owner, architect, manager, prospective tenants, technical services, etc.) influence the way the building is used. Good collaboration and communication at all stages of the project are key factors here. This includes examining the commissioning process even before construction work begins. The technical services also need to be trained in the maintenance and management specificities of such buildings. The settings of the technical equipment need to be checked at the beginning of each heating season for at least two consecutive years.

Accompanying[4] users during the appropriation period (1-2 years) is the other key to the good "energy" use of the building. Finally, the occupants need to be able to individually adjust their heating temperature over a range of a few degrees. Without this, the technical services will experience recurring complaints, even if everything works perfectly!

Drawing of an appartment made by one of the inhabitant of the project l'Espoir and an information session on passive building.

4.2. What real consumption ?

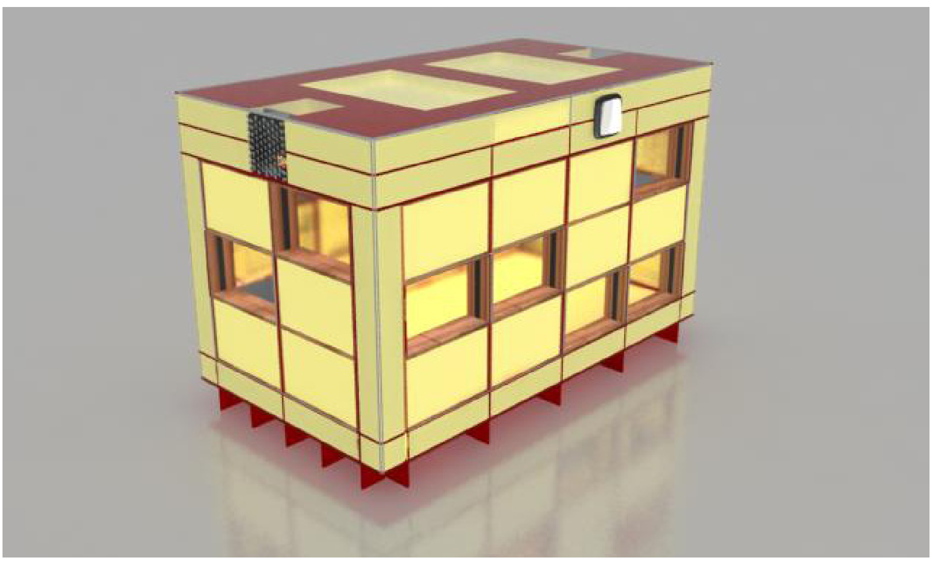
The concept of Rational Use of Energy assumes that rational information leads to a rational use of energy. This fails, however, to take account of personal habits, socio-cultural practices, opportunities, etc. With energy representing on average only 6% of household expenses, this is not a priority for everyone[5], even if 715,000 Belgian households struggle to pay their energy bills.[6]

Energy consumption results from the interaction of climate, technology and lifestyles. In energy terms a building is designed to produce the best technologically possible universe - a building – which is then exposed to the risks and uncertainties of its use. A building's actual energy consumption for heating depends on several factors:

- At the level of the **site**: climate and bioclimatic potential (available sunlight, cloud cover, protection, location, etc.)
- At the level of the **building** :
    - The **envelope** determines, based on the architect's energy competence, the net heating requirement;
    - The **technical installations** cause losses;
    - The **energy source** (production and distribution chain, etc.) determines the environmental impact (CO_2 emissions, pollutants, etc.).
- At the level of **individual users :**
    - **Occupants** behave according to their socio-economic environment and market opportunities.
    - **Technical services** maintain private and public buildings; their organization, training and competence largely affect the efficiency of different facilities (heating, ventilation, water, etc.).

Certain parameters are easy to change, others not. They are all interlinked: users' behaviour, for example, depends on their mastery of the specificities of the building. Consumption estimates are calculated on the basis of reference climatic parameters, the structural characteristics of the buildings and their "normal" use. Many times the actual consumption differs from the calculated energy needs. The causes of these differences are many,

"Passive Box" (Michael Arens, Tom Jonckheere, Lennart Luchtens, Toon Vermeir)



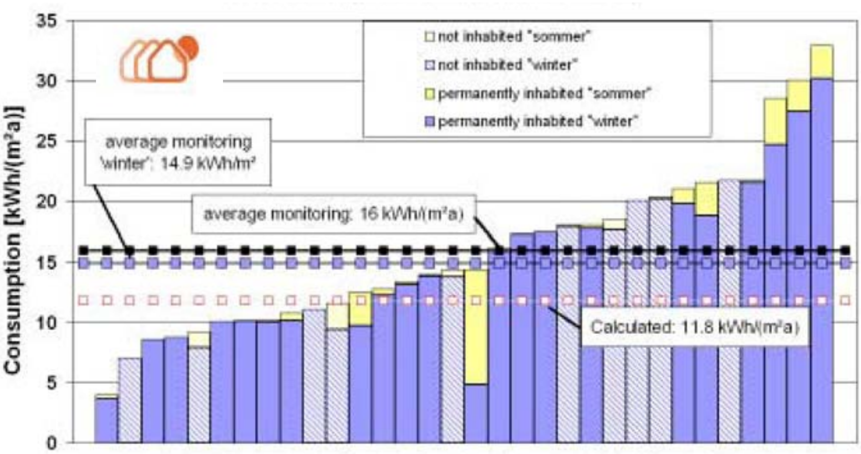
but relate in particular to the variability of user behaviour.

The passive standard is most scientifically monitored energy concept ever. It was investigated first by the PHI[7] (spin-off of the University of Darmstadt), the Vorarlberg Energy Institute[8] and also in international high-level studies (CEPHEUS[9], 2001; PassREG[10] today), before being picked up by the international open source communities.[11] Brussels Environment has signed up to this scientific and technical culture by making many tools available to individuals and businesses on its site.

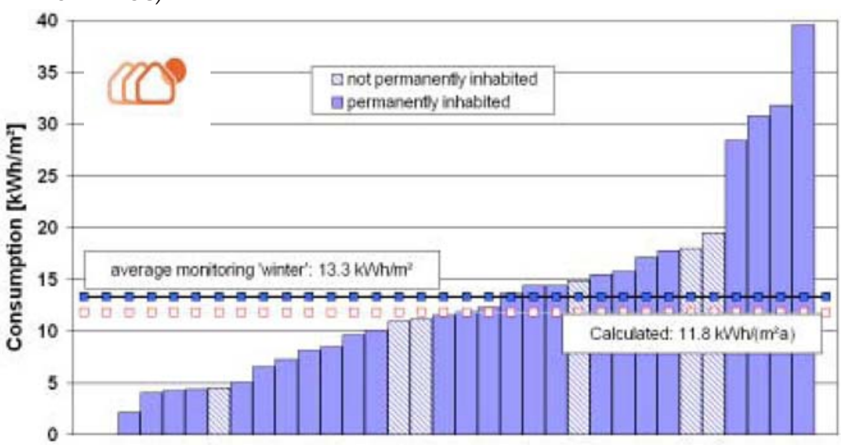
4.2.1. CEPHEUS Monitoring (EU)

The CEPHEUS study (Thermie program) monitored 221 passive dwellings in Germany, Sweden, Austria, Switzerland and France. The researchers found the average consumption of passive housing to be in line with expectations, although with a wide variation between individual results.

For example, the actual consumption of 32 passive dwellings in Hanover ranged from 4 to about 32 kWh/m²/year, but the average consumption (two years of measurement) corresponds to the PHPP calculation of 13.4 kWh/m²/year.



Comparison of the mesured heating consumption and the projected (calculated) heating consumtpion in the first year of measurement (1.10 1999 to 30.9.2000) (source CEPHEUS)



Comparison of the mesured heating consumption and the projected heating requirement values (calculated) in the second heationg period (1.10.2000 à 30.4.2001) (source CEPHEUS)

CEPHEUS sites

Lodernael housing | Innsbruck | Neue Heimat Tirol, Gemeinnützige WohnungsGmbH, Innsbruck | architect: architekturwerkstatt din a4 en teamk2 [architects] ZT GMBH

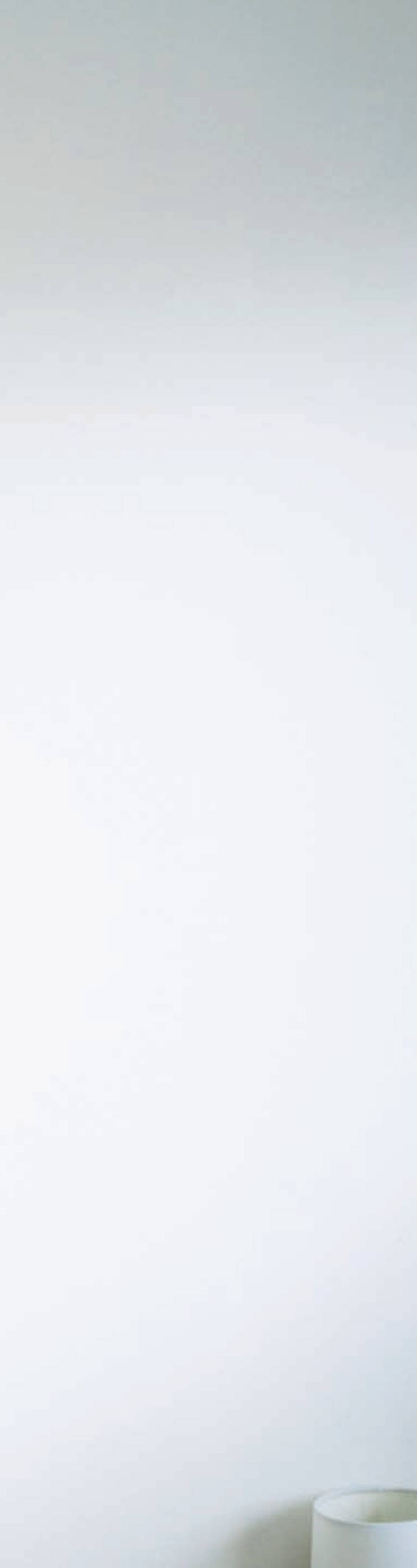
This demonstrates the reliability of the PHPP. It also shows that the standard allows for great freedom of lifestyle: between persons who like to live with all windows open (and consume more) to those who live like enclosed monks (and consume less). Passive building smooths the differences, reducing the differential impact of different lifestyles, in favour of the personal freedom of occupants.

4.2.2. Monitoring at Lodenareal (AU)

The Lodenareal[12] district of Innsbruck (Austria) contains two passive housing developments built in 2009 for the Neue Heimat Tirol social housing executive. With 354 dwellings, it is the largest certified residential project anywhere. It cost about 11% more than the base case (equivalent to 35 kWh/m²/an); 7% of which was covered by a government grant and 4% of which comes from energy savings.

A monitoring exercise[13] by several universities analysed over a two-year period (2010-2011) the energy consumption of 354 homes (heating, network loss, electricity, fans, etc.) and various comfort parameters in 18 apartments (room temperature, humidity, CO_2 in living rooms and bedrooms).

The Vorarlberg Energy Institute concluded from this study that “passive building has kept its promises.”[14] The actual NHR came to 17.6 kWh/m² in the first year, and 16.3 the second. This figure is calculated at the real average temperature inside the dwellings of 23.6° C. Correcting the annual heating consumption data for 20° C, NHR comes to 13.6 kWh/m² in the first year and 14.6 in the second.



4.3. Comfort survey

No comprehensive study on comfort in Belgian passive houses has yet been conducted. Other studies in Belgium and abroad provide significant elements for reflection. Drawing her inspiration from the German study “Living in a Passive House”[15], architect Laurianne Hoet[16] questioned some twenty occupants of passive houses.

Ines Camacho
Brussels
2 passive duplex
architect : Ines Camacho

Questionnaires sent
Germany: 210 persons questioned 160 responses (76%)
Belgium: +/- 60 questionnaires sent 20 responses (33%)

What influenced the choice of passive construction / upstream work
Germany: 50% personal conviction / 50% architect’s advice
Belgium: 65% personal conviction / 20% professional environment/15% other

Comfort during heating period
Germany: 92.7%: pleasant
Belgium: 100%: pleasant

Comfort during summer
Germany: 62.5% rarely too hot / 37.5% often too hot
But those who have adjusted the ventilation system complain less than the others
Belgium: 50% very good / 50% good

Importance of solar protection
Germany: 71% consider essential / 26.8% important
Belgium: 70% essential / 30% important

Ventilation, adjustment?
Germany: 50% bien depuis le début / 35% bien après ajustements.
Belgium: 50% bien depuis le début / 50% bien après quelques ajustements.

Ventilation, easy?
Germany: 58% easy / 37% easy with practice / 5% difficult
Belgium: 60% easy / 40% easy with practice

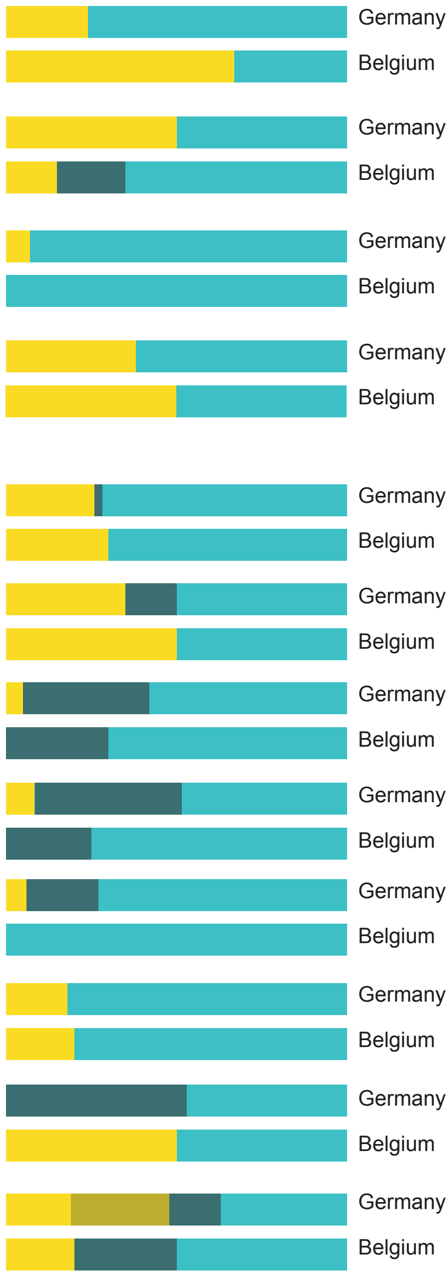
Opening windows
Germany: 48.4% never / 43.3% seldom
Belgium: 75% seldom / 25% sometimes

Air humidity
Germany: 73% pleasant / 21% too dry
Belgium: 100% pleasant

Solar installation
Germany: 82% yes
Belgium: 80% yes

Influence on health
Germany: 45.7% positive evolution / 54.3% no change
Belgium: 50% positive evolution / 50% no change

Overall satisfaction level
Germany: 15.4% very good / 42% good / 23% satisfactory
Belgium: 50% very good / 30 % good / 20% satisfactory

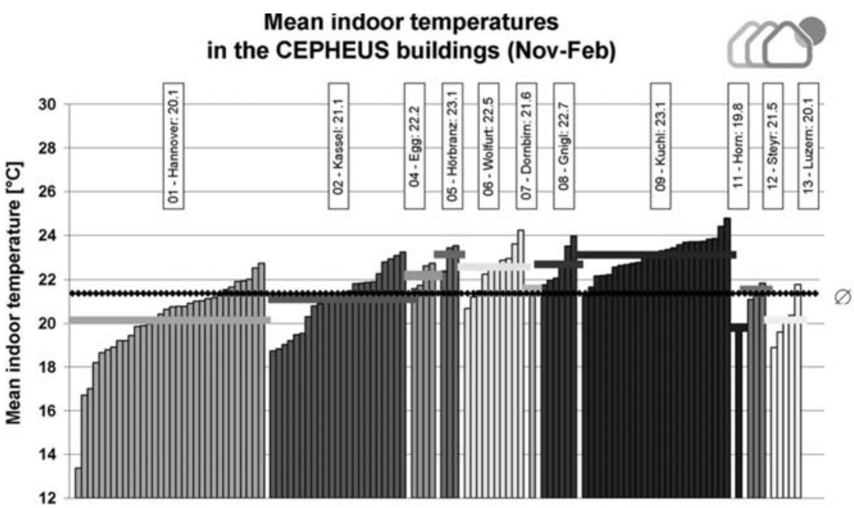


4.3.1. The CEPHEUS study (EU)

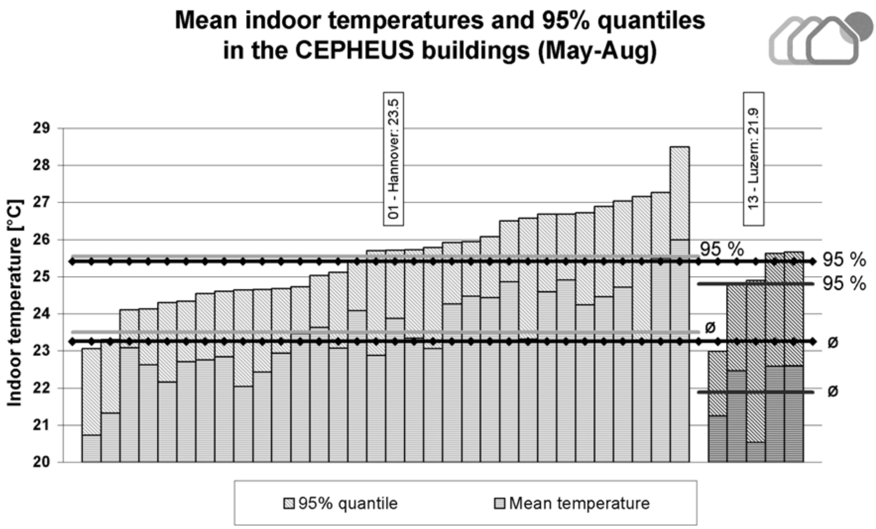
The CEPHEUS study also examined comfort in housing units and how passive building was assessed by its occupants. 900 questionnaires were analysed by scientists, with some of these supplemented by interviews.

4.3.1.1. Indoor temperature

During the first winter (left), monitoring showed a mean indoor temperature of between 21 and 22° C (with temperatures below 17° C recorded in Hannover in unoccupied houses). In summer[17] (right, Hannover and Lucerne) the maximum temperatures are reached between 1 May and 31 August. These lie between 21.9 and 23.6 °C for 95% of the time. The values above 27° C are due to unoccupied buildings (no natural ventilation brought into play) or dwellings with excessive internal inputs (confirmed by extreme power consumption).[18]



Average indoor temperaturs in winter (nov 1st to feb 28th)



Average indoor temperatures from May until augustus and 95% quantiles from Hannover and Lucern projects

Further qualitative studies show that the low ventilation flows make air movements unnoticeable: draughts are non-existent and temperature stratification[19] is very low at about 1.1° C, which increases the feeling of comfort.

Comfort is further enhanced by a very uniform distribution of surface temperatures and very low radiative asymmetries. Other simulations show that while comfort is ensured by the high surface temperatures of insulating glazing (Uw = 0.85 W/m².K), this is not the case with insulating double glazing (Uw = 1.60 W/m².K).

House in Sint-Niklaas | Sint-Niklaas | Tom Segers & Leen Waterschoot | architect: BLAF architecten

4.3.1.2. Acceptance bu occupants

One of the satisfaction surveys focused on the passive dwellings in the Kronsberg district of Hannover. All occupants said they were satisfied. Compared with traditional accommodation, the higher temperatures of the interior surfaces are perceived as “very pleasant”, with comments like “at last I no longer have cold feet!”

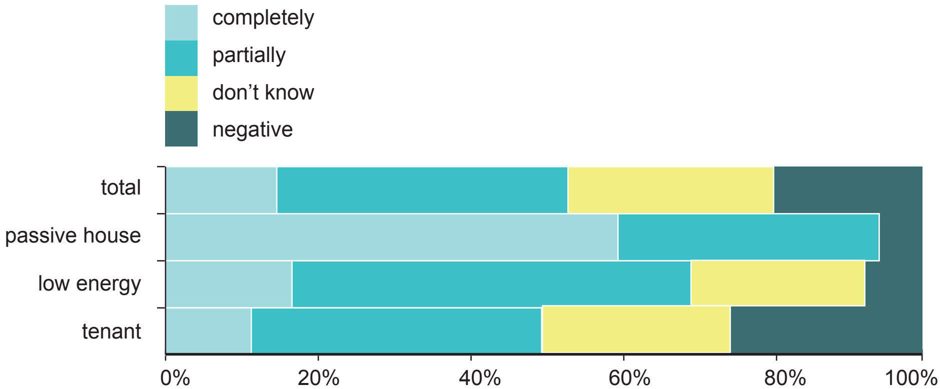
After getting used to their passive housing, more than half of the occupants said they were satisfied with their bedroom temperatures. In summer, 88% of occupants are satisfied or very satisfied with the indoor temperatures, especially with the rooms kept cool by having the windows closed. At night, most occupants ventilate naturally.

4.3.1.3. Ventilation

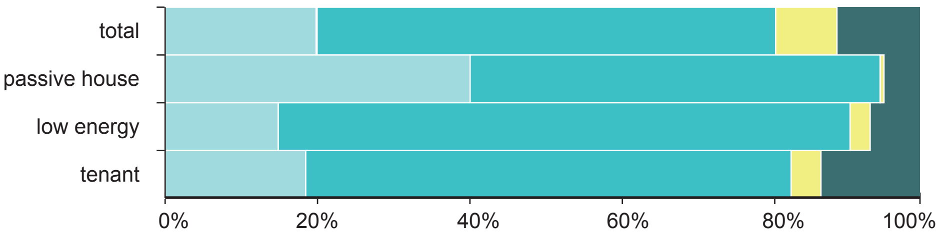
The air quality is judged “good” to “very good” by 95% of occupants. No negative feedback was recorded, even though the air exchange in passive houses is less than that required by a number of regional regulations (e.g. NBN D50-001). With the dual flow system, pollutants emitted by the building materials inside the housing are continuously discharged, while the dust entering with incoming fresh air is trapped by the filters. The renewal rate needs to be set so as to remove excess moisture without drying the air.

In terms of ventilation, while 82% of the occupants rely entirely on their double flow system, 7% open the windows for a few minutes a day, 4% for 15 minutes and a further 7% for several hours a day. In total, 96% of occupants of passive houses are “satisfied” to “very satisfied” with their ventilation systems.[20]

It should be noted that this very high satisfaction rate is typical of passive houses, dropping to 55% as soon as we include the low-energy housing in the sample.



Acceptance of the ventilation system



Satisfaction rate in relation to expectations for the occupants of Kronsberg

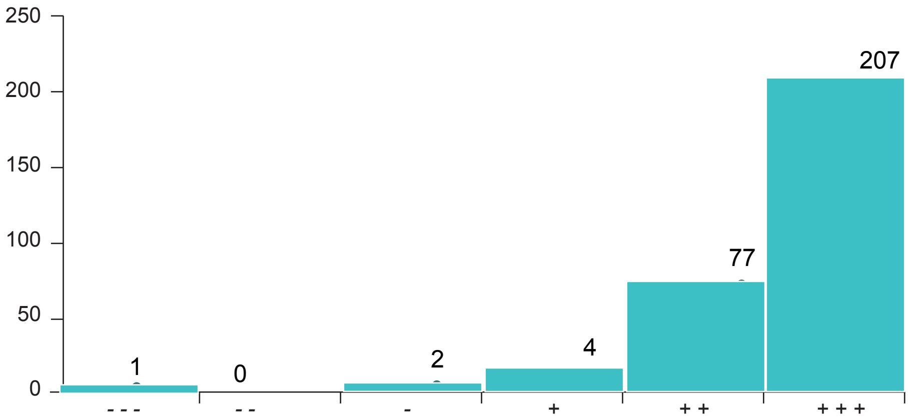
4.3.1.4. The Minergie® surveys (CH)

In Switzerland, satisfaction surveys have focused on Minergie-certified sustainable buildings.[21] To date, the label has been awarded to over 31,633 buildings, or ± 37 million heated m² in new and renovated premises. Passive building is supported here by the Minergie-P label, with more than 2,182

Alex De Broe and Barbara Oelbrandt
Asse
House
Architect : Blaf architecten

passive buildings (residential, commercial, new and renovated), plus 553 ecological passive buildings carrying the Minergie-P-Eco label.[22]

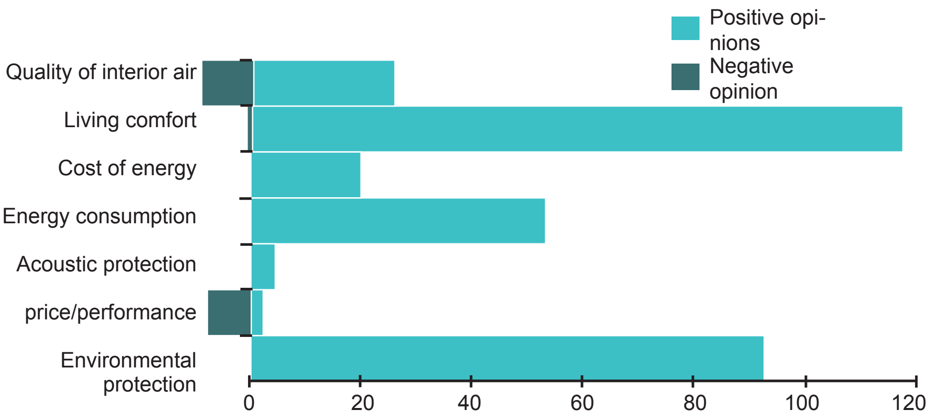
A study[23] combines a detailed analysis of 52 residential buildings and the satisfaction and consumption results of 506 residential buildings. It shows that, out of a panel of 291 respondents (where insulation and double flow ventilation with heat recovery are installed as standard, but which do not necessarily meet the passive standard), 97% of respondents are "satisfied" to "very satisfied" with the feeling of comfort.



Are you satisfied with the MINERGIE comfort?

> 1.1.5.2
p. 28

User satisfaction with air quality and the cost/benefit ratio is also very good, with 94% of respondents saying they were 'happy' or 'very happy'. Finally, almost all respondents recommended the label. The main argument in favour of the label is comfort (with 119 favourable opinions), ahead of environmental impact (93 favourable opinions) and savings (53 favourable opinions).



Positive opinions on the MINERGIE label

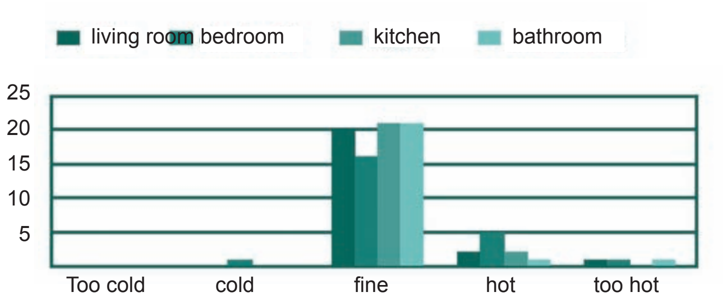
4.3.1.5. Micro study by Brussels Environment

In 2012, Brussels Environment conducted a micro-survey of residents of 27 Batex homes:, that is 8 separate houses and 19 apartments, representing 20 new builds and 7 renovations, with 21 classifying as passive, 4 as very low energy and 2 as low energy, 22 being owner-occupied and five tenanted. .

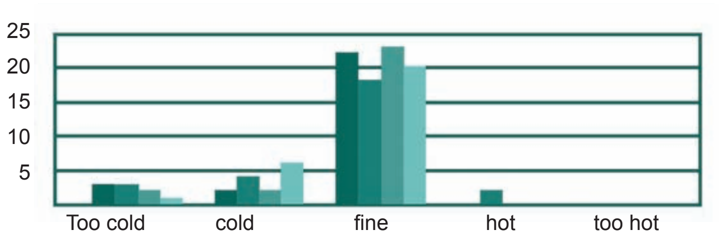
Temperatures are widely perceived as comfortable (neither too hot nor too cold). Satisfaction is 85% in summer and 77% in winter, with a marginal trend of feeling "hot" in summer and "cold" sometimes in the winter. This corroborates the idea of a standard that is not "bolted tight" to a uniform temperature, but fluctuates gently according to the season. Passive building changes occupants' references: "*The difference with a normal house? Here you can be fooled by the comfort! We dress lightly and, once we step outside, we realize it is actually quite a bit colder.* "

04

Edwin Vanaeren
Schaerbeek
ARCO offices
Architect: Architectes Associés

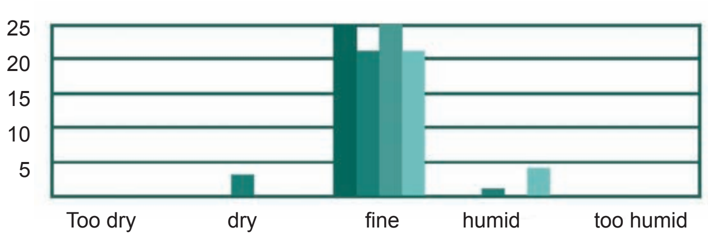


Indoor temperature – summer

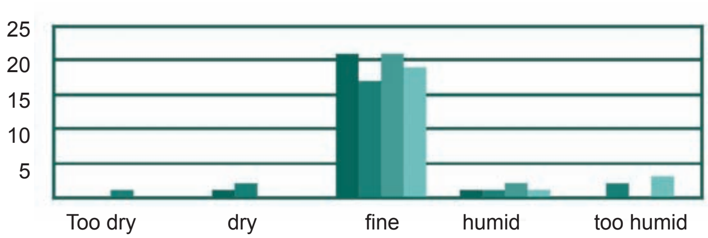


Indoor temperature – winter

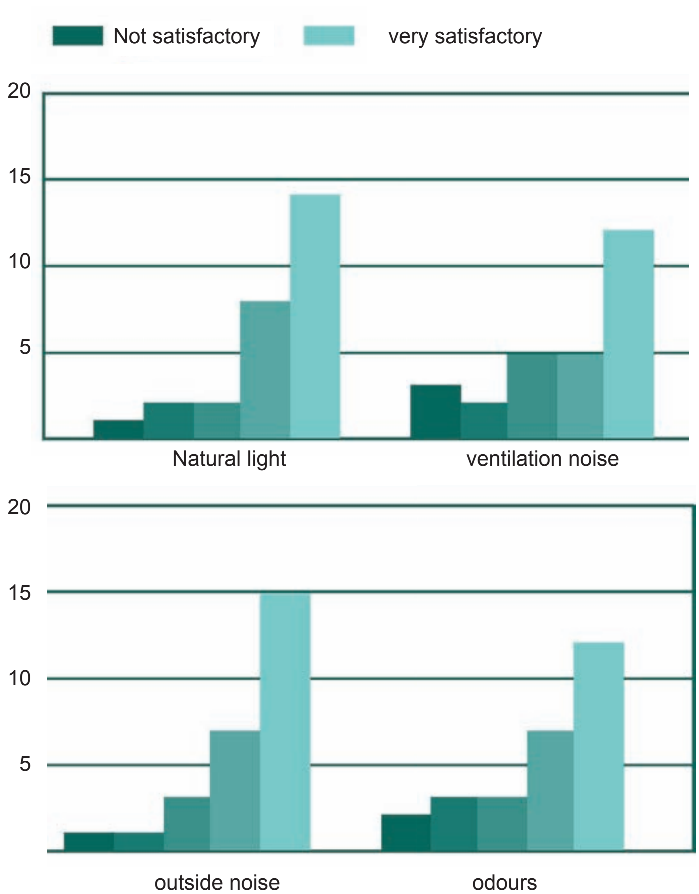
Air humidity also appears to be widely perceived as comfortable in both summer (92%) and winter (85%). Items like light and acoustic comfort and odour control appear very satisfactory, with scores between 80 and 90%.



Air humidity – summer



Air humidity – winter



Not satisfactory
very satisfactory
20
15
10
5
Natural light
ventilation noise
20
15
10
5
outside noise
odours

04

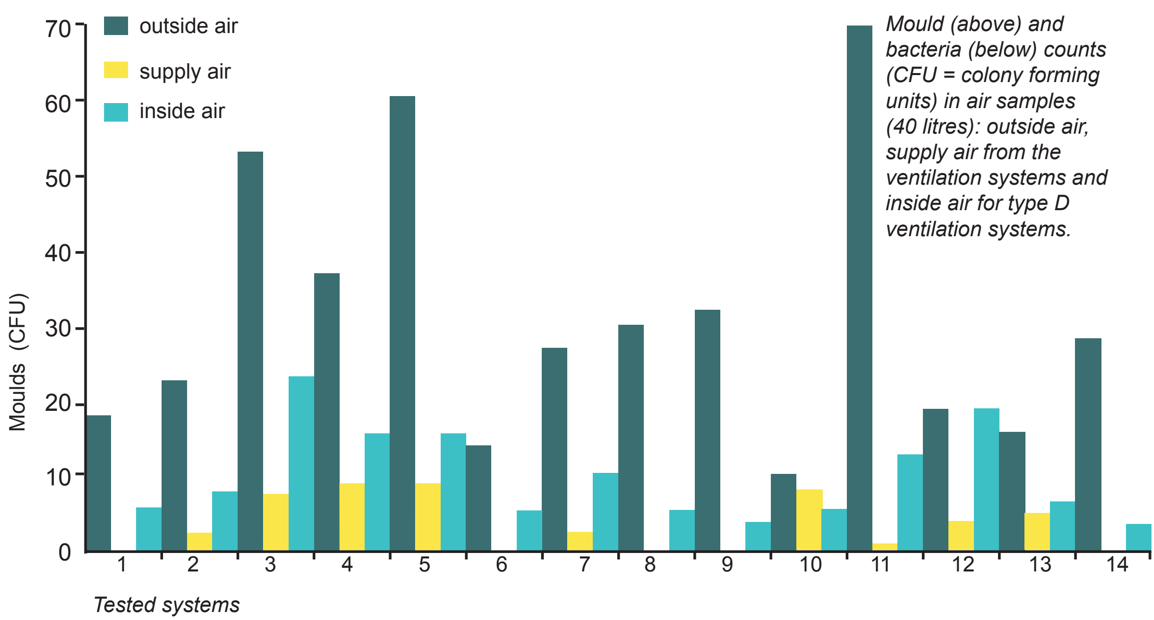
Elin et Georges
Forest
Family home renovation
Architect: Gwenola Vilet

4.4. Occupant health

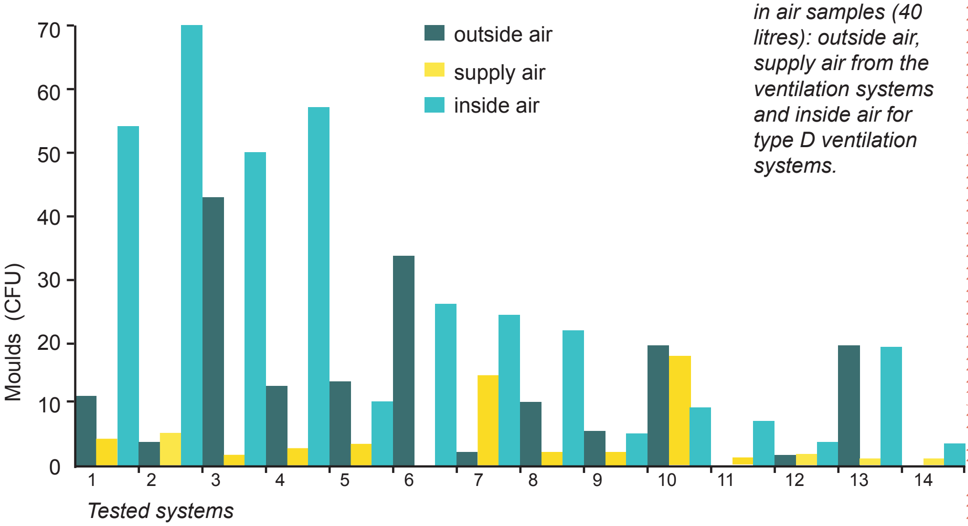
Occupant health is closely related to air quality, with concern concentrating on ventilation. A study[25] has showed that the sealing quality of passive houses does not necessarily protect from radon, a radioactive gas that seeps into homes from the ground. Otherwise, questions focus on the effectiveness of ventilation systems and their impact on the occupants.

4.4.1. Air quality with type D ventilation systems[26]

In 2011, the Centre Scientifique et Technique de la Construction examined the air quality in 18 mainly new passive or low energy homes (15 ventilated using type D systems, 3 using type C systems) to verify the actual flow rates and microbiological air quality (mould and bacteria).



Mould (above) and bacteria (below) counts (CFU = colony forming units) in air samples (40 litres): outside air, supply air from the ventilation systems and inside air for type D ventilation systems.



Bacteria counts in air samples (40 litres): outside air, supply air from the ventilation systems and inside air for type D ventilation systems.

The study found that the moulds were mainly present in the outdoor air samples (influenced by the location of the housing: wooded, country environment, etc.). For type D systems, the lowest counts were found in the supply air. The bacteria counts were higher inside than outside. This makes sense as the quantity of bacteria relates to the presence of occupants (people, pets, plants, etc.). Again, fortunately, it is always in the supply air that the lowest counts are found.

Childcare KAE | Etterbeek | GOI Onderwijs van de Vlaamse Gemeenschap | architect: evr-architecten

Both supply air and extraction filters were examined from the microbiological viewpoint. Microorganisms are always more present upstream than downstream, presumably because they are stopped by filters and accumulate upstream. Microscopic study of the filters indicated the presence of pollen and other non-living particles, but no trace of spores were detected on the surface. The study found that there was no growth of microorganisms in type D ventilation systems.

4.4.2. Air quality in schools

An MA thesis[28] (Ghent University) has examined the air quality in 12 schools in Flanders by measuring temperature, CO2 concentration and relative humidity at each school over a one-week period. The new buildings scored best (the difference between indoor and outdoor concentrations of CO_2 concentrations is required to be under 1000 ppm).

	Old school buildings	New school buildings	Passive school buildings
∆ CO2 < 1000 ppm	48,70%	62,82%	100,00%
∆ CO2 > 1000 ppm	51,73%	37,18%	0,00%

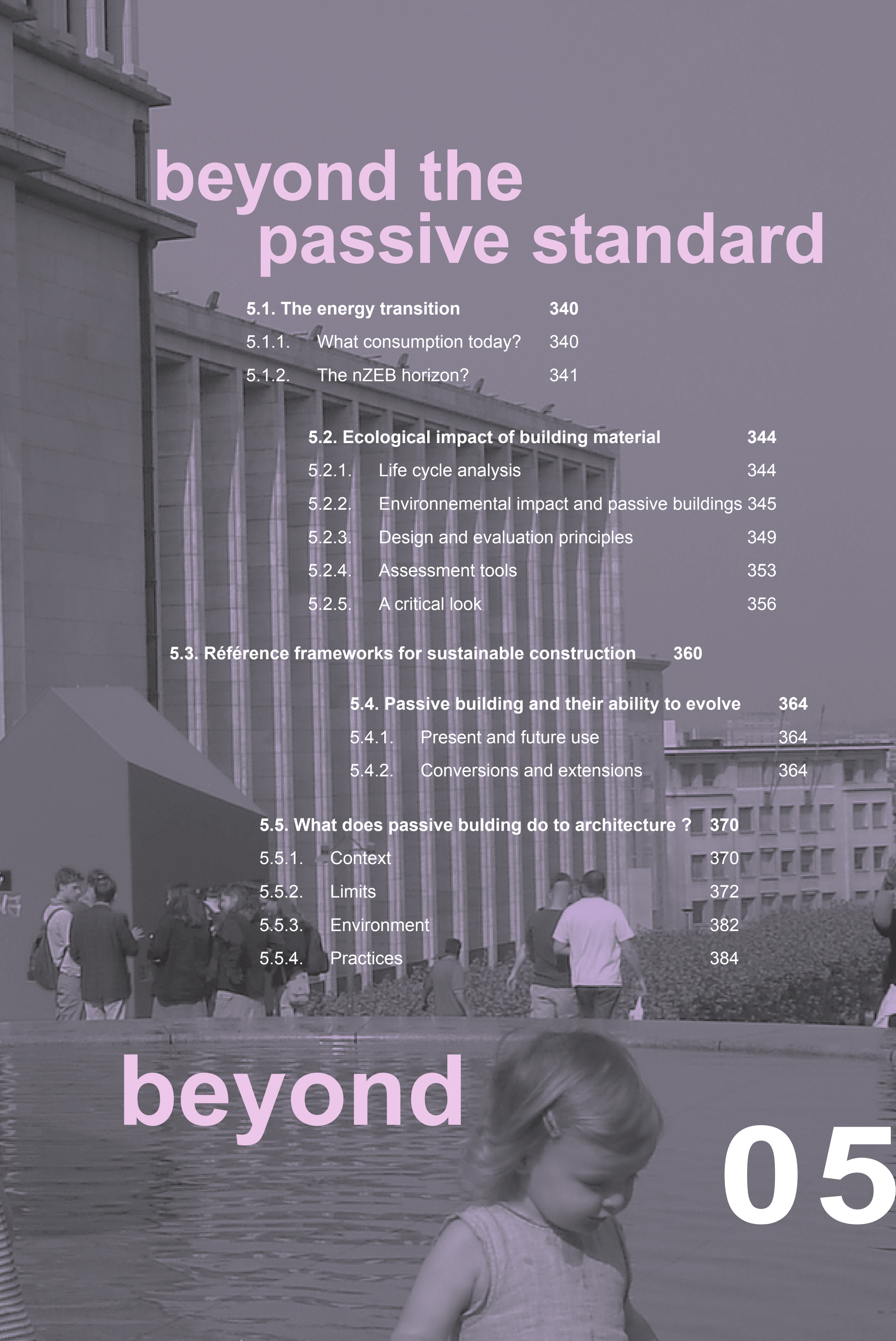
In the old school buildings, the CO_2 concentration is unacceptable more than half the time. The most recently built schools score better and the passive school achieved an irreproachable air quality. The sample, however, is insufficient to draw general conclusions.

	No ventilation	A System	D System
Δ CO2 < 1000 ppm	59,80%	36,84%	82,19%
Δ CO2 > 1000 ppm	40,20%	63,16%	17,81%

In terms of systems, the type A system is less effective than that of the old schools (no ventilation). Intake input grids are often closed in winter to reduce heating costs. Ventilation using the type D system (as used here in particular in the passive school) provided the best results, even if perfect air quality was not obtained. Researchers have offered several explanations for this: in the first case, the ventilation rate was insufficient for the number of persons present; in the second, the problem might have been due to under-dimensioning or poor adjustment; in the third, ventilation was controlled by the clock and the air quality was very good 95.5% of the time.

References:
1 **be.passive 01**, p.29.
2 www.bonnevie40.be > Vivre le passif
3 **be.passive 18**, p.51.
4 **be.passive 07**, p.46 ; 15, p.92.
5 Grégoire **Wallenborn** et al, *Détermination de profils de ménages pour une utilisation plus rationnelle de l'énergie, Plan d'appui scientifique à une politique de développement durable*, 2006.
6 Agence **Belga**, 27.02.2014.
7 www.passiv.de
8 www.energieinstitut.at
9 Cost-Efficient Passive Houses as European Standards, www.passiv.de/old/07_eng/news/CEPHEUS_final_long.pdf
10 www.passreg.eu
11 http://passipedia.passiv.de/passipedia_en
12 **be.passive 13**, p.51. www.neueheimattirol.at
13 Waldemar Wagner et al, Forschungsprojekt Passivhauswohnanlage Lodenareal, Endbericht, Energie Tirol, 2012
14 www.oekonews. at/index.php?mdoc_id=10813
15 R. Danielzyk, Institut für Landes und Stadtenwicklungsforschung – NordRhein Westfalen), www.ils-forschung.de
16 **be.passive 01**, p.89.
17 **be.passive 05**, p.56.
18 **CEPHEUS**, pp.76-77.
19 **CEPHEUS**, p.78.
20 **CEPHEUS**, ibidem, p.79.
21 www.minergie.ch (15.05.2014)
22 www.minergie.ch/tl_files/download_fr/Statistik_2010_fr.pdf
23 Silvia Gemperme, Severin Lenel, FHS, Hochschule für Technik, Wirtschaft und Soziale Arbeit St. Gallen, available on www.minergie.ch/fr/download/Enquete.pdf (2005); the main results are included in the brochure published by Minergie www.minergie.ch/tl_files/download_fr/Flyer_Minergie_en_question.pdf
24 Bernard **Deprez**, Jean **Cech**, *À Bruxelles, les bâtiments exemplaires se racontent*, éditions Racine, 2012
25 **be.passive 13**, p.82.
26 Ventilation systems are broken down in Belgium into A, B, C and D systems. A is natural ventilation, B is mechanical feed and natural outlet, C is natural feed and mechanical outlet; D is mechanical ventilation.
27 Samuel **Caillou**, Paul **Van Den Bossche**, V*entilation systems: monitoring of performances on site*, Passivehouse Symposium 2011, Brussels. Actes, pp 206-217. be.passive 11, p.78.
28 **be.passive 03**, p.49

house in Oudenaarde | Oudenaarde | Dirk Van Dorpe | architect: Dirk Baart & Bernard Libert



beyond the passive standard

beyond

05

5.1. The energy transition

Bernard Deprez

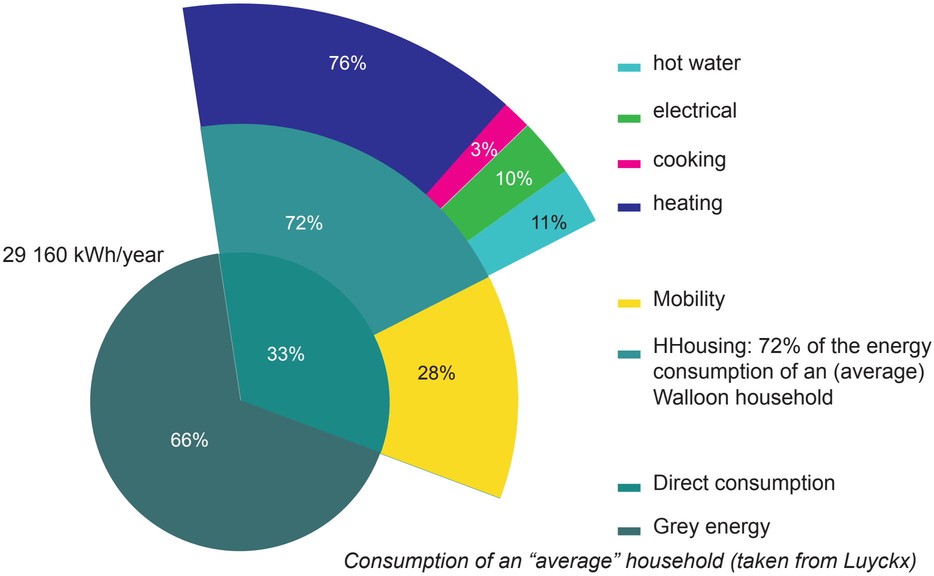
Faced with the need to reduce CO2 emissions and their dependence on fossil fuels, Belgium, the EU and many other countries are not standing idle, as evidenced by the Kyoto Protocol (1997), the PEB directive, "Recast" and the objective of near-zero consumption (nZEB) in new construction (2019 for public buildings, 2021 for all buildings), the "Energy-Climate"[1] package and similar initiatives.

With its "Passive 2015" PEB regulation, Brussels-Capital is an active participant in this movement. This tightening of energy requirements responds to new societal expectations for an "energy guarantee".

> 5.2.1
p. 344

5.1.1. What consumption today?

The final energy consumed annually by an average Belgian household[2] is divided into two-thirds 'grey energy' (consumer goods, building) and one-third operating energy. 72% of the latter goes on housing (29,160 kWh), in particular for heating (76% of energy consumption in the home)[3].



Consumption of an "average" household (taken from Luyckx)

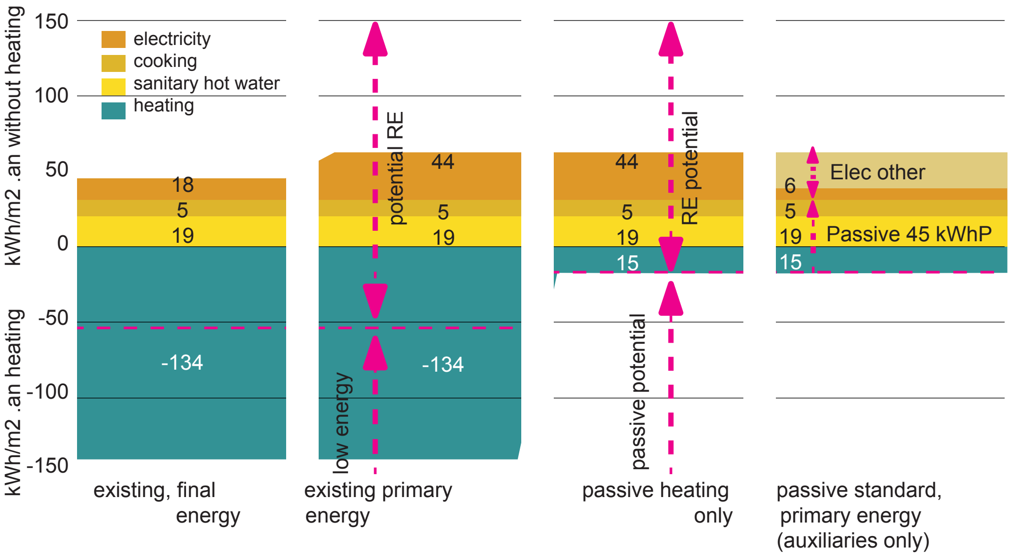
In the non-residential area, energy consumption depends on whether the building is used as offices, shops, schools, hospitals, or whatever. Detailed profiles are available on the Energie+ website.[4] Overall, except for old buildings where heating can remain the major item, final consumption of heat and electricity are comparable.

5.1.2. The nZEB horizon?

Approaching the "zerogenous" zone of nZEB implies that beyond passive housing and heating, it will be necessary to offset other energy uses: domestic hot water, cooling, electricity, etc. We are no longer talking about installing a few m² of photovoltaic cells to reduce the electricity bill, but of producing energy in substantial quantities.

Once all the potential heating savings for a building have been harvested (because it is passive), it will be necessary to encourage the production of renewable energy and improved technology (domotics etc.). Energy-efficient construction and renewable generation offer their potential effectiveness, but they too have their limits. Both demand a resource that is expensive (enhanced insulation in passive building and/or production or storage areas for REs).

Looking for a moment at the energy consumption to be offset in the residential area[5], we see that a major RE potential is necessary to compensate all forms of energy consumption. If the potential of passive conservation is mobilized only at the low energy levels (left), the RE potential needs to absorb the additional NHR (60-15 = 45 kWh/m²/year).



Passive potential and potential RE

Two situations present themselves:

- If the RE potential is limited, it is advantageous to focus the energy saving on (passive) construction in order to approach the nZEB level.
- If the RE potential is substantial, it can be put to good use to offset all or part of the consumption (including the 15 kWh/m²/year of heating, or more).

All installed RE equipment should allow the possibility of improving the building envelope a posteriori to avoid significant additional costs (dismantling/rebuilding, etc.). Certain RE technologies, possibly more profitable, can even have a lever effect to make the overall operation profitable more quickly.

Unfortunately, not all sites have the same RE potential. In the current state of technology, Brussels-Capital estimates its own potential as just a few %

of its needs. It seems therefore logical that the principle of sobriety will be more effective in dense sites than in open sites, and vice versa. Dense urban situations favour compactness (party walling, collective housing), reducing the amount of insulation needed to achieve a given performance level, but are unfavourable to REs owing to many urban constraints (poor orientation, solar masking, urban regulations, etc.), or simply because the same catchment surface area will be shared by many more people in town.[6] Conversely, low density (detached suburban housing, single family dwellings) reduces the compactness (thus increasing the need for insulation and its relative cost), but favours RE (available ground, roof and facade surfaces).

Recent debates on public policy in favour of RE7, the delay in Europe in energy saving[8] building and the likely evolution of electricity pricing all seems to point to the adage: the best energy is the energy we do not consume.

5.2. Ecological impact of building material[9]

Aline Branders

5.2.1. Life cycle analysis

Any approach to sustainable construction involves thinking about materials and construction systems to avoid excessively increasing the environmental cost of buildings. The initiatives introduced at national and international level show this to be an essential and growing target area.

This approach challenges traditional construction methods. Adapting buildings to the new requirements involves more than thickening the insulation. Questions of indoor comfort, energy and the environment represent a call to envision buildings as a whole, taking a fresh look at the current constraints in order to come up with the most appropriate solutions.

The choice of building technologies and materials is customarily guided by technical, economic and aesthetic aspects. These rarely take into account the environmental or health impact. But the fact remains that all construction products are responsible for such impacts, whether at the manufacturing/building stage, during use, upon replacement (during the lifetime of the building) or at the time of disposal.

Most of the tools for assessing the environmental impact of materials, structural elements and buildings are based on a Life Cycle Analysis (LCA). This approach, which started in the ‘70s and became normative with the EN ISO 1040 series of European standards, quantifies in the form of qualitative or quantitative indicators the main environmental impacts of a product, service or process throughout its lifecycle (“cradle to grave”) from the mining of the raw materials to the end of its life, through all the intermediate stages of production, transmission and consumption.

Various research projects are still under way and steps have been undertaken in recent years to harmonize the assessment methods. The European Committee for Standardization (CEN) TC 350 “Sustainability of Construction Works” published in 2012 new European standards for life cycle analyses for construction products (EN 15804) and buildings (EN 15978). These standards define in particular the categories of environmental impacts to be included in an LCA (CEN indicators)[10] :

- climate change

- destruction of the stratospheric ozone layer,
- terrestrial and aquatic acidification
- eutrophication
- formation of photochemical ozone (smog)
- depletion of abiotic, fossil and non-fossil resources

Other indicators (CEN+) are not mandatory but are already included in many environmental impact assessment methods:

- particle formation,
- ionizing or radioactive radiation
- human toxicity,
- terrestrial and aquatic ecotoxicity
- occupation and transformation of the territory,
- depletion of water resources.

Only with a consistent set of criteria is it possible to assess accurately a particular environmental impact.

5.2.2. Environnemental impact and passive buildings

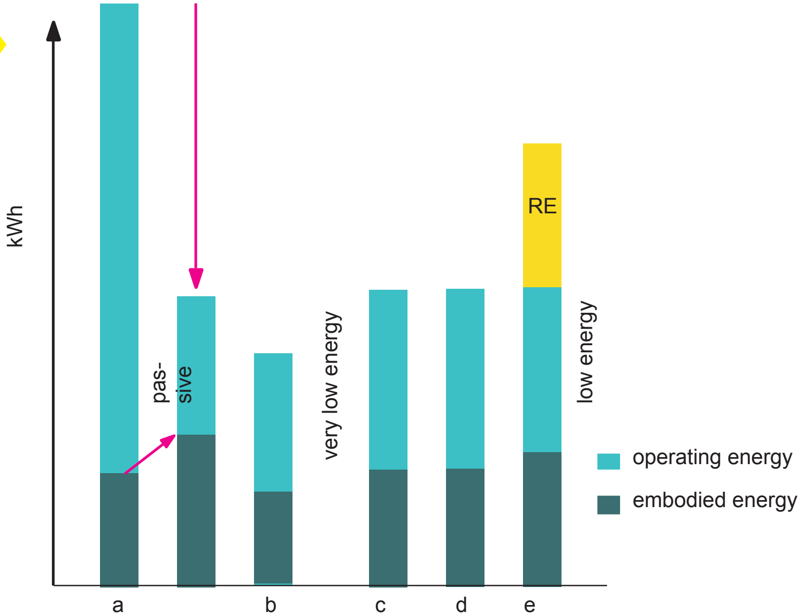
Passive buildings reduce their need for operating energy and the associated environmental impacts. On the other hand, they often require an increase in the material used, thereby increasing the environmental impact of the construction stage (in particular embodied energy). The fact is that it is obviously the overall balance throughout the life cycle (production, use, demolition) that matters. Reducing operating energy is of course a priority, but other means can be selected, depending on the context (new construction, renovation), to arrive at a good overall balance, in particular by reducing the environmental impact of materials.

House in Hoeilaart | Hoeilaart | M and Ms Geers-Liebaut | architect: Eugeen Liebaut

05 beyond

The graph below illustrates these principles by comparing the overall energy consumption (embodied energy + operating energy) of a building according to different energy performance standards. Energy is only one environmental indicator, but the approach is the same in the case of an overall assessment with multiple indicators[11].

> 5.2.1
p. 344



Global grey energy and operating energy needs

- (a) passive: reduced operating energy need, but with greater investment in embodied energy.
- (b) passive: use of materials with low embodied energy content giving an even better overall performance.
- (c) and (d) very low energy: lower investment in embodied energy to arrive a comparable overall performance despite the increase in

operating energy.

- (E) low energy: higher investment in embodied energy not in the envelope but in the technical installations (which offset by producing renewable energy).

Energy on its own does not, of course, suffice in order to define the sustainability of a project. Only an LCA incorporating various indicators permits a well-founded assessment based on the environmental impact. However important it is to pursue energy efficiency in buildings, it is only by focusing also on construction materials and methods with low environmental impacts that globally consistent responses can be achieved to the challenge of sustainable construction.

5.2.3. Design and evaluation principles[12]

A. Functionality, scalability, flexibility[13]

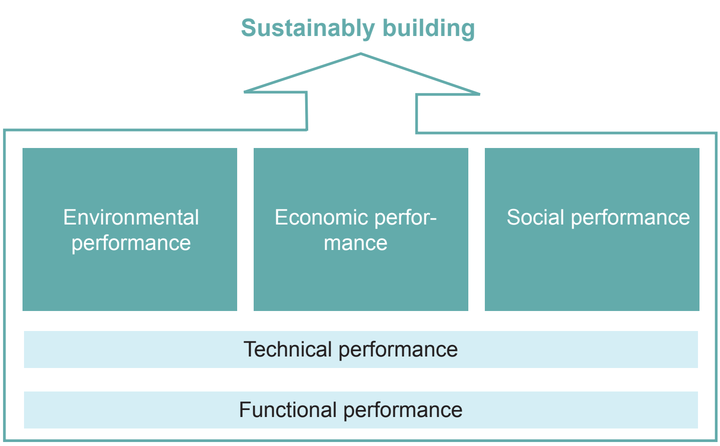
Above all, the longer a building lasts, the longer the period over which the impacts associated with its construction, use and demolition can be "written off". A sustainable building needs therefore to be designed to best suit its function, while being adaptable over time to the changing needs of its occupants. Reuse[14] and recycling of materials are also ways of extending the life of the construction elements.

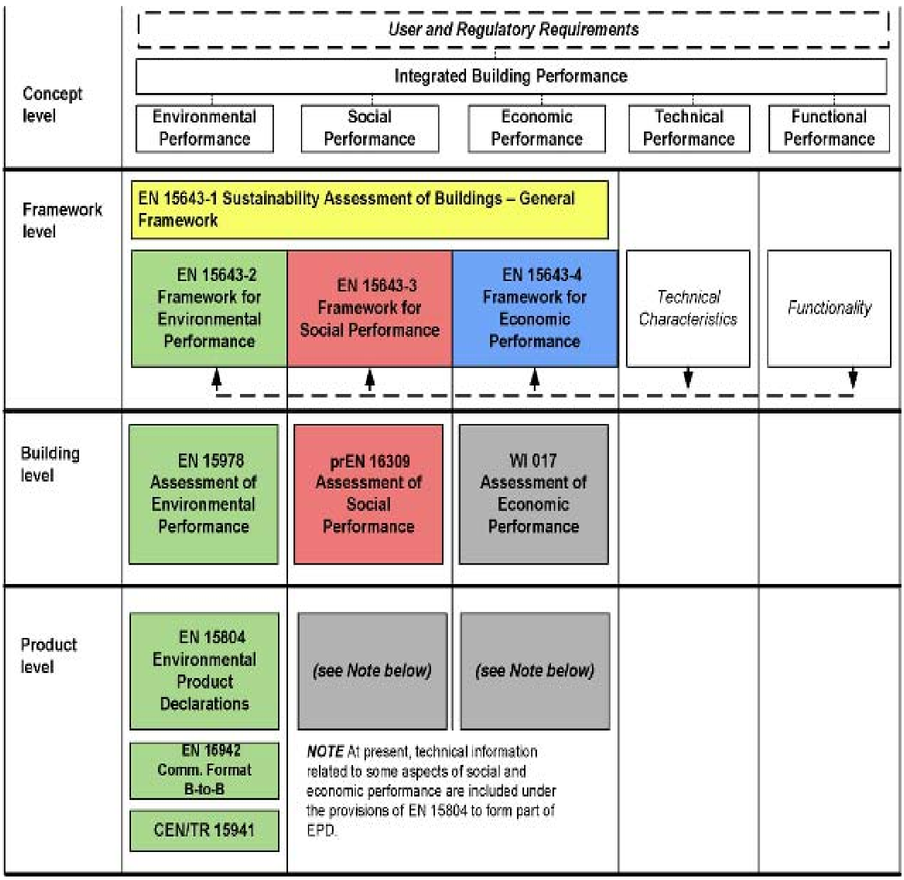
B. Rationalization

Careful design can rationalize the amount of material used. This includes prefabrication, limiting construction waste, using systems that favour easy disassembly and promoting reuse and recycling. etc.

C. Global assessment

The choice of construction techniques and materials should always seek a balance between the various constraints of the project: functionality, performance (strength, fire resistance, insulation, diffusion of water vapour, inertia, etc.), aesthetics, environmental impacts, social aspects (health, employment via local products, etc.) and cost.





CEN/TC 350 evaluation system: (source: CEN AFNOR standardisation)

D. For the building as a whole

Most tools provide assessments at the level of the material. But the fact remains that these materials are not finished products, but parts of larger wholes, interacting with other products according to construction typologies, fixing systems, thicknesses, connections and the like. Products' environmental performance also depends heavily on the way they are incorporated into the building and on technical constraints.

Just as with energy, sustainability can be measured only at the level of the building. In terms of energy, passive standards do not impose any particular means, but a final result expressed by a particular criterion of heating or primary energy requirement. For materials, the same approach can be observed: there is no simple recipe, no ideal method of construction or material. Choices have to be made on a case-by-case basis taking into account all parameters: it is the final outcome that matters.

Where it is not possible to undertake this examination at the level of the building, the component elements need to be compared at equal performance levels for their particular function (for insulation: comparison with an equivalent thermal conductance U). As the encoded density for each material can also strongly influence the calculation of impacts, its value should be as close to reality as possible.

E. Over the entire life cycle

It is essential to assess buildings over their entire life cycles in order to take full account of all environmental impacts, particularly the working life of the materials, as well as maintenance, replacement and the like.

F. Based on multi-criteria scientific data

> 5.2.1
p. 344

Many databases and tools exist today, providing accurate information based on life cycle analysis and incorporating various indicators

5.2.4. Assessment tools

The choices made at the design phase define a building's impact on the environment and human health throughout its life cycle. The designer must have all requisite information to hand concerning the materials and construction methods with which to sensitize the project owner and the contractor for making responsible and consistent choices. Numerous tools exist to guide consumers and professionals:

5.2.4.1. Labels (type 1 environmental declarations)[15]

Based on LCA, these reflect the environmental qualities of products in a concise and undetailed manner. This makes them useful more for final consumption products (finishes, special-purpose elements, etc.). The criteria and requirements differ from one label to another. In all cases, the assessment is controlled by an external certification body, giving it greater reliability.

5.2.4.2. EPD (type 3 environmental declarations)[16]

In these fact sheets, the producer or distributor provides standard quantitative data based on LCA and checked by an independent party. A common normative basis for developing EPDs (environmental product declarations) for construction products was established in 2012 by means of a new European standard. As yet there is still no Belgian EPD system, but work on it is in hand. An EPD takes the form of a data sheet both summarizing the various environmental impacts and providing a complete and detailed evaluation. Direct comparison between EPDs is not the objective, but the data can serve as input for a more advanced LCA by comparing different products offering equal performance, at individual component or building level. Interpretation of EPDs therefore requires the use of a LCA assessment tool and analysis by a professional.

5.2.4.3. Classification tools[18]

Widespread and relatively easy to use, these compile LCA results for particular construction materials or elements, taken from generic databases or sometimes manufacturers' own assessments (EPDs or others). They are based on fairly wide-ranging lists of criteria, each of which is scored, with weighting to give the final result, in the form of an assessment expressed as a percentage. The conclusions may vary considerably from one tool to another, depending on the databases used, the criteria and weightings applied, the steps of the life cycle taken into consideration, etc.

5.2.4.4. Assessment tools[19]

These are the most complete and most useful tools for arriving at a comprehensive view of the environmental quality of a building. They usually take the form of software that uses databases on materials, during construction, use and demolition. Some offer an assessment at the level of the building component; others undertake a comprehensive analysis of the building, including the environmental impact of the technical systems and energy consumption. The impacts considered and the degree of complexity and detail vary from one tool to another. The most advanced of them call for a certain degree of expertise in LCA.

Assessment of the impact of building materials on the environment and on health is a relatively new line of research which is set to expand further. Different initiatives launched in Europe should permit major advances in this field. In Belgium too, development work is still needed to create a framework and tools specific to the construction industry.

New tools also need to be created to guide architects and others involved in the design process. Currently, such information is very scattered. Lacking the necessary time, most architects tend to turn to traditional solutions. It would be very useful to group the basic information (technical performance, hygrothermal properties, aesthetic quality, cost, maintenance) and the specific data on the environmental impact of materials. Only when all of these criteria are considered together is it possible to make a responsible and correct choice.

In this context, we refer the reader to:

- the Sustainable Building Guide[20] of Brussels Environment (in French and Dutch)
- the bank of λ value certifications[21] and the Be Global[22] tool of the PMP (Passive House Platform),
- the library of energy-efficient and environmentally friendly walls produced by Architecture et Climat[23],
- the publications of the CSTC.[24]

5.2.5. A critical look

As it stands, it is still best to view the data on the environmental impact of materials in terms of orders of magnitude, allowing for example the comparison between different solutions (using the same assessment tool). Producing a more accurate and advanced eco-report requires a thorough knowledge of LCA databases and principles. One is well advised to use specialized consultancies for this type of analysis.

Furthermore, evaluation of materials should ideally be done at the level of the building as a whole, over the full life cycle and using advanced multi-criteria scientific databases. Depending on the type of tool used and the level of expertise, it is not always possible to fulfil these conditions. Compromises must then be found, but always keeping a critical eye on the assessment method and maintaining a certain critical distance vis-à-vis the results obtained

Indeed, critical analysis is essential in order to effectively process the plethora of information facing the designer and to avoid preconceptions or partial analysis.

For example, a natural material is not in itself necessarily good for the environment or health. Some materials are also almost exhausted, others are renewable only in the very long term or present production problems. This being said, many renewable-source materials have hygrothermal, acoustic and other properties that are interesting and favour their use.

Another example is the fact that the theoretical recyclability of a material can be compromised by the way it is used in the building (impossibility of disassembly, etc.) or, more simply, by the lack of a recycling chain or its negative energy or environmental impacts. As a general rule, to ensure the sustainable management of resources, re-use, up-cycling and recycling options are preferable to consumption followed by a landfill.

These positive and negative arguments demonstrate the importance of a critical and comprehensive vision. It is essential to take into account all the criteria characterizing building materials (technical and hygrothermal performance, environmental and health impacts, financial criteria, aesthetics, maintenance, etc.) in order to arrive at globally successful, healthy and sustainable projects.

House Montagne street | Uccle | Gerard Bedoret and Véronique Damas | architect: Gerard Bedoret

05 before

Hous ein Brussels | Brussels | private | architect: Amandine Sellier & AAC

5.3. Référence frameworks for sustainable construction

For several years now, numerous measures have contributed to improving the energy efficiency of buildings and reducing their consumption. While this objective is a worthy one, sustainable construction also has other targets.

Various reference frameworks and benchmarks serve to assess the sustainability of projects. These are structured around recurring themes: physical and human environment, mobility, biodiversity, energy, water, material, comfort and health, innovation, etc.

Each tool offers performance objectives, calculation tools, evaluation criteria and weighted scores. These methods are not without their critics but have the advantage of offering a certain objectification of project sustainability.[25] Some references in Belgium:

- **BREEAM** (www.breeam.org)[26]: British Research Establishment (BRE) for Environmental Assessment Methods (UK):BRITISH RESEARCH ESTABLISHMENT (BRE) FOR ENVIRONMENTAL ASSESSMENT METHODS (UK): British label with an international reputation. Brussels Environment and UPSI[27] are working with BRE to adapt BREEAM certification to the Belgian office construction context.
- **Sustainable Building Reference Framework** (in French and Dutch) (www.ref-b.be). A supraregional reference framework for the certification and labelling of sustainable buildings. Right now under development, and directed at both housing and office buildings, it is currently organized into 9 themes (Management; Mobility; Nature development; Physical environment; Human environment; Materials; Energy, Water, Wellbeing, comfort and health). The intention is for it to be compatible with BREEAM. The BSBC (Belgian Sustainable Building Council) is the non-profit association responsible for managing the certification of sustainable buildings in Belgium.
- **Batex** (www.bruxellesenvironnement.be) : a recognition granted since 2007 by Brussels Environment in competitions to promote the construction and renovation of "Exemplary Buildings" in the Brussels-Capital region.

Bellevue housing | Sint-Jan-Molenbeek | Nelson Canal | architect: A2M

Prize-winning entries are selected by a board of judges based on four criteria: highest possible energy efficiency; lowest possible environmental impact; reproducibility and efficacy of the proposed solutions, their architectural coherence and urban integration. The winners receive financial aid and technical assistance.

- **Sustainable Building Guide** (in French) (http://guidebatimentdurable.bruxellesenvironnement.be): a design assistance tool for professionals, structured in the same way as the Sustainable Building Reference Framework.

These tools are mainly based on technical and quantitative criteria related to a building's performance. Energy is a crucial factor with a generally predominant weighting. Passive buildings therefore score well on this point. Other criteria are also influenced by energy performance: thermal comfort, life cycle analysis, life cycle cost, etc. The architect must also of course focus on other areas in order to meet the requirements of the sustainability reference frameworks. Another important target relates to the choice of building materials. By way of example, here is the weighting as provided by the Sustainable Building Reference Framework[28].

5.4. Passive building and their ability to evolve

Sabine Leribaux

Specific to Man is his awareness of the Other. It is only the ability to replace a “me now” mind-set with an “other people tomorrow” one that makes enables us to develop projects that will be in phase with future worlds.

5.4.1. Present and future use

Whether programmed or not, it is no longer acceptable that buildings erected in the late 20th century be already obsolete within twenty or thirty years from now. Each new building must imperatively include, each in its own way, a real capacity of adaptation without being a burden on society at large. This civic requirement applies to any responsible project manager, and de facto to passive projects. Two rules can therefore be proposed:

1. The use of the premises for the intended function should, from the start of occupation, be as free, flexible and modulable as possible with minimal light conversion;

2. The future use of the premises - but this time for a broader spectrum of functions - should be as free, flexible and modulable as possible with light conversion or limited heavier conversion.

5.4.2. Conversions and extensions

To arrive at a built entity that can evolve over time in a consistent and sustainable way, options that block the way to subsequent evolutions will therefore be rejected throughout the genesis of the project, from drawing board to building site. Just as a financial market is referred to as “liquid” when it adapts to changing transaction types, so a “liquid” project will be able to adapt to changing uses easily, quickly and inexpensively.

There is no one easy recipe for achieving this flexibility. However, observation of recent buildings (across all functions) points to potential avenues, often in combination, but rarely all at once:

Simplicity of shape allows greater flexibility both spatially and technically (in the extreme, a cube-shaped building will more easily permit a greater number of leasing alternatives and even functions than one shaped like a cockscrew coil).

Shallow building allows better distribution of natural lighting and natural ventilation (openings).

With **strict layering and uniform modulation of the structure**, the load-bearing elements present less of a problem in varying short, medium and long-term usage scenarios, permitting even major structural changes and avoiding (expensive) case-by-case solutions.

Minimizing the impact of structural elements both on the outside walling and inside the building makes it possible to move towards open-plan spaces, in which the shell and other load-bearing walling are kept to a bare minimum (bracing, etc.) thus freeing up space. This also offers considerable flexibility when applied to the skin of the building: in the extreme, a non-load-bearing façade without breasting and using light-weight filling offers more future than a façade of pre-holed, pre-fabricated insulated concrete ('premur') walling.

The **constructional simplicity** of the façade, including the most continuous air and water sealing runs possible, facilitates short and medium-term technical adjustments of façade elements. This simplicity, including easily removable modules permitting the seamless insertion of later upgrades, facilitates the replacement of façade elements in the longer term.

Applying a uniformly modulated **façade framework** allows for a wide range of modifications of use or, in the extreme, a single-module or at least repetitive framework. This framework could generate a "modulo" façade in which each element (or module) is complete and autonomous in terms of thermal and acoustic performance, lighting and natural ventilation, etc.

Maximizing clear heights make it possible to accommodate a larger number of functions and to integrate more easily any change in the initial technical installations or add new elements (installation of double flow ventilation for converting the building from offices to dwellings, etc.). It also makes it easier to meet the needs of structural adjustment (like preserving the necessary beam height if piercing is needed).

Judicious siting of vertical distributions (elevators, escalators, chutes, etc.) prevents or at least limits the creation of new openings (expensive) in case of major rehabilitation and leads to the optimal placing of horizontal traffic, thus ensuring an optimal net/gross ratio, which is fundamental to the

ELIA HQ | Brussels | ELIA System Operator | architect: Architectes Associés

economic viability of any project conceived in an evolutionary perspective.

The **extreme modularity of partitioning** right across the building, applied also to the distribution of special installations (fluids, electricity, IT, etc.) broadens the range of possible spatial organizations for the same function: the smaller and more comprehensive the base module, the more flexible will the project within the limits of what is technically and economically feasible (even if this means over-dimensioning certain technical elements, including terminal units (vents, grilles, radiators, etc.). This modularity provides the requisite flexibility when the time comes to fully or partially change the function of the building.

Reduction and simplicity of finishing reduces the interventions required in case of modification, removal or replacement.

The independence of each section of the building from the others, within the limits of what is technically and economically feasible (structure, technology, façade, finishing, etc.), facilitates the modification or replacement of all or part of each section in the event of partial or complete upgrade of the project, for a similar or changed function.

The above avenues are directed primarily at five interrelated criteria::

1. spatial organization,
2. the constructive principle
3. the outer skin
4. the technologies,
5. the finishings.

All this lead us to the principle of a structural frame reduced to its simplest expression, providing an optimal net/gross ratio, into which independent secondary elements (façade modules, TS modules, completions, etc.) can be "plugged " or "unplugged".

Such a roadmap, while enabling a form of "liquidity" in a coherent and efficient temporal continuity, cannot, however, omit one last decisive factor even in the absence of those mentioned above: the emotion aroused by the

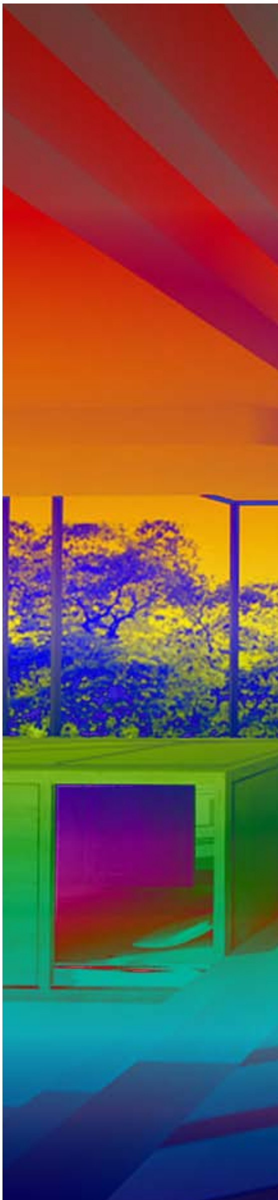
ELIA HQ | Brussels | ELIA System Operator | architect: Architectes Associés

visual power of spaces and architectural elements that constitute them. What affects humans today will continue to touch them in the future, regardless of the function or the message of the original architecture. An energy-focused approach does not alter this situation.

5.5. What does passive bulding do to architecture ?

Julie Willem

This book presents the many technical changes the passive standard implies in the practice of building. While in principle fairly simple - add a little more insulation, ensure airtightness where fittings pass through walls and floors - put together, their combined effects influence the design process and lead to a more fundamental questioning of architecture and architectural practice.

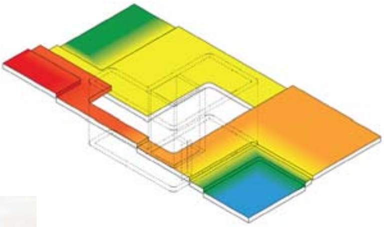


5.5.1. Context

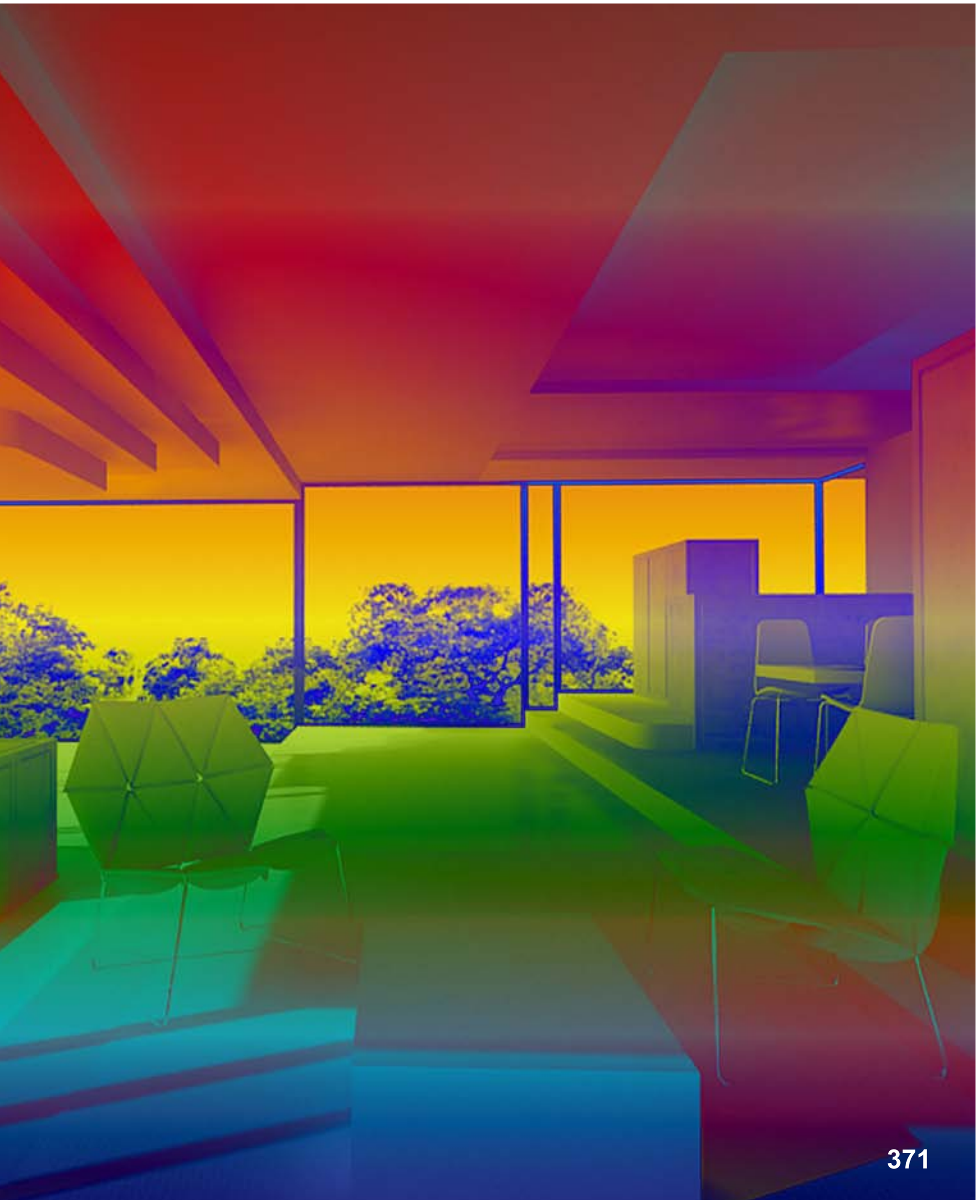
Human constructions seek, among other things, to protect our activities from external climatic variations. Whether to protect us from wind, rain, cold, hot, or again from day and night, the shelter they provide allows us to "stay alive". In Lisa Heschong's words: "*Life exists within a narrow range of temperatures.*"[29] While, obviously, architecture's role is not limited to producing a habitable interior environment, the latter remains an inseparable part of our physical occupancy of buildings.

A long period of evolution has allowed us to move from a state of involuntary submission to the whims of the external environment (natural, variable and unpredictable) to almost total control, with fingertip regulation of the indoor climate (homogeneous, stable and artificial).

While the handling of the outer envelope has long guaranteed the sustainability of buildings, modern technologies (central heating, air conditioning, electricity) reduce - if not abolish - the boundary between inside and outside, while maintaining occupants' comfort. "*The fascination of this power of control over our environment has led to the invention of mechanical systems that have overshadowed natural thermal strategies, making them obsolete by comparison*."[30]



Convective building | Hambourg | IBA Hamburg | architect: Philippe Rahm



If the quality of the indoor climate was for centuries generated by the physical elements of the architecture - the shade of a porch or the thickness of a wall - a radical shift occurred when technology took hold of this area, taking over this function from the physical elements, that had become too heavy, static and limited.

Passive construction turns this de facto situation on its head. To return to a less technology-centred approach is to raise a more architectural question. In a way, passive building takes us back to the earlier situation: material regains its preponderant role, and architecture becomes a major factor of comfort. A passive building can no longer be a simple cosmetic packaging, the defects of which are erased which by dint of technological compensations. Therefore, beyond the technical aspects discussed above, the question arises: what does passive building do to architecture?

5.5.2. Limits

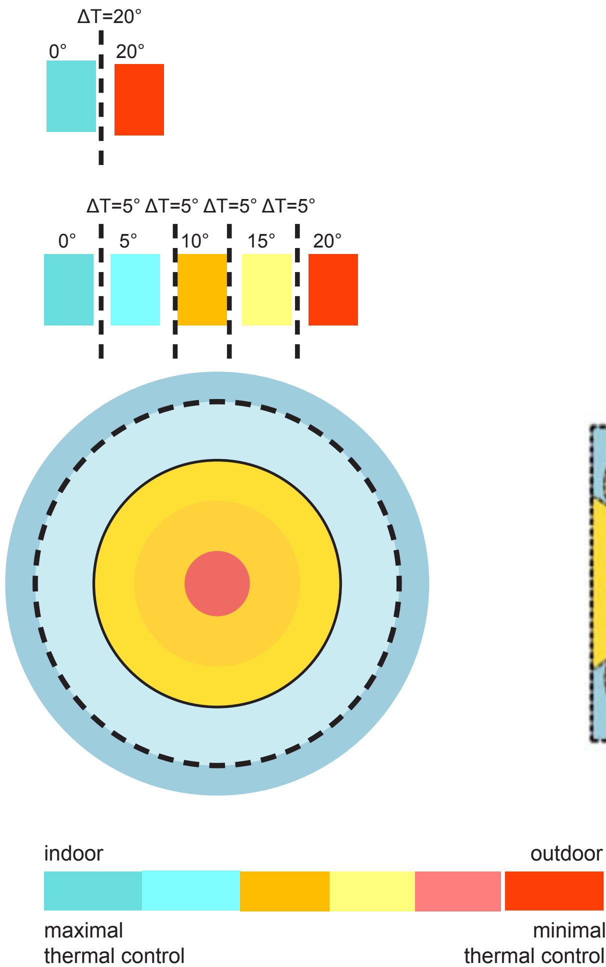
Traditionally, the transition from outside to inside is governed by rather rigid layers such as, in Belgium, the load-bearing wall and its brick cladding. With passive building, a thick cottony mass, malleable and containing mainly immobile air, infiltrates this interface. While insulation was previously a small residual layer applied hastily inside cavity walls, the physical proportions of the insulation become dominant in walling. Thickened to the maximum, insulation pulls expands the envelope, even at times separating out the elements of what traditionally was considered an almost homogeneous element: the outer wall.

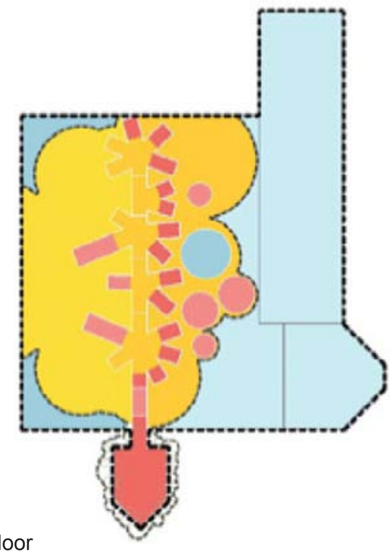
For far from strictly environmental considerations, Lacaton and Vassal have already dissected the boundaries of the La Tapie house, spatially separating the waterproofing from the thermal insulation. The building envelope has been carefully studied in terms of the building's components so as to offer several types of protected volumes to its inhabitants. By separating out the components of the outer envelope to produce an environment that is neither inside or outside, a variable occupancy zone widens the boundary between natural and controlled environments.

House Latapie | Floirac | private | architect: Lacaton & Vassal

However, the insulating layer cannot be inflated with impunity without architectural consequences. With this gradual separation of the individual layers, the wall as such falls apart, with each layer examined in terms of its physical properties:

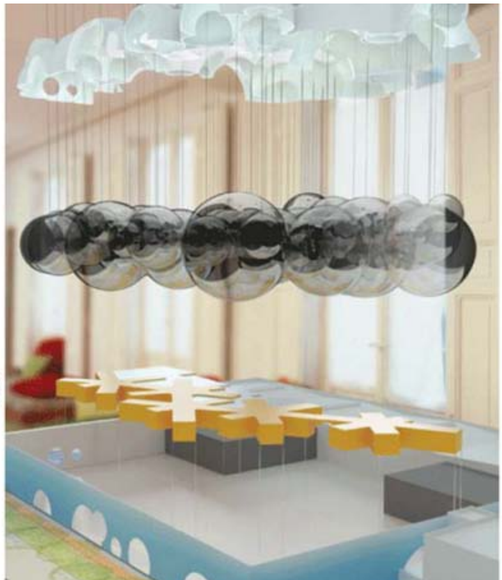
- the outer layer protects against water and wind;
- the most insulated one regulates the heat flows;
- seldom directly connected to the insulation, the structure is located in front of, behind or alternating with it;
- the innermost layer regulates the humidity flows;





In the renovation of the Oostcamp town hall by the architect Carlos Arroyo, the space between the entrance and the areas where people work 8 hours a day is subdivided into "thermal strata." These strata are assigned for use in accordance with the resulting temperature. When it is 0°C outside, the hall will have a temperature between 10°C and 15°C, the temporary clusters will have a temperature between 15°C and 20°C.

OostCampus | Oostcamp |
Municipality of Oostcamp |
architect: Carlos Arroyo



beyond 05

The Plume project consists of a solid façade (concrete blocks) packed in EPS insulation. Instead of an outer rendering, the architects are exploring a modular glued surface covering. The module becomes the basic pixel for the design of the facade. Furthermore, the insulation layer is bevelled towards the windows to obtain an effect of plasticity and light.

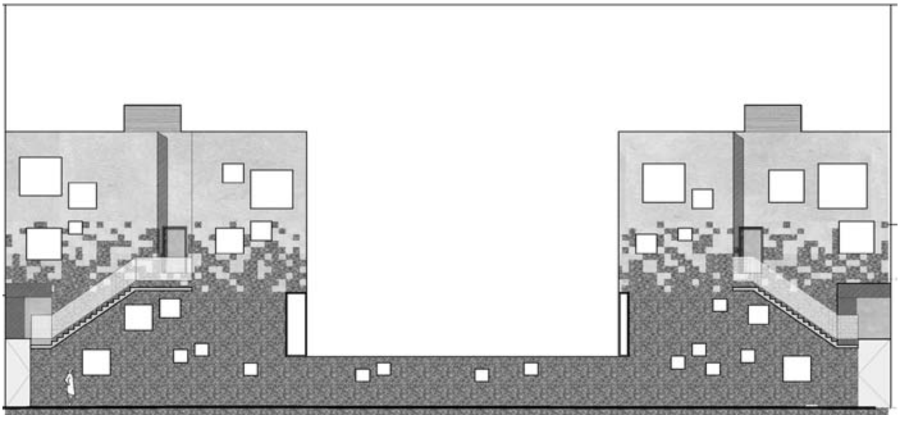
Plume housing | Brussels | Le Foyer Bruxellois | architect: B612 associates

From a 'shell' architecture, a sort of hard, protective exoskeleton, we move gradually, as from insects to mammals, to the endoskeleton: a rigid structure packaged in soft materials.

Many building clichés are challenged in the process. For example, the traditional Belgian brick facing is well "insulated" at 30 cm from a structural wall. But a structure which is built twice over to ensure its stability becomes unaffordable. Building solutions adapt quickly but we remain prisoners of increasingly obsolete models. Taking again the comparison with the human body, skin offers feeble protection to our organs, but we no longer have a shell.

Separating the skin, thickening the envelope, peeling the layers.

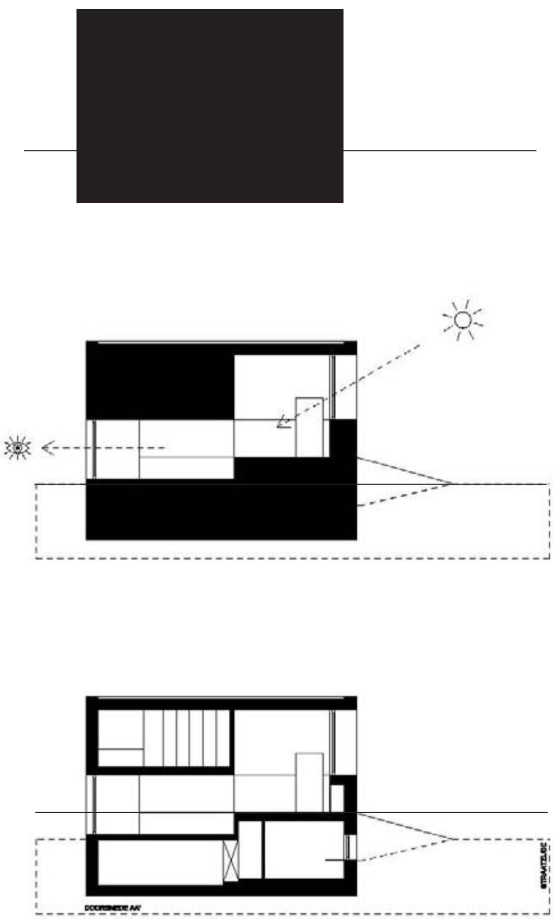
Whether constrained by building standards or taste, architects have seized the new opportunities presented by this field from 20 to 30 cm thick, the matter, texture and coating of which they can manipulate at leisure. Not a thick, uniform protective layer, but a prominent layer that has become preponderant, that they can play with finesse. The architects of B612, for example, use the plastic capabilities of the insulation of the Plume project to dig large oblique openings around the windows, to dream up a new scale of texture and create plays of shadow and light by manipulating the thickness of the insulation.



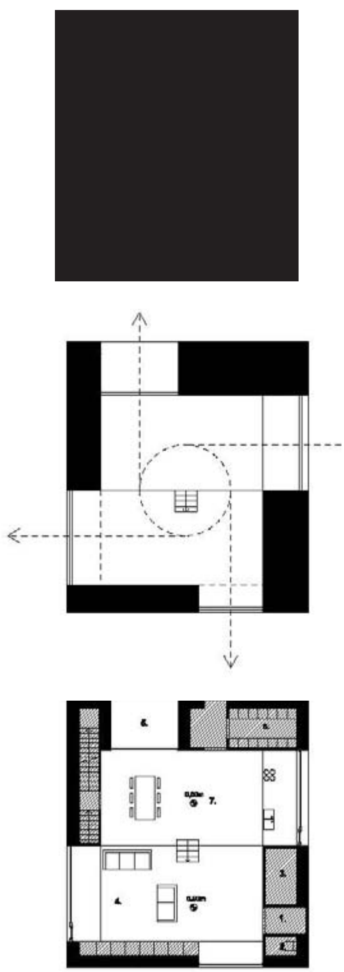
The multiplication of limits aimed at providing more spaces at a lower cost of the Lacaton-Vassal project is also found in other projects. In their article "*Finesse de l'épaisseur*"[31], Bernard Baines and Gery Leloutre point to this multiplication of limits and the at times habitable intermediate spaces. They observe the return of a solid materiality and deployment of the transition between environments.

Playing on the effects of exaggeration, the GBL house project[32] by Blaf Architecten exploits this new dimension to the extreme. The outer envelope presents itself as a compact mass, inside of which the living areas are carved out. The walls contain not only the insulation but also various services, staircases, a laundry and others elements. The contrast of the opaque walls with the large, angled of the bays enhances the feeling of space nestled in the hollow of a mass, revealing the thickness that envelops us. Jacques Lucan explores this complex transition territory between exterior aspect and interior form in his treatise on the "*Généalogie du poché*".[33]

This densification of the envelope, the affirmation of its materiality and its spatial deployment are not just a consequence of energy consumption statistics. The buildings mentioned here are among the first to take on board, experiment with and take stock of the upheavals in which we are immersed.



Section



Plan

House GBL | Lokeren | Gert Stuyven & Bea Hageman | architect: *BLAF architecten*

House GBL | Lokeren | Gert Stuyven & Bea Hageman | architect: *BLAF architecten*

"Junkspace is like being condemned to a perpetual Jacuzzi with millions of friends." [34]

5.5.3. Environment

This transformation of the physical part of the construction also results in a fresh look at interior spaces. Studying the flows of heat, air and moisture through walls involves considering the interior space no longer as a void but as a fluid, dense substance with multiple parameters.

Let us examine what a building produces: the quality of architecture has often been related to plays of shadow and light, but these interventions also alter, among other things, the flows of air, heat and moisture. These constant relationships and flows enable us to talk of architecture in terms of creating environments.

Environment here embraces all the "climatic" transformations induced by the architecture: the heated air of a closed dwelling, the micro climate created by an outside patio and so on. Environment is what architecture creates: we are in the presence, not of empty space, but of a mass with known values such as temperature, humidity, speed, and exposure to light.

"Environment" appears a more appropriate term to address these fluid relationships than the term "space" - that covers a relatively broad semantic field - or "empty area" - which could be interpreted as a lack of material. The environment created by architecture refers to the mass and, by extension, to its quality. However, assessment of the quality of this mass is often relegated to the technology level only, with air conditioning making any construction viable.

In his eponymous essay, Rem Koolhaas defines junkspace as "the product of the meeting of the escalator and air conditioning, conceived in an incubator in Placoplatre (all three missing from the history books)." *He adds: "It is always inside, and so extensive that one rarely perceives its limits. (...) Gravity has remained the same, and we try to fight it with the same arsenal we have employed since the beginning of time; but air - an invisible and therefore unnoticed medium - has truly revolutionized architecture. Air conditioning has given birth to endless buildings.*"[35]

By dint of systems and ducting, it is technologically possible to maintain a constant temperature, light intensity, humidity level and atmosphere from north to south and from the beach to the mountains. Infinite? Not really any more. The pin of sustainable development has burst this thin bubble, a superhuman vision of glass towers built under a blazing sun. In contrast, a passive construction is deeply embedded in the characteristics of a particular location, the topographical and climatic conditions of which it cannot free itself. The qualities of this internal environment depend directly on the physical characteristics of the envelope. In passive building, it is no longer possible split the task, with the architect looking after the material side and the engineer taking care of the technology: here the construction material is inseparable from the environment it creates.

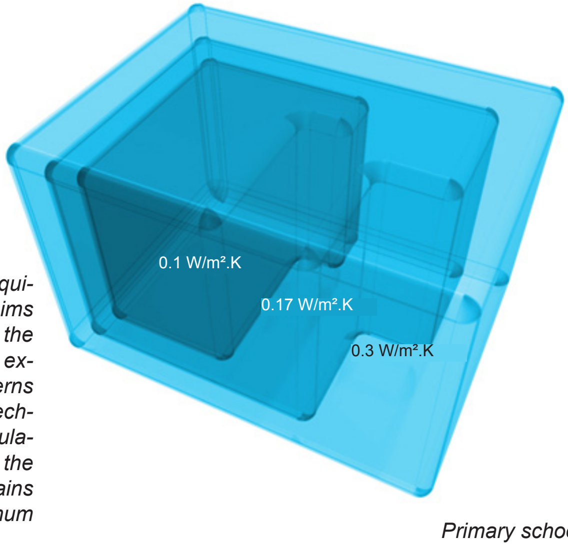
Contrary to our experience of matter, which is external to our body and we apprehend from afar with our eyes, environment is something we are immersed in: it englobes us, we breathe it, it penetrates us as much as we penetrate it.

However, in respect of our perceptions and the sensual character of the architecture that we experience, the qualitative contribution of passive architecture remains invisible. Very evident, on the other hand, are the constraints it imposes indirectly, the increased thickness of the building shell, the strict enclosure of the volume and, to a lesser extent, its compactness. These constraints indicate exactly where the quality of the spaces designed around these new requirements is to be found. It is in the transformation of our relationship to the environments in which we live and to the boundaries by which we distinguish them that passive building changes the quality of the spaces we inhabit.

5.5.4. Practices

Awareness of these changes brings about not only a renewal of individual architectural elements but also new modes of composition, a kind of typological reformulation that critically challenges the criteria of form and programme. While the passive nature of a construction is no guarantee of its architectural quality, but it is difficult today to bypass it totally. This being said, questioning matter, form, light and materials represents a real challenge at a time when construction is increasingly regulated.

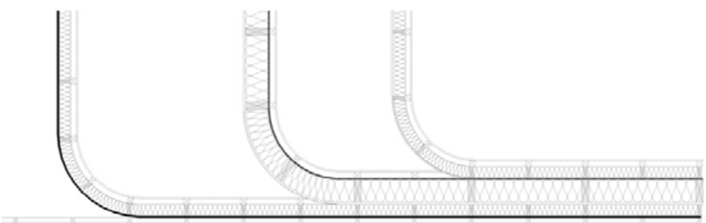
Just like computing software has enabled the creation of forms at the limit of stability, the current tools enable us to re-capture the creation of the internal environment as an integral part of the project. They provide the keys for tackling these changes, no longer either blindly or in experimental mode, but with a real capacity for action.



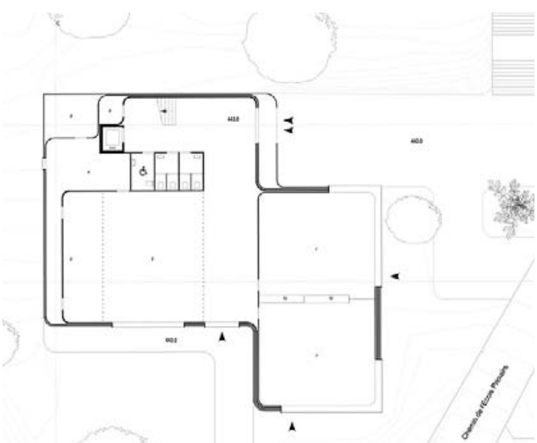
How can the thermal conditions required be transformed? This project aims to increase the thermal resistance of the envelope gradually. More sensitive to external variations, the first layer concerns spaces where less time is spent (techniques, etc.). The second, more insulated layer concerns the corridors and the hall, and the final 40 cm layer contains the classes and guarantees maximum comfort.

Primary school in Neuville | Neuville, Suisse | private | architect: Philippe Rahm

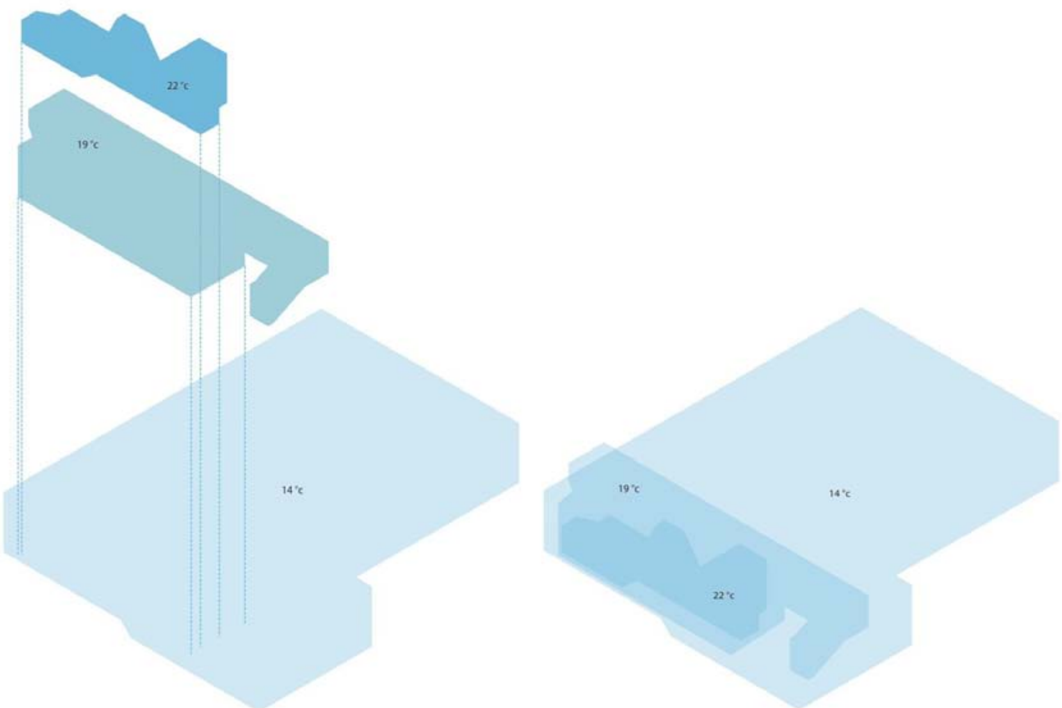
Principle of successive interweaving of different thermal layers



Programmatic stratification according to the thermal coefficient U

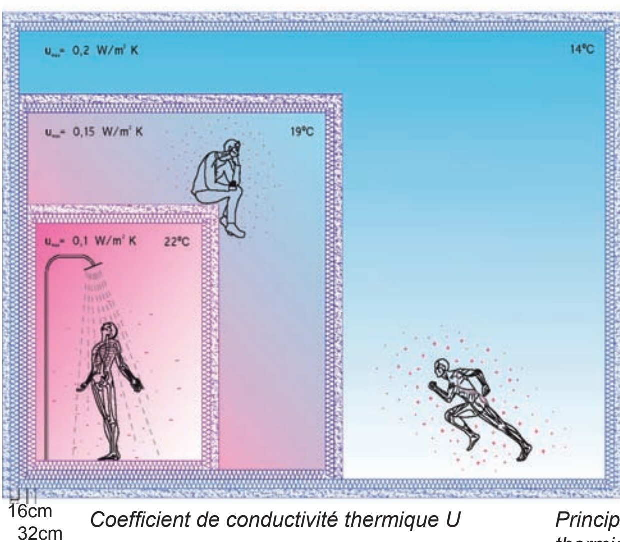


ground floor plan

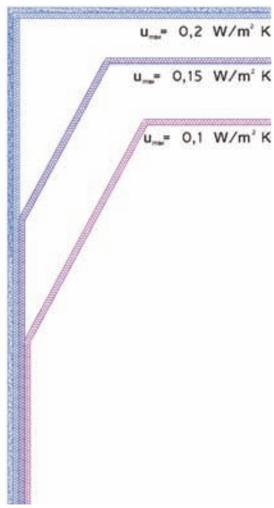


In his sports hall project, Philippe Rahm breaks down the thermal envelope of the building as a function of activities and needs. The sports hall proper, where bodies are moving, can have a relatively low temperature. Cafeterias and places where bodies are inactive are wrapped in a second insulating layer. And like Russian dolls, a third layer protects the changing rooms where bodies are naked and vulnerable. [36]

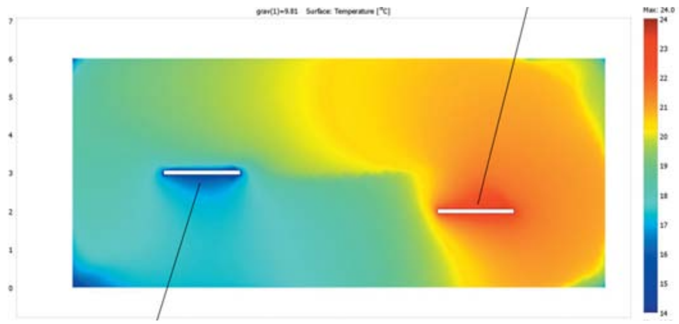
Three Thermal Bubble | Vetroz | Ecole Les Plantys | | architecte: Philippe Rahm

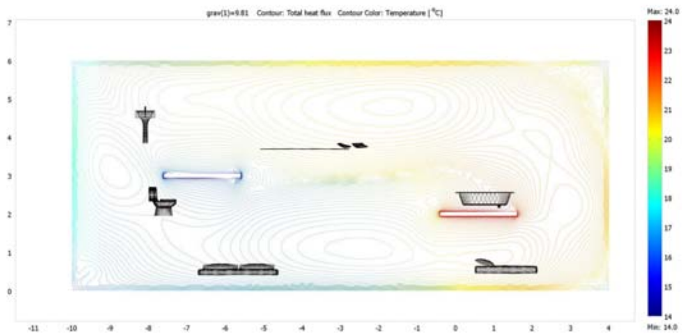


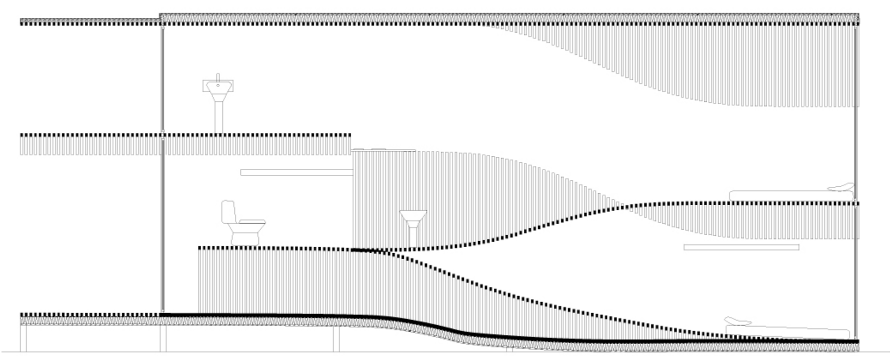
Coefficient de conductivité thermique U



Principe d'addition des couches thermiques d'isolation







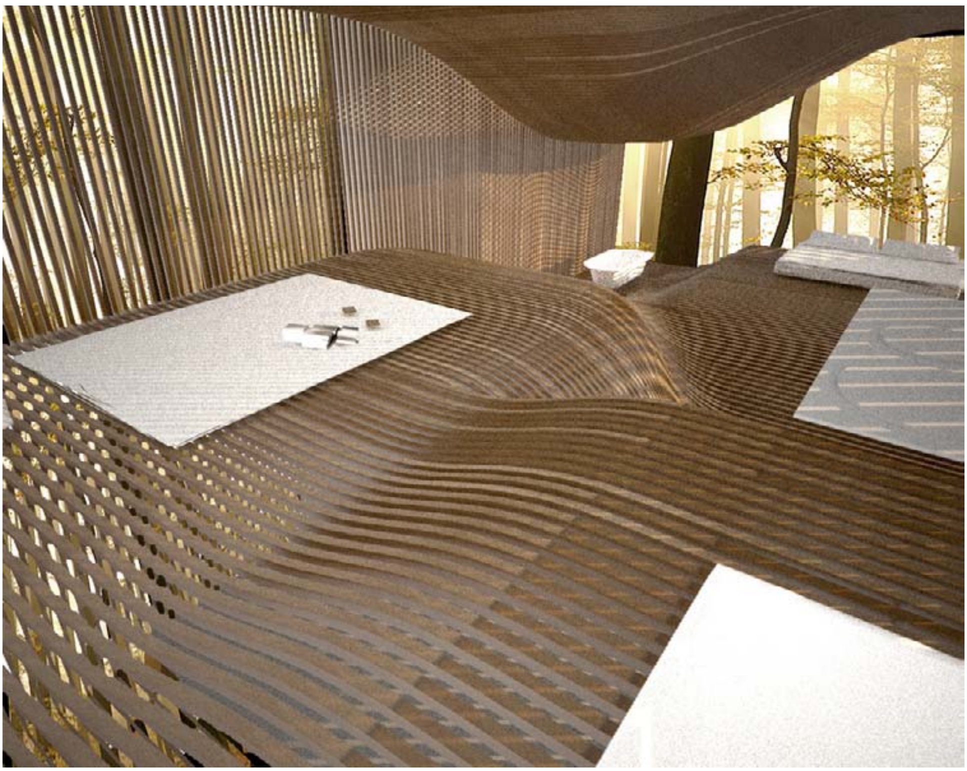
The thermodynamic phenomenon of the Golf Stream provides a way to escape the standardisation and homogenisation of modern space. This climatic phenomenon is created by the polarisation of two different thermal sources: a cold one, on the one side, and a hot one on the other. This thermal polarisation generates a convective air movement which defines different temperature zones.

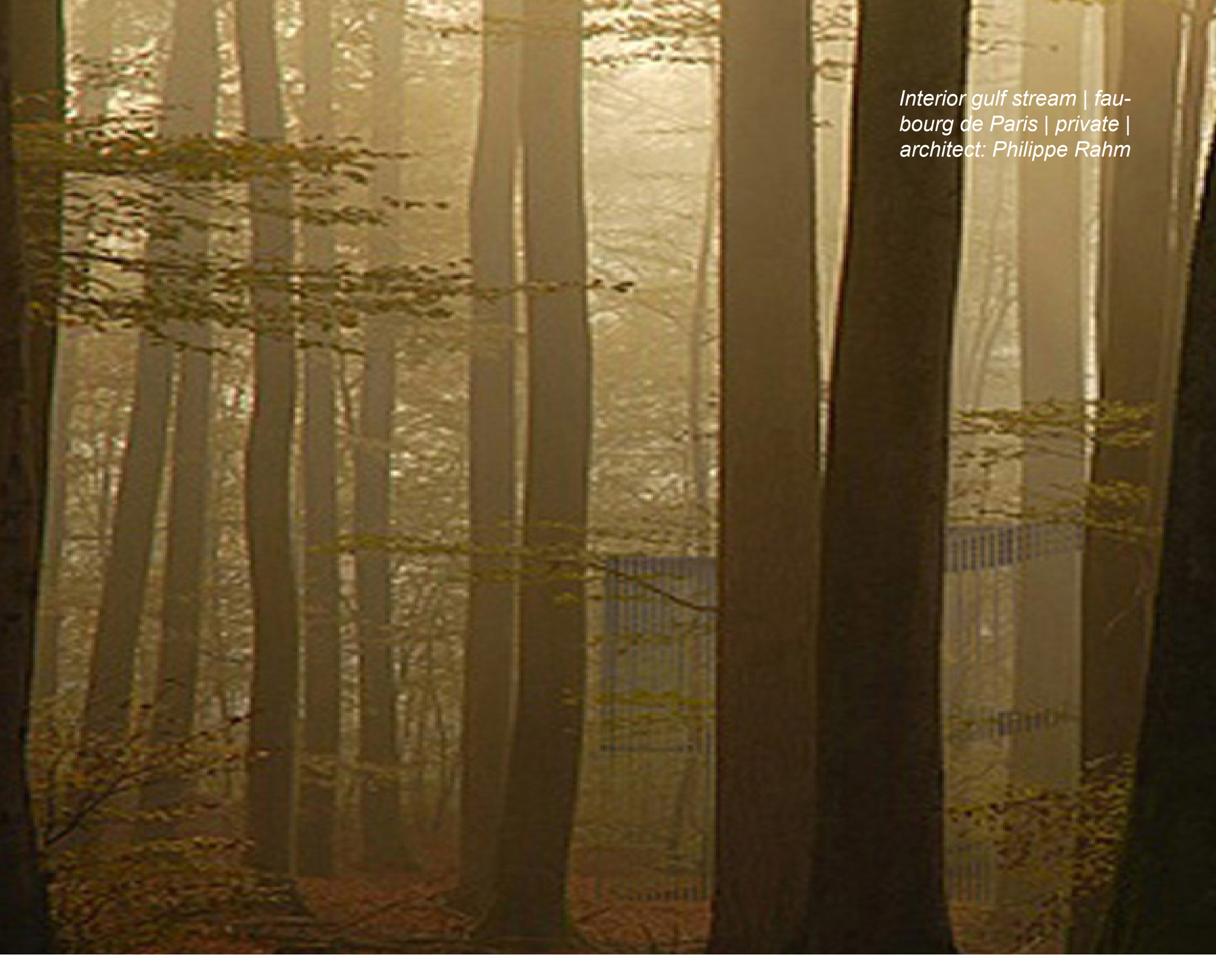
The Swiss SIA 3842 code defines the ambient temperatures to be reached:

Living room 20°C	*bedroom 16 to 18°C*	*bathroom 22°C*
Bedroom used as living room 20°C		*staircase 12°C*
kitchen 18 to 20°C	*hall and toilets 15 to 18°C*	*laundry room 12°C*

Thus, instead of heating the entire space to 20°C, Philippe Rahm proposes installing these functions according to the analysis of the result of the temperature zones engendered by the hot and cold source.

Interior gulf stream | faubourg de Paris | private | architect: Philippe Rahm





Interior gulf stream | faubourg de Paris | private | architect: Philippe Rahm

References

1 It sets 2020 targets for reducing greenhouse gas emissions (-20%), the development of renewable energy (20% of the energy mix) and improved energy efficiency (20% +).

2 Éric Luyckx, Paysages énergétiques, in *Après le pétrole*, Etopia, 2006 ; available on www.etopia.be/IMG/pdf/Luyckx__paysages_energetiques.pdf.

3 Grégoire Wallenborn et al, opus citum.

4 Énergie+, version 8, www.energieplus-lesite.be

5 According to figures from Eric Luyckx (see note 179) and those of the Century 21 agency (average living space = 119 m² per dwelling, http://portic.be/pdf/news/news_portic_33.pdf) agency.

6 The population density in Brussels (7,152 inhabitants/km² at 01.01.2013) is almost 20 times that of Belgium (364 inhabitants/km²)

7 Fiasco énergétique, Texquis, 2014.

8 **be.passive 19**, p.16.

9 **be.passive 12** □ 18, section be.global

10 www.cstc.be > Services > Aide à l'innovation > éco-construction et développement durable > documents > choisir des matériaux durables

11 **be.passive 12**, p.81.

12 **be.passive 17**, p.81.

13 http://guidebatimentdurable.bruxellesenvironnement.be > Matière > G MAT01 – Le cycle de vie de la matière Bruxelles Environnement (IBGE).

14 Many interesting initiatives have been developed at this level in Belgium: http://www.res-sources.be/ http://opalis.be/. be.passive 19.

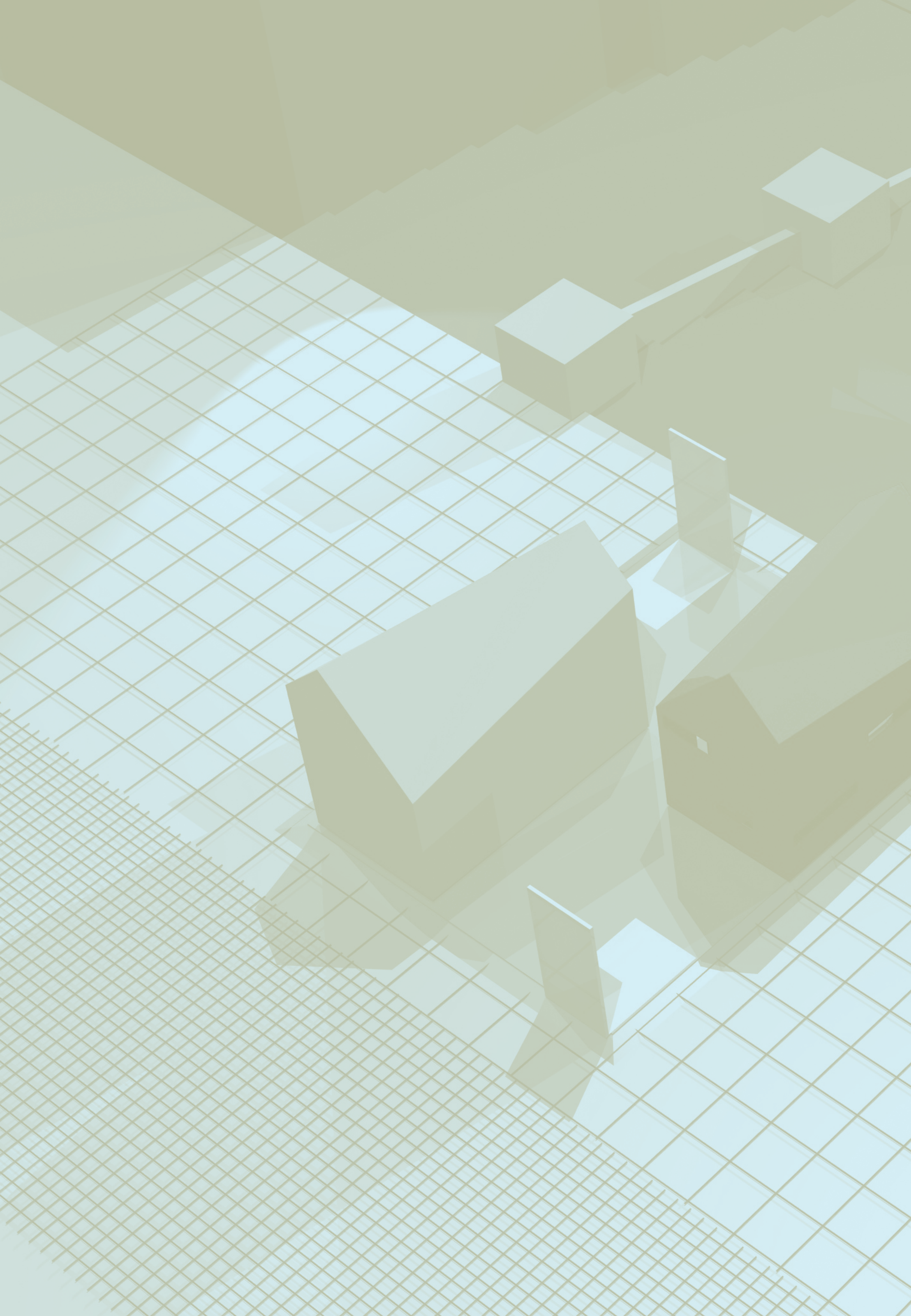
15 **be.passive 14**, p.84, www.infolabel.be

16 **be.passive 15**, p.88.

17 EN 15804, published in 2012 by (CEN) TC 350.

18 **be.passive 16**, p.80.

19 **be.passive 17**, p.80.
20 http://guidebatimentdurable.bruxellesenvironnement.be / http://gidsduurzamegebouwen.leefmilieubrussel.be
21 www.ponts-thermiques.be/fr/attestations
22 http://be-global.be
23 Sophie Trachte and André De Herde, *Choix des Matériaux – Écobilan de parois*, Architecture et Climat, UCL, Louvain-la-Neuve, 2010.
24 An Janssen, Laetitia Delem, Johan Van Dessel, *Principes et points d'attention lors du choix de matériaux de construction durables*, Centre Scientifique et Technique de la Construction – Labo Développement Durable, 2012.
25 **be.passive 05**, p.25.
26 **be.passive 05**, p.47.
27 Union professionnelle du secteur immobilier
28 Given that the Sustainable Building Reference Framework is still under development, the weighting could be changed.
29 Lisa **Heschong**, *Architecture et volupté thermique*, éditions Parenthèses, 1981, p.17.
30 Ibid, p.28.
31 In "*matières 7*", coll. Laboratoire de théorie et d'histoire (LTH), PPUR, 2005
32 Rem **Koolhaas**, *Junkspace*, Éditions Payot & Rivages, 2011, p.84.
35 Ibid, p.86
36 **be.passive 13**, p.18.



post-face

Post-face

Bernard Deprez

Architecture uses constructive means to produce the shapes we inhabit. It transforms space into units of meaning, utility, collective organization and values. Despite its instrumentality, architecture is reflective in nature. Its constantly iterated work on form questions its own production process, in terms both of the means it selects (space, matter, energy, etc.) and of the objectives imposed on it (how it is to be inhabited).

Born at the same time as agriculture, architecture is, like the former, a matter of bodies and of materials, concepts and forms. It provides the pivot point between the planet - unique, finite, alive - and our human worlds - disparate and historical societies. Architecture intimately combines material with immaterial, the laws of nature with human rules. In this sense, it not only connects inhabitants with the space in which they live - both in terms of their physical bodies and of their identity - but equally "couples" them with the ecosystem on which they depend and with the social structure in which they evolve.

>
p. 2-3

The emphasis in this book on construction methods (materials, energy, shapes) opens the way to a discussion on architectonics and "residential purpose": what societal models should we adopt for land use (dense city, scattered housing nuclei, etc.),and decision-making (participation, mutualization[1], etc.)? An approach is sustainable because it is ecologically based, but also because it manages to tie ecological benefits to individual and societal issues.

All this tells us that the ecology of human bodies, minds and communities is tied to architecture. We must therefore examine architecture and question its ecological embedding[2], which models the well-being of its inhabitants by shaping their living spaces and by the eco- and socio-systemic benefits it offers.

This applies also to energy: not only does its use directly affect the way we build, but its impacts affect equally inhabitants (health, economics), ecosystems (pollution, global warming) and social systems (insecurity, vulnerability, technological transitions, lifestyles and territorial models). In this sense, energy sustainability in any form is based on an integrated ecological vision in which choices of form, materials and energy are inter-related.

An ecological approach is not therefore something that comes “after” energy, but is rather its precondition: the earth in which it is set. Even more: an energy approach such as the passive standard will have real life only by remaining reflexive, that is capable of moving beyond its own operational and technical horizon to challenge the architectural practices of its time by confronting them with their ecological impact.

References:

1 **be.passive 08**, p.40.

2 **be.passive 01**, p.27.

The "Ice Challenge" after 44 days

Bibliography and illustration

Index of architects

Index of clients

IBA Hamburg, p. 371
Immobel, p. 9
Immobilière Comte de Flandre, p. 9
Investsud, p. 8
Katholiek Basisonderwijs Lozen vzw, p. 8
Kervyn Guillaume, Boels Lucas, p. 8, 50
Le Foyer Bruxellois, p. 376
Housedu Travail asbl, p. 9, 23
M. and Mme Geers-Liebaut , p. 346
Ministère de la communauté flamande, VMM, p. 8
Nelson Canal, p. 9
Neue Heimat Tirol, Gemeinnützige WohnungsGmbH, Innsbruck, p. 311
Oryx-projects, p. 9
Parc de l'Alliance, p. 8
Parlement de la Communauté Française, p. 9
Passive House Developers Society, p. 28
Project T&T, p. 9, 48, 189
Province of Antwerpen, p.8, 232
Province of Brabant Wallon, p. 66, 68, 222
Régie autonome de Mortsel, p. 8, 279
Ridgewood Bushwick Senior Citizens Council, p. 129
School 't Piepelke, p. 8
Segers Thomas, p. 318
SOHA, p. 229
Synergy and Croissance, p. 8
The International Polar Foundation, p. 26
Thomas and Piron, p. 8, 86, 162-163, 199
Van Ginderachter D. et De Ridder N., p. 166
City of Charleroi, p. 8, 260
City of Brussels, Régie Foncière, p. 9, 93, 224, 286

Photography credits

Unless indicated otherwise, the summary images and plans belong to the developers of the projects.
B Boccara, p. 255
Stijn Bollaert, p. 8
Thomas De Bruyne, p. 279
George de Kinder, p. 9

Marc Detiffe, 176, 181, 366
Filip Dujardin, p. 8, 9, 31, 36, 40, 68, 86, 97, 108, 163, 241
Pierre Kroll, p. 21
René Robert, p. 26
Willem Julie, p. 149
Philippe Ruault et Lacaton & Vassal, 373
Christophe Urbain, p. 312, 322, 326, 330
Jeroen Verrecht, p. 363
Valerie Clarisse, p. 337

Illustrations credits

p. 47 Photomontage from a photo from the NASA database ©
p. 17 Variation on the Superman theme created by Jerry Siegel and Joe Shuster
p. 25-26 Jacobs House, architect: Frank Lloyd Wright, Madison Wisconsin, USA
p. 26 Positive House DTHsur, Copenhagen, Denmark
p. 26 Pléiade House, architect: Jaspard, Louvain-La-Neuve, Belgium
p. 88 Schock© structural thermal break profile
p. 112 Image of a non-air tight connection, source: www.luftdicht.de
p. 137 Illustration: membrane and beam + ridge tile; source: magazine CSTC-Contact nr. 33 (2012)
p. 130 Detail of wall base ©Recticel
p. 120 Condensation under the roof, source: Fraunhoffer Institut
p. 124 Condensation behind a vapour barrier, source: Fraunhoffer Institut
p. 133 Superficial condensation on the facade, source: Fraunhoffer Institut
p. 146 Cracking of the masonry surface due to frost, source: Fraunhoffer Institut
p. 147 Type of water repellent, source: Wacker Chemie A.G.
p. 151 Class of joinery performances, source: magazine CSTC-Contact nr. 33 (2012)
p. 169-171 39 Ventilation combinations, source: PassiefhuisPlatform and www.better-ventileren.be
p. 173 Type of ventilation, source: Enesta
p. 183 Dynamic simulation and report by CREA-TEC
p. 191 Commissioning, source: Annex 47 of the AIE
p. 193 Dynamic simulation by CES
p. 196-198 Dynamic simulation and report by Architecture et Climat and Matriciel
p. 218-219 Blue House Award 2013
p. 244 Results of blower-door test measurements by Haufman and Dupont
p. 245 Results of blower-door test measurements by Isoproc
p. 250 Electromagnetic spectrum, source: FLIR©

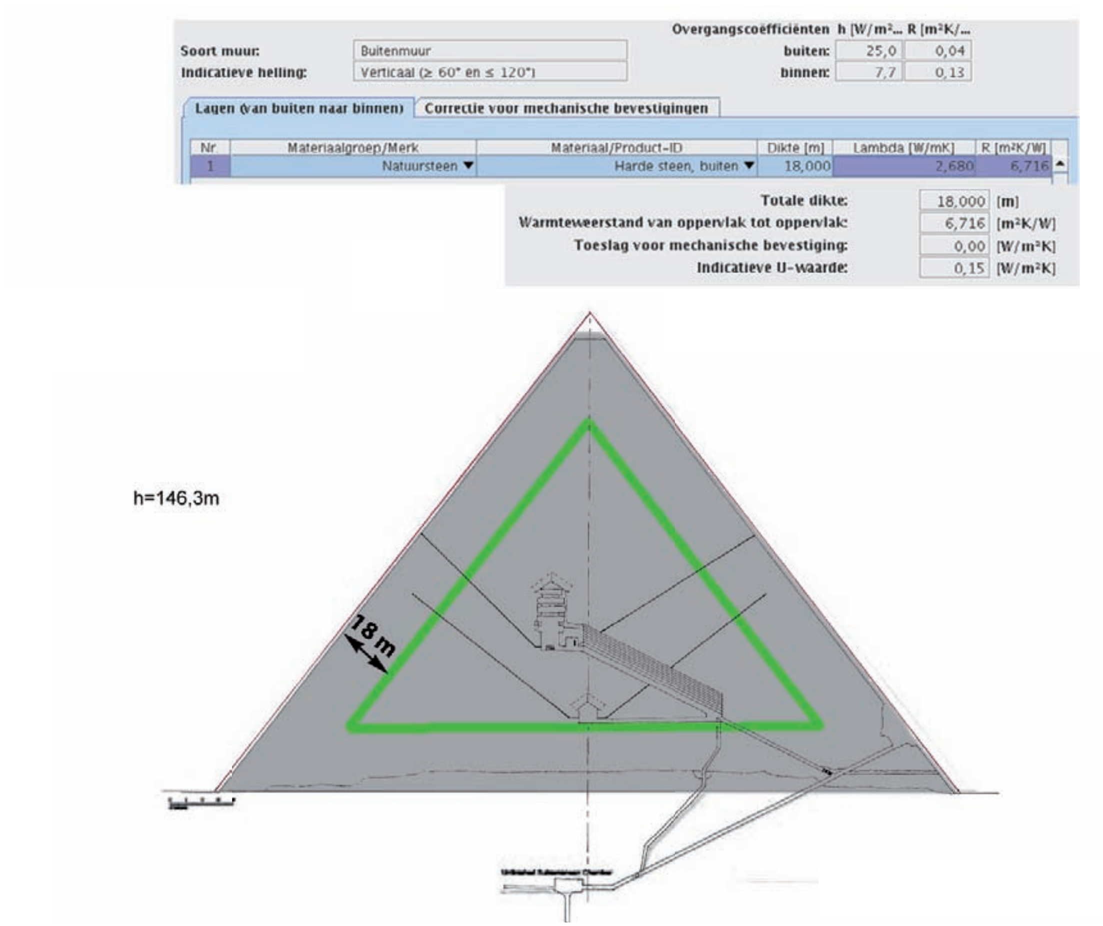
p. 251 Thermography applied to a smartphone, source: FLIR ONE©
p. 351 CEN/TC 350 evaluation system (source: CEN AFNOR standardisation)

Index of projects

House in Eupen | Eupen | Famille Henz-Noffalise | FHW > 144
House in Oudenaarde | Oudenaarde | Dirk Van Dorpe | Dirk Baart & Bernard Libert > 337
House in Lodernael | Innsbruck | Neue Heimat Tirol, Gemeinnützige WohnungsGm-bH, Innsbruck | architekturwerkstatt din a4 en teamk2 [architects] ZT GMBH > 311
Province Antwerpen HQ | Anwerpen | Province Antwerpen | XDGA > 8, 232
House in Brussels | Brussels | private | Amandine Sellier & AAC Architecture > 361
House in Hoeilaart | Hoeilaart | M and Mme Geers-Liebaut | Eugeen Liebaut > 346
House GBL | Lokeren | Gert Stuyven & Bea Hageman | BLAF architecten > 8, 30, 36, 378
House in Sint-Niklaas | Sint-Niklaas | Tom Segers & Leen Waterschoot | BLAF architecten > 318
House Latapie | Floirac | private | Lacaton & Vassal > 373
Medical house | Ciney | CESI | Atelier 4d > 8
House Montagne street | Uccle | Gerard Bedoret and Véronique Damas | Gerard Bedoret > 9, 358
Maison de l'emploi and childcare | Forest | Municipality of Forest | A2M > 9, 54
Maison de l'emploi | Ixelles | Administration communale d'Ixelles | A2M > 183-184
OostCampus | Oostcamp | Municipality of Oostcamp | Carlos Arroyo > 374
Court building of Hasselt | Hasselt | n.v. SOHA | J. MAYER H. Architects, a2o-architecten, Lensºass architecten > 229
Parlement de la Communauté Française | Brussels | Parlement de la Communauté Française | Cooparch-r.u. > 9
Passivehouse Darmstadt-Kranichstein | Darmstadt | Passive House Developers Society | Professor Bott- Ridder- Westermeyer > 28
Sport hall | Schaerbeek | Municipality of Schaerbeek | O2 architects > 9, 157
Soap factory Heymans | Brussels | CPAS of Brussels | MDW architecture > 317
FBZ HQ | Brussels | FBZ | A2M > 40, 103-108
Holcim HQ | Nivelles | Thomas et Piron | A2M > 8, 86, 162-163, 199
Brussels Environnement HQ | Brussels | Project T&T | Cepezed > 9, 48, 189
Princess Elusabeth Polar Station | Antarctica | The International Polar Foundation | Samyn & partners > 26
Three Thermal Bubble | Vetroz | Ecole Les Plantys | Philippe Rahm > 386
Trebel | Brussels | Atenor Group | Jaspers-Eyers architects > 9
WTC IV | Brussels | Befimmo | Jasper-Eyers architects > 9

The first passive house?

The very first passive house according to BLAF architecten: the pyramid of Giza (Egypt) where 18 m of stone wall => U value = 0.15 W/m².K ...



Contributors:
Abdennour Aananaz, engineer, deputy director, Democo sa
Aline Branders, architect, A2M scsprl
Bram De Meester, civil engineer, ARCADIS sa
Bernard Deprez, architectural engineer, lecturer at the faculty of architecture of the ULB (French-speaking Free University of Brussels)
Stéphane Desmet, Institut scientifique de Service public (ISSeP) Wallonia, direction des risques accidentels, Cellule " Contrôle et certification "
Daniel Devroey
Marny Di Pietrantonio; architectural engineer, director of PMP asbl
Sabine Leribaux, architect, director of Architect Associés sc
Frédéric Loumaye, attorney-at-law at the Brussels bar
Benoit Meersseman, architectural engineer, JZH sprl
Sebastian Moreno-vacca, architect, director of A2M scsprl
Julie Willem, architect, director of be.passive asbl

The publication of this book was made possible through the grant n° IBGEBIM/ ENERGIE/ E{3.205 and the proofreading of Bruxelles Environnement:
Grégoire Clerfayt, director ff
Yannick d'Otreppe, project manager
Hilde Carens, project engineer
Thibaut Hermans, chief of département
Gaëtan Quinet, project manager
Thierry Vandergoten, project manager

Translation into Dutch
Kathleen Kempeneers
BDD translation

Translation into English
Michael et Richard Lomax

Proofreading in English
Julie Georges Garkov

Graphic design and prepress
Julie Willem, Sebastian Moreno-Vacca

Graphics
EVRST
Paolo Gavazzi

Thermal bridge simulations
Jade Deltour

Printer
CLAES-ROELS

The first passive house?

The first complete and functional passive house was, was not a house at all, but a boat –Fridtjof Nansen "Fram" (1883). He had this to say in his memoirs:

"…The walls are covered with tarred felt, then a layer of cork, afterwards fir woodwork, then another layer of felt, then airtight linoleum and finally new wood panelling. They are about 40 cm thick in all. The window, through which cold could get in particularly easily was protected by triple glazing and in other ways. This provides a pleasant and comfortable living space. Whether the thermometer drops below 5°C or 30°C, there is no fire in the stove. The ventilation is excellent… since we discharge the winter cold air with a fan. I am playing with the idea of getting rid of the stove. It's in the way, if anything."

The Austria passive platform has estimated the "U" values of the components: the average is 0.1 W/m².K !
Read: "Dans la nuit et la glace" [In Night and Ice], F. Nansen 1887
> www.fram.museum.no/en/