LYCÉE SAINT-JACQUES

Can passive house be the solution to our energy problems, and particularly with solar energy ?

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Abstract

I wrote this document as a "final work", by ending my secondary school, in the Lycée Saint-Jacques, in Liège.
Firstly, I wanted to write a document about WiFi technology, but my professor asked me to write about passive houses.
Note to the reader: Read it carefully, because it was written in January 2008: many elements have changed since that month.
Some passages (and some figures too) are written in French because I had to write this present document this way.

Résumé

J'ai écrit ce document comme un “travail final”, pour la fin de mes études secondaires au Lycée Saint-Jacques, à Liège.
D'abord, je désirais écrire un document à propos de la technologie WiFi, mais mon professeur me demande d'en écrire un à propos des maisons passives.
Note au lecteur : Ce document est à lire prudemment, car il fut écrit en Janvier 2008 : beaucoup d'éléments ne sont plus les mêmes quant aux maisons passives depuis cette date.
Certains passages (et figures) sont écrits en Français, car c'est de cette façon que l'on m'a demandé de rédiger ce présent document.

THANKS

Je désire sincèrement remercier ma mère, pour la motivation, l'aide, et le soutien qu'elle m'apporta durant la rédaction de ce présent document. Sans elle, peut-être n'y serais-je jamais arrivé. En tout cas, elle fit le travail que mon promoteur aurait dû réaliser.
Je remercie également Mr. Jean-Marc Guillemeau, du Centre Interdisciplinaire de Formation de Formateurs de l'Université de Liège (CIFFUL), qui apporta une supervision postérieure à la date de rédaction de ce travail.
Tout ceci sans non plus oublier Mr. Paul Wagelmans, également du CIFFUL.
Finalement, un remerciement sincère va également à mon professeur d'Anglais, Mme. Frederick, qui m'a compris et écouté (Lycée Saint-Jacques rhétos promotion 2007-2008).

CHAPTER 1

INTRODUCTION

Contents

From small beginning come great things.
– ANONYM.

1.1 Motivations: problematics

WE're progressively destroying our planet, by the daily emission of more and more intense pollution.
Furthermore, since 1850, the energy needs are highly increasing, and the estimated needs will still increase from 54% in the 20 next years.
The fossil energies are also becoming rarer and rarer.
So, against this worldwide problem, we must find solutions.
Reducing the energy's consumption and improving the energies called "at sustained development".
Different solutions coexist, in many domains; it is high time to experiment, to analyze and to compare them, to prevent the human consumption from harming more the Earth environment.

Later, we shall have to choose an energy source for our house; that is why we are "actors of tomorrow's environment".

1.2 Working hypothesis

1. Use, creation, and exploitation of technologies called "at sustained development" would be primordial for the environmental wellness (reducing the pollution, and the energetic waste);
2. The passive house seems to be an appropriate solution to reduce the energy consumption;
3. The different technologies, among others, the use of solar energy, applied or not to the passive house would go in the way of this approach.

1.3 Working method

We are going to try to explain the way and the conditions of a passive house, associated, or not, to the new technologies, and, after, analyze the results, in favour of the environmental wellbeing.

We intend to explain the different architectural and environmental characteristics which make a house less "greedy", and detail the cost of such a house.
We also want to check the interest of privileging the solar energy, and, especially clarify the use of solar panels (photovoltaic and thermal).

Furthermore, the electrical providing of a house by solar energy seems to take on other advantages than to protect our planet: production and use of electricity in the farthest places, resale of electricity produced by the consumer to the network, or the regional premiums offered to the future builders.

We also think that giving a clear opinion about this rising technology is very important, so that the future decisions will be taken knowingly.

We are going to weight the pros and cons about the use of solar energy; so, trying to answer our work's question: can solar energy be the (or one) solution to resolve the problems linked to the non-renewable energies (their future shortage, their danger, . . .), and if so, at which level?

CHAPTER 2

PASSIVE HOUSE

Contents

The beginning is scary; the end is usually sad, but it's what's in the middle that should count.
– ANONYM.

2.1 Introduction and definition

A PASSIVE house is a house where the energy losses are reduced to the minimum by using different technologies.

These have two fundamental principles: optimizing the basis conditions (making the basic houses' components more performing) and minimizing the losses (keeping the house's warmness). See appendices figures A.0.1 and A.0.2.

There are fixed norms detailed in appendices. See B, p.III.

The passive house also uses the solar rays by using many sophisticated technologies (PV panels: electricity production and thermal panels: sanitary warm water $[SWW]$ producing, and heating).

In this chapter, we will use the *U factor* notion, detailed further (see *U factor*), and in the appendices. See D, p.VI, or the lexical, p.47.

2.2 Optimizing-performance conditions

A passive house plays on different factors to restrict the energy consumption:

1. The architectural ordering (and the solar exposition and geographical conditions);
2. The insulation;
    (a) having the most inferior *K factor*;
    (b) being airproof;
    (c) avoiding thermal bridges (temperature difference, which could come from a weakness in the layer);
3. The characteristics of the materials used; the windows;
4. The mechanical ventilation double-flux with air exchanger;
5. (The Canadian/Provençal well, which is not essential for a passive house);
6. The use of the sun: photopiles and thermopiles;
7. The user's behaviour.

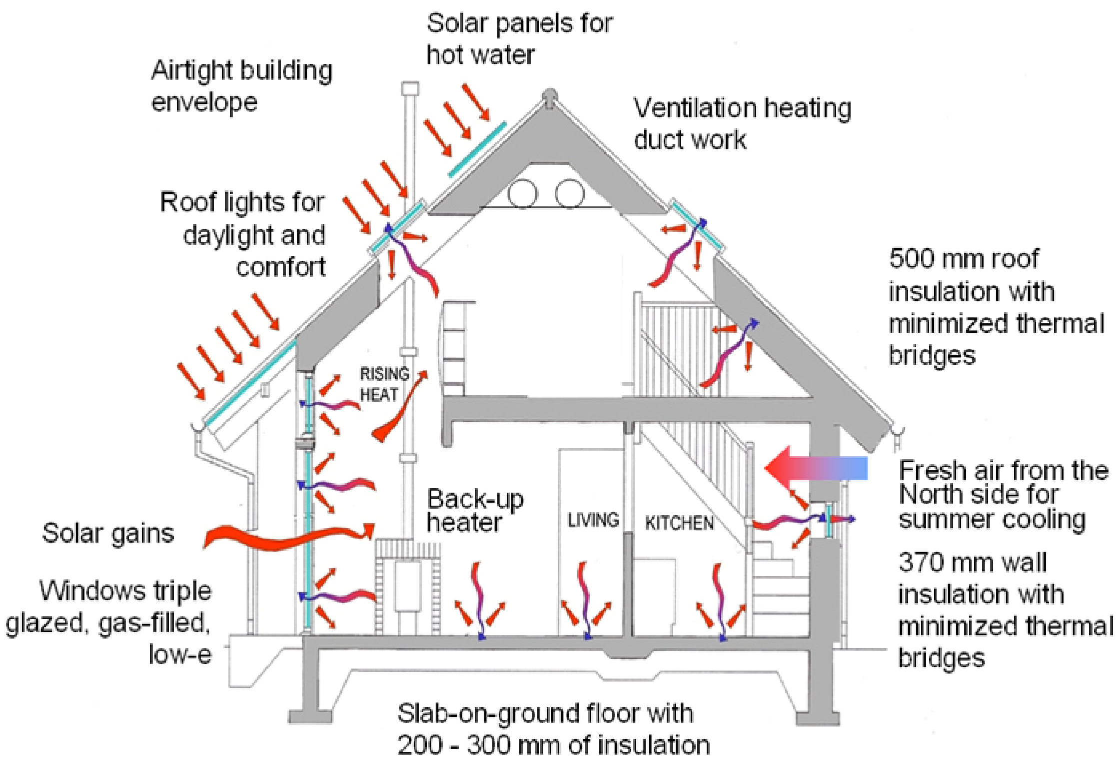


Figure 2.2.1: Optimizing-performance conditions.

2.3 Solar exposition and spatial layout

To optimize a passive house's output, we must think about:

1. Protecting from dominant winds;
2. Avoiding valleys and shady places, such as northern slopes (see figure 2.3.2) or the north side of dense forests or high buildings;
3. Avoiding over-shading from neighbouring buildings, non-deciduous vegetation (so, avoid planting near the house), railings, balconies, roof non-optimized-overhangs, *etc.* (see figures 2.3.3 and 2.3.2);
4. Preferring the house which is adjacent to another, or, if it is possible, even grouping passive houses or even making an "ecological village", such as in Freiburg, Deutschland, to lower the energy demand from 15% to 30%;
5. Exposing the house: ±30° of south orientation to benefit from the best of the sun, with south-facing windows areas (because, e.g. a $1\,m^2$ North-oriented-window receives 50 W, when a $1\,m^2$ South-oriented-window receives 150 W);
6. Avoid overheating (in summer) by using (see appendices C.0.1, p.V for more information):
   (a) a sloping roof;
   (b) or optimized overhangs of roof structures (see figure 2.3.1), for south orientations;
   (c) or solar shades (*i.e.* sliced-stores), useful until 1 P.M., because, after 1 P.M., the sliced-stores take over, because the sun's lower;
   (d) or a mobile protection, for west and east orientations;
   (e) or greenery, that looses its leaves in winter, so that, in spring and summer, because of the leaves, the solar rays can't come through (see figure 2.3.3);
   (f) or, if it is very necessary, by setting a higher ventilation rate (see figure 2.6.4, p.20), it also minimizes the risk of condensation on surfaces of windows.
7. (Placing solar panels with an angle included between 30° and 45°);
8. (Using a tracking-array (it is a device where the PV panels are put on, this device follows the sun trajectory) because it increases solar input from 15% to 40 %).

Figure 2.3.1: A passive house with optimized overhangs, at 2.P.M..

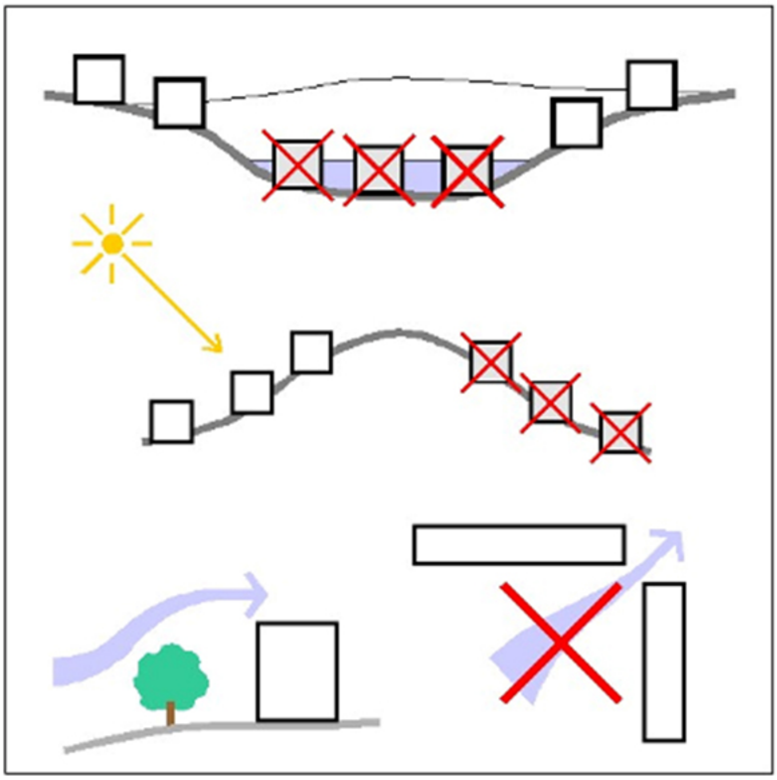


Figure 2.3.2: Optimum site offers for a possibility to use passive solar energy efficiently, however, Passive House design emphasizes technologies that do not depend on solar irradiation.

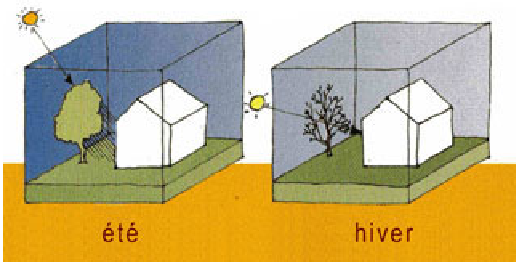


Figure 2.3.3: A house in the two fundamental seasons (French).

2.4 Architectural arrangement

It is also interesting to minimize the external surface areas, so the heat loss (because the heat is more rapidly lost on external surface), by creating a compact house.
The "warm" rooms should be put as near as possible to the other rooms, so as they can warm them, e.g. putting the sauna (if there is one, to relax after work) and the boiler room in the middle of the house (see figures 2.4.1, 2.4.2 and 2.4.3).

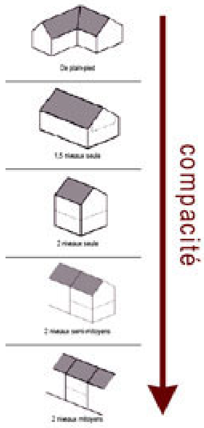


Figure 2.4.1: Degrees of compacity of a house (French).

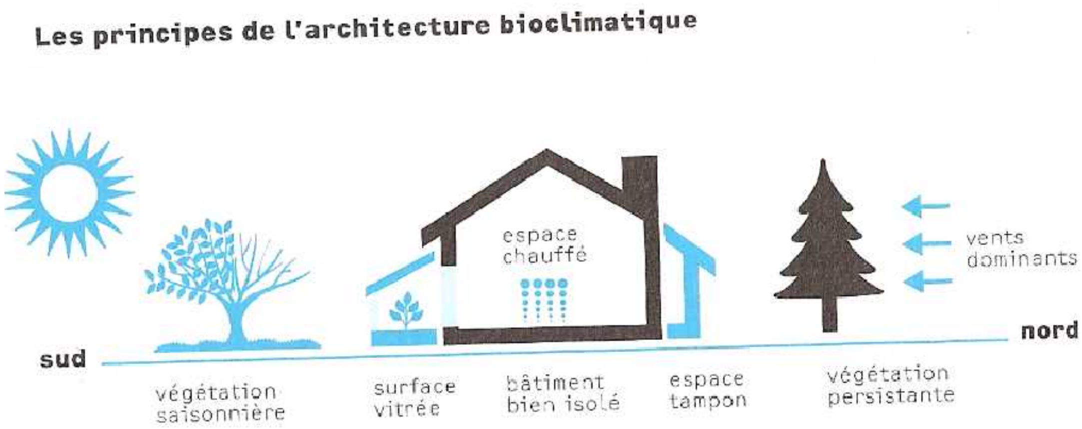


Figure 2.4.2: Principles of bioclimatical architecture, 1/2 (French).

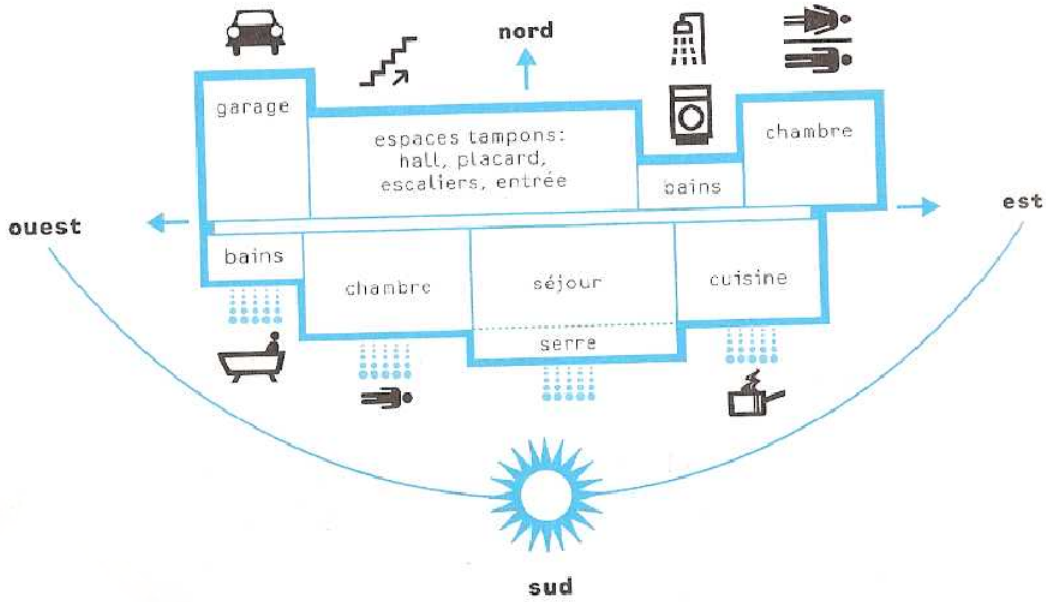


Figure 2.4.3: Principles of bioclimatical architecture, 2/2 (French).

2.5 Insulation

The insulation and airtight are very important to prevent from heat losses. Every layer of the house must be isolated, so as the insulation is not discontinued. Some layers of the house require more isolation than others. For example, the floor must be less isolated than the roof, because the floor is always warmer than the roof, even in winter.

Insulation of: frames, windows, floor, roof, walls (furthermore, if there are any radiators, it is simple to put a reflecting panel behind them), and of the plumbing (water, heating valves, vent pipes).
Furthermore, sewage and water lines must be short too.
Insulation must prevent sewer and cold water lines from condensation and freezing.

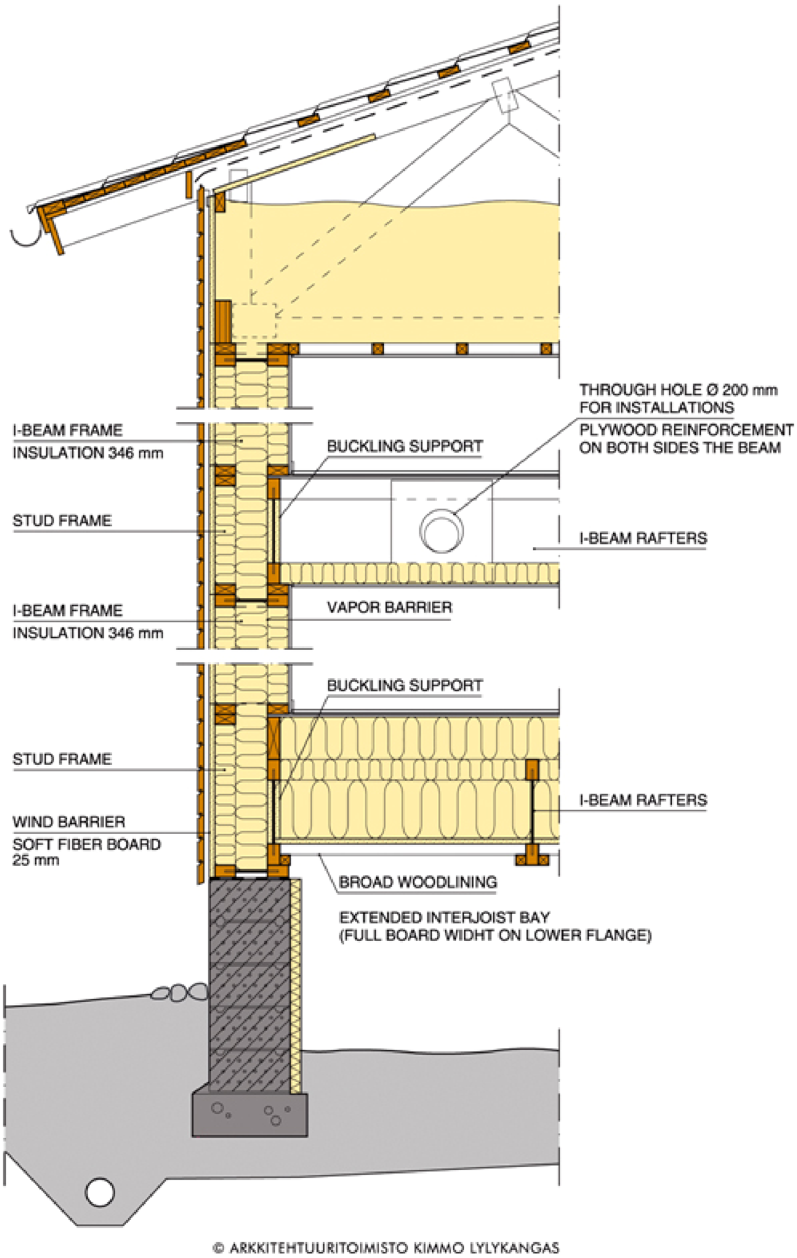


Figure 2.5.1: Building envelope's thermal properties need to be accurate for heating system design.

2.5.1 Four pillars to avoid thermal bridges, and to minimize the heat losses

1. Where an interruption in the insulation is necessary, the thermal resistance (in the insulation plan) must be as high as possible;
2. In the building's connections, insulation layers must join each-other thoroughly;
3. Preferring obtuse angles, because acute angles favour heat waste;
4. The ventilation must be double-flux (with air exchanger), to renew the house's air as much as possible.

Nota bene: The four pillars to avoid thermal bridges are illustrated by the figures 2.5.2 and 2.5.3.

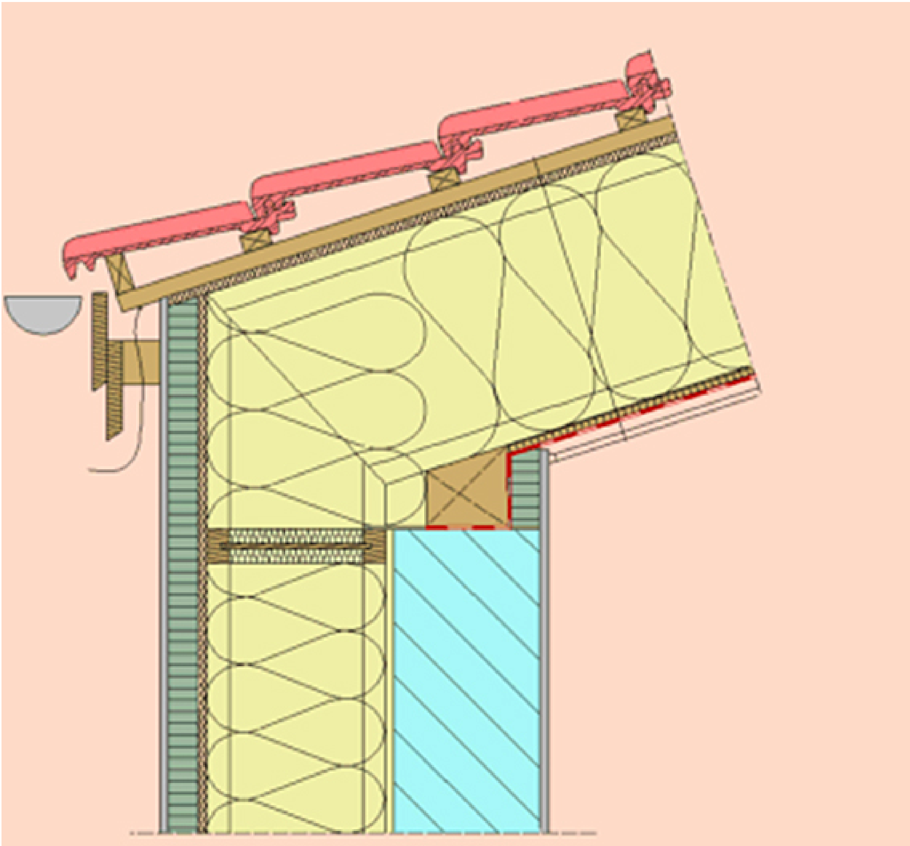


Figure 2.5.2: Thermal bridges need to be included into the thermal design of the building envelope, but they should be avoided as far as possible. (PHI)

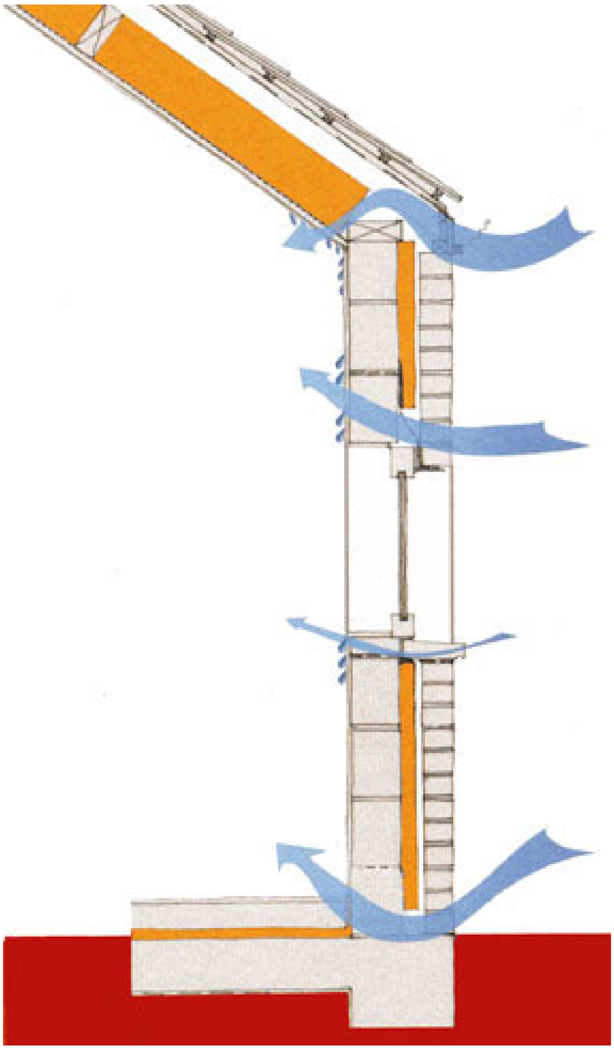


Figure 2.5.3: Thermal bridges-risk areas.

Some tests exist to check whether the house is airproof or not, for the outer air.
Among them, there is, e.g. the Blowerdoor test, (see figure 2.5.4) which allows to hunt out the leaks. There is also the thermograph (see figure 2.5.5), the anemometer, or the artificial fume.

Figure 2.5.4: Blowerdoor test.

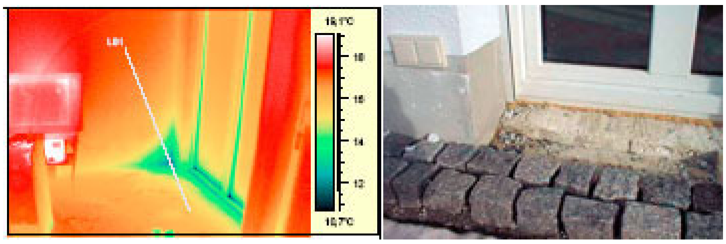


Figure 2.5.5: Thermography: on the color scale, blue and green show the coldest temperatures, and illustrate the heat loss.

2.5.2 U factor

Definition 2.5.1 (U factor)**.** The *U factor* represents the quantity of heat loss (as a flux) through a material ($1\,m^2$), for a temperature difference of 1°C between indoor and outdoor.
It is expressed in $W\,m^{-2}\,K^{-1}$ in Europe.

Property 2.5.1. *When the U factor is high, the thermal transmission is high, so the insulation is low, and reciprocally. The ideal U factor is lower than* $1.20\,W\,m^2\,K^{-1}$*, but it is changing, depending on the kind of layer.*

There are other factors, detailed in the appendices. See D, p.VI.

2.5.3 Passive house / Traditional house: comparison of their U factor

By comparing the respective *U factors* of the two houses' components (passive and traditional), we can see how the passive house is insulated.

House's component	**Maximum *U factor*** ($W\,m^{-2}\,K^{-1}$)	
	Passive House	Traditional house
Wall	0.15	2.2
Floor	0.15	0.9 (isolated)
Roof	0.15	0.45 (isolated)
Window	0.80[1]	5.8 (simple-pane), 3.3 (double-pane)
Mounted window (=window and glazing)	0.85	2.68
Door	0.80	1.25 (for PVC)
		2.69 (for Alu) or 1.5 (for isolated Alu)

Table 2.1: Passive house / Traditional house : comparison of their *U factor*.

Here is a concrete example of the insulation in a passive house, in Tennevilles, Belgium:

Component	**Details**	***U factor*** ($W\,m^{-2}\,K^{-1}$)
Foundation slab	Betony, insulated with 5 cmof cellular glass.	
Floor	On ventilated cellar, built on betony roughcasting, insulated from the bottom with 20 cmof EPS, and standing on 5 cmof cellular glass, to prevent from thermal losses.	0.15
Walls	Full betony, EPS, and betony blocks (Stepoc), 20 cmthick.	0.10
Windows	Triple-pane ROTO.	0.68
Roof	Self-supporting coffers, containing 13.3 cm. of EPS, and sub-coffers insulated with 20 cmof EPS.	0.09
Maximum air speed in the Canadian well	$1.8\,m\,s^{-1}$	
Ventilation rate	$357\,m^3\,h^{-1}$	
Floor area	$108\,m^2$	

Table 2.2: Concrete example of the insulation in a passive house, in Tennevilles, Belgium.

2.5.4 Advantages and disadvantages

See advantages and disadvantages of the passive house (summary draw, point 2.9, p.32).

2.5.5 Used insulating materials characteristics

Definition 2.5.2 (Thermal insulator)**.** A thermal insulator meant for building is a product with a low thermal conductivity, expressed in $\mathrm{W\,m^{-1}\,K^{-1}}$, or in $\mathrm{W\,m^{-1}\,F^{-1}}$, then a conductivity lower or equal than $0.065\,\mathrm{W\,m^{-1}\,F^{-1}}$, so a high thermal resistivity (higher or equal than $0.5\,\mathrm{m^2\,K\,J^{-1}}$).

If it is not the case, the thickness must have to be higher to reach the same result (U=0.15). It is clearly visible on the figures 2.5.6 and 2.5.7.

The U coefficient also plays a role in the glazing, and in the frame, depending on their respective qualities (cf. figure 2.5.8, p.16).

To obtain a good thermal insulation, it is important to keep a maximum of heat where it is needed to, and, to avoid the heat losses, to keep an adequate temperature (20°C, in a passive house), with no use of appoint heating.

Matériau	Conductibilité thermique en W/mK	Epaisseur en mètre pour U=0,13 w/(m²K)
Béton ordinaire	2,100	15,80
Brique	0,800	6,02
Brique aérée	0,400	3,01
Bois de résineux	0,130	0,98
Brique isolante	0,110	0,83
Paille	0,055	0,410
Isolant conventionnel (laine de verre, cellulose, polystyrène,...)	0,040	0,300
Isolant plus performant (Mousse de polyuréthane,...)	0,025	0,188
Panneau isolant sous vide	0,015	0,113
	0,008	0,060

Figure 2.5.6: Kinds of materials, their thermal conductivity, and their thickness for a 0.13 U (French). Note that the value of 0.025 is often replaced by 0.028.

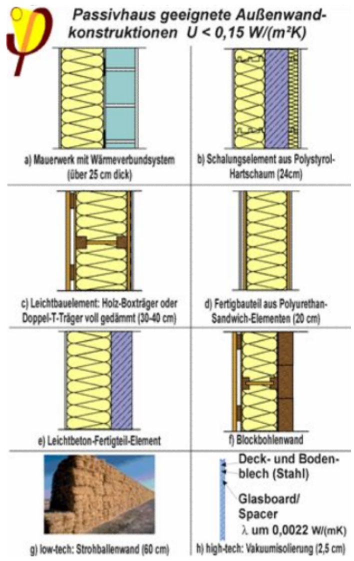


Figure 2.5.7: Kinds of insulating materials.

Type de châssis		Châssis en bois	Châssis en PVC				Châssis en polyuréthane (PUR)	Châssis en métal (aluminium, acier, ...)					
			avec plusieurs chambres		à une chambre			avec coupure thermique				avec assemblage par point	sans coup. thermique
			sans renfort métal.	avec renfort métal.	sans renfort métal.	avec renfort métal.							
U_{ch} : W/m²K		1,80	1,50	1,70	2,80	3,00	2,90	3,50	3,80	3,90	4,20	4,80	6,00
VITRAGES													
Type de vitrage	Uv : W/m²K												
Simple vitrage 4mm	5,70	4,53	4,44	4,50	4,63	4,69	4,86	5,45	5,23	5,25	5,33	5,48	5,78
Double vitrage Standard	2,88	2,71	2,62	2,68	3,01	3,07	3,04	3,19	3,26	3,29	3,36	3,51	3,86
Double vitrage basse émissivité (HR) avec air	1,75	1,98	1,89	1,95	2,28	2,34	2,31	2,40	2,47	2,50	2,57	2,72	2,81
Double vitrage basse émissivité (HR) avec argon	1,32	1,67	1,58	1,64	1,97	2,03	2,00	2,08	2,15	2,18	2,25	2,40	2,49
Double vitrage basse émissivité (HR) avec krypton	1,20	1,59	1,50	1,56	1,89	1,95	1,92	1,99	2,06	2,09	2,16	2,31	2,40

Figure 2.5.8: Comparison of U, depending on the glazing and frame qualities (French).

2.5.6 Windows

1. Using the minimum of windows in North exposure, to avoid thermal losses, but using a lot on the South, orientated from South-East to South-West for a maximal insolation (see figure 2.5.9); the aim is to avoid from overheating;

2. They should be triple-pane and Low-E (low-emissivity), so they should have an invisible layer of metal oxides which allows the incoming light to come through, but which blocks the interior heat ray (Ar or Kr).
   If it is not possible, double-panes windows with a heat-mirror should be used. Quadruple-panes windows are less interesting, except for their weight (because the quadruple-glazed windows are not really composed by four layers), which is lighter (see figure 2.5.10);

3. They must be perfectly airproof, and have a good *U factor* (see figure 2.5.8, p.16).

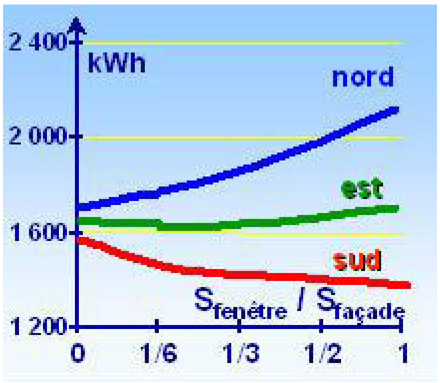


Figure 2.5.9: Heating needs, according to the glazing proportions and orientations (French).

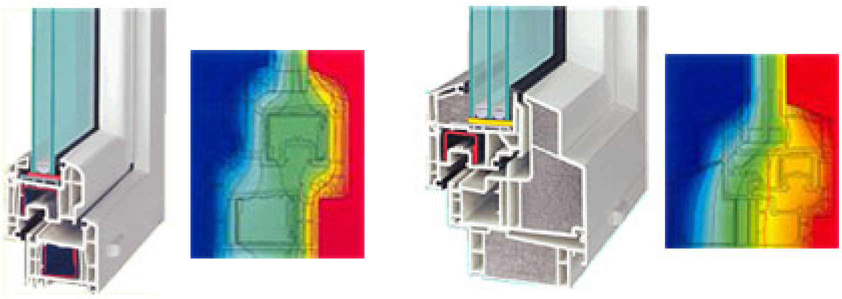


Figure 2.5.10: Comparison between double and triple glazing, in a frame. Thermography shows a warmer (orange) right interior area than the right interior area of the double glazing.

2.6 Mechanical ventilation: why and how ?

The mechanical ventilation is an essential component in a passive house because of its different advantages. The passive-house's ventilation is a double-flux one, and called (for "Electrical Controlled Ventilation"). For more information, see the lexical, p.47.

2.6.1 Why using a mechanical ventilation ?

Its aim is to renew the house's air –without any thermal losses– by bringing purified and warmed air, because, in theory, the windows are never opened and the air quality is very important for the house's inhabitant.
To purify air, and to have a good air-climate, it is important to:

1. Filter the air with different filters;
2. Evacuate:
   (a) Bad smells and dangerous substances, such as chemical products in the air, e.g. coming from the used materials
   from the building;
   (b) Moisture (by diminishing humidity level: (the mirrors are not misted up anymore !).
3. Lower the CO_2 level, which is coming from the person's breathing.

Another aim of the ventilation is to heat the houses' air in winter, thanks to the warm, outgoing and vitiated air recuperation[2] and its heating; in summer, it has to cool it down, so the temperature in the house is always the same, all the year long, and in all the rooms (see figure 2.6.4, p.20).

2.6.2 Way of work

The principle of the mechanical ventilation is the following: fresh air is taken to dry rooms (e.g.: living, personal rooms, ...), and evacuated in moist rooms (bathroom, ...).
Air is carried by the alimentation / air evacuation apparels, or by "transfer openings" in the doors or the dividing walls, travelling through corridors and stairs.
As dry air has a high pressure, and wet air a low pressure, an air flux is created, so the smells (coming from kitchen, toilets, ...) are not brought to living rooms (see figures 2.6.1 and 2.6.3).

The ventilation system has an output from 75% to 95%; that's why it is a heat-exchanger between polluted warm air (coming from the wet rooms) and fresh incoming air put in dry rooms.
Exhaust air is sent outdoor (see figures 2.6.1, 2.6.2 and 2.6.3, p.19), fresh air is pre-heated.

Even if mechanical ventilation uses up additional energy, it is not that much in regard to the heat losses of a natural ventilation system.

The best is to put the air-to-air exchanger near the thermal insulating envelope (*i.e.* in the insulating envelope, or at the lower floor).
Place the air heater inside the insulated envelope, and provide additional insulation to the central unit and air heater as appropriate, to avoid noises and thermal losses.

[2] which preheat the coming air

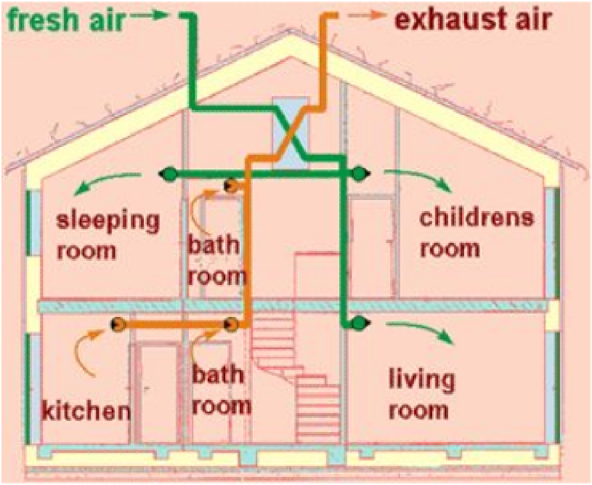


Figure 2.6.1: The way the ventilation works (1/3).

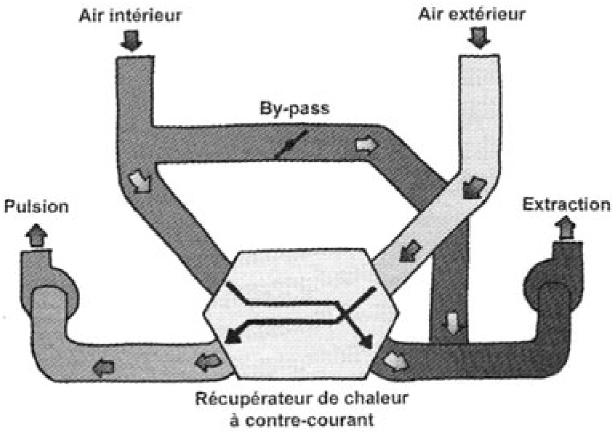


Figure 2.6.2: The way the ventilation works (2/3) (French).

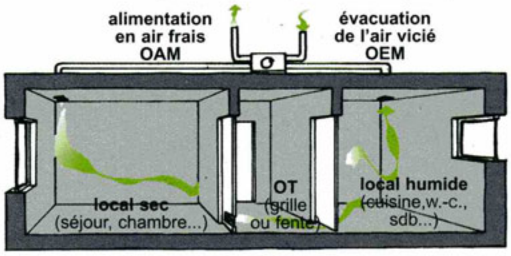


Figure 2.6.3: The way the ventilation works (3/3) (French).

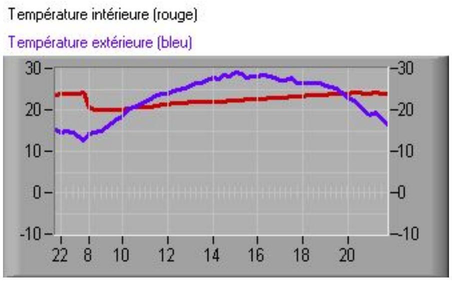


Figure 2.6.4: Heat wave: when the ECM is active, the house's temperature keeps constant (French). In X, we have the hours.

2.6.3 Advantages and disadvantages

See advantages and disadvantages of the passive house (summary draw, point 2.9, p.32).

2.6.4 The Canadian / Provencal well

The Canadian well is a kind of ventilation which is complementary to the mechanical ventilation, because the differences of temperature of the outdoor exhausted air (conditioned) are compensated by the air passage and its natural warming in the underground corridor of the Canadian well.

The principle is the following: the air, coming from outdoor, moves in a tunnel in the ground (at 1.5 mdepth), then, goes to the mechanical ventilation; in summer, by passing in the ground-tunnel, it becomes colder (because the ground is colder then the air), so, it cools the ventilation's air.

At the opposite, in winter, by passing in ground-tunnel, it becomes warmer (because the ground is warmer then the air), so it warms the ventilation's air (see figure 2.6.5, p.21).
Globally, it permits to diminish the coming-air temperature from 5°C to 8°C.
The Canadian well's slope must be from 1,5 to 2 m of depth (preferably under water, to have more freshness in summer), and from 30 to 40 m long, situated under the house and the garden.
At the end of the air-ground exchanger, it is better to put a condensation outlet, to avoid moisture in the underground corridor.

As the air coming from the Canadian well is naturally dry, because of its passage in the dry underground corridor, it is better not to have a too big air debit, to avoid humidity values lower than 30 %, because 30% is a comfortable humidity rate.
In a passive house, the air renewal-rate (expressed in $m^3\,hour^{-1}$ is reduced of half, compared to the traditional house's one, that justifies a lower thermal loss.

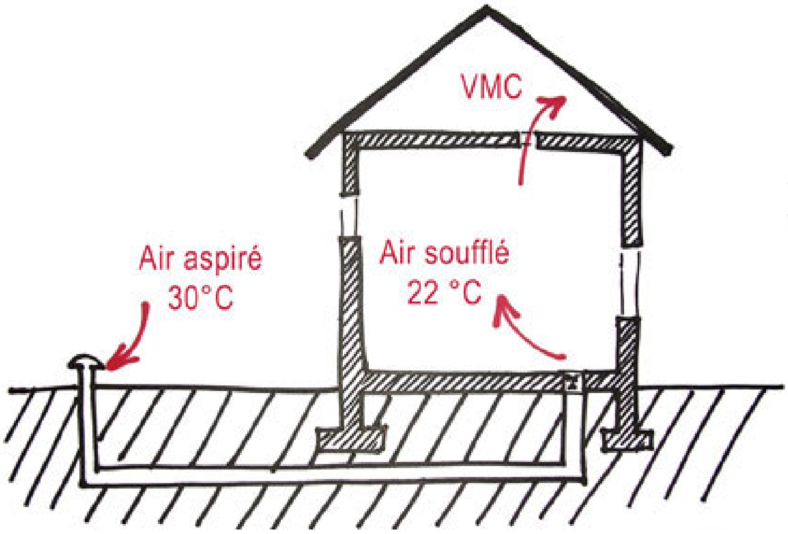


Figure 2.6.5: The Canadian well (French).

2.7 Solar use: photopiles and thermopiles

The solar energy is the energy coming from the sun.
We can optimize the solar output thanks to new technologies, to capture, amplify, transform, and stock solar energy.
For the passive house, we will develop particularly two technologies: the thermopiles, and the photopiles, which will be able to improve the passive house's performances.

2.7.1 Thermal solar energy - Solar thermopiles

Solar thermopiles have an easier way of work than photopiles.
The principle of work is the following...

A flat captor, is covered by a glass, to generate a greenhouse effect, and, coated by a paint which is mat (to avoid reflections) and dark (to have a good absorption coefficient). It is also insulated to limit the calorific losses.

This captor is set with a sloping angle included between 30° and 45°, to be maximally displayed under the sun; it must also be east-west oriented, and with a sloping angle superior to 10°than the geographical latitude, to obtain a better output.

It is composed of many pipes, and receives the solar energy.
When the sun rays reach the receiving pipes, which contain a fluid, water or an antifreezing one (most often water in warm areas), the fluid is heated and sent from the bottom part, to be gathered at the top (see figures 2.7.1 and 2.7.2, page 22).

Because of the radiations irregularity, we must think about water stocking, in the best conditions possible so as to keep it warm.
The water can stay in the flat (captor), depending on the needs, but it is better to stock it in a lagging tank (see figure 2.7.2, p.22).

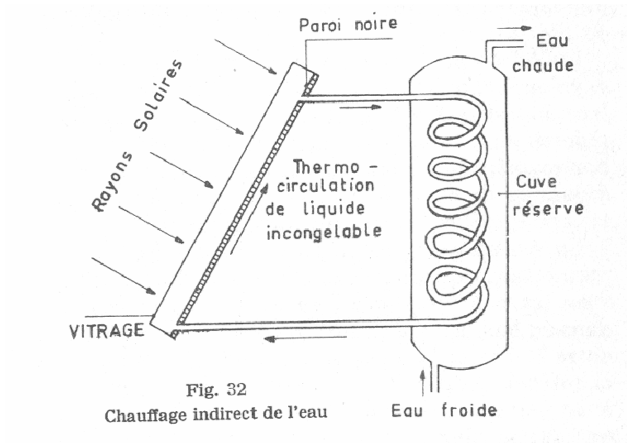


Figure 2.7.1: A thermal installation (French).

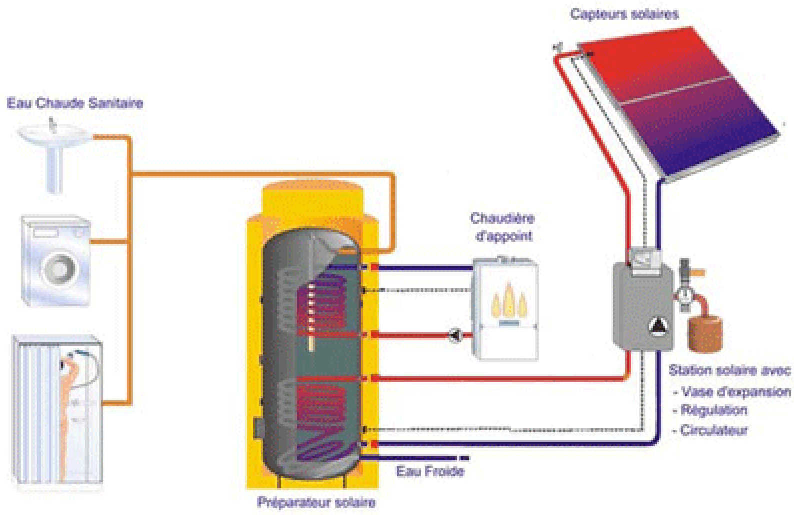


Figure 2.7.2: A thermal installation for production of hot water (French).

We can calculate the output by using the flat-captor's theory.

Property 2.7.1. *The W_u energy taken by a fluid (of a specific C heat and a D debit) is given by:*

$$\boxed{W_u = DC(T_2 - T_1)}, \tag{2.7.1}$$

where:

1. T_1 et T_2 are respectively the input and output fluid-temperatures, the two temperatures are expressed in °C;
2. $T_2 < T$ (collector's temperature), T is expressed in °C;
3. $C = 1$, because, in the simple systems of traditional manufacturing, water is directly warmed; under temperate latitudes, there is freezing risk. It is expressed in $\mathrm{kJ\,kg^{-1}\,°C^{-1}}$;
4. D is expressed in $\mathrm{m^3\,s^{-1}}$.

In temperate regions, the warmed liquid is not the used water. It is a liquid with a low-freezing point, e.g. water and antifreeze, like a car convector.

This liquid, when warmed in the solar-energy collectors, moves to a tank, or, better, to a serpentine which crosses the to-warm water's tank.
An additional electrical heating is also useful, when it starts automatically with a too-low water temperature.

The annual solar radiation rises up to $\frac{1000\,\mathrm{kWh\,year}}{\mathrm{m^2}}$.
For optimal use, the collector surface has to go from 1 to 1.5 $\mathrm{m^2}$/person (from 650 $\mathrm{kWh\,year^{-1}}$ to 1000 $\mathrm{kWh\,year^{-1}}$).

For a family fitting (a 300 L tank), a 4 to 5 $\mathrm{m^2}$ collector, if well oriented, can be enough to bring hot water, between 40°C and 50°C.

The solar thermal captors reach 80 % of output, today.
Generally, installations are built to cover from 30% to 70% of the annual heat needs and *SWW* (Sanitary Warm Water).

2.7.1.1 Advantages and disadvantages

See advantages and disadvantages of the passive house (summary draw, point 2.9, p.32).

2.7.2 Photovoltaic solar energy: Direct electricity production

2.7.2.1 The PhotoVoltaic (PV) cell

A PV cell, or photopile, is built from semiconductor materials.
These materials have electrical conductivity properties which are intermediate between those of metals and those of insulator; they also convert the light they receive into electrical charges.

It uses the Si technology, in its different forms: crystalline (or amorphous, "a"), mono (more expensive)- or poly (cheaper)- crystalline, which have respective outputs of 16% and 13 %.

During its building, the semi-conductor is enriched in impurities (doped), either to add electrons (that is n type), or to make it poorer (that is p type).

The PV cell is constituted of these two kinds of semi-conductors, they make the PN junction, which has the property to let current going in one way (diode).

2.7.2.2 Semi-conductors

1. The semi-conductors have a low-free charge concentration, and a crystalline structure. It means that the atoms are linked together by electrons from the external layer (valence electrons);
2. These liaisons are in equilibrium at the absolute zero.
   Therefore, there is no free electron. But we know that the electrical conductivity is due to the presence of free electrons, which are moved by an electrical field.
   Therefore, at the absolute zero, a semi-conductor behaves as a perfect insulator.
   At normal temperature, or, under the action of a radiation, the linking of the Si semi-conductor will break, and electrons will be freed.

All the semi-conductors have an energy called "band gap energy", called E_g, which is expressed in eV; it symbolizes the level at which an electron linked in its atom is freed, so it conducts the electric flow (1.1 eV for the c-Si and 1,7 eV for a-Si).

In the network, the vacant-let spaces are called holes. Symbolically, a positive charge is given to them. The electrons move in the network until they are grabbed by incomplete atoms, and fill holes. That's why the holes seem to move in the opposite direction from the electron moving direction.

In a pure crystal, the electrons and the holes are present in the same proportion, and it explains why the recombinations are frequent.
Then, the conductibility remains low. To improve the conductibility, it is important to use *doping*.

2.7.2.3 Doping of semi-conductors

It consists in introducing, in a tetravalent crystal, a tiny quantity of impurities, constituted by pentavalent atoms (so, they have 5 valence electrons).

These atoms will take their place in the network and, as all the possible liaisons are done, an electron is available for each impurity atom.
Just little energy will be able to take it from its nucleus, and to free it.
In this case, the impurity is called "giver".
Here, the electrons can easily move, and the probabilities of recombination are very small.

The semi-conductor gains then a very high conductibility.

We can obtain a similar effect by incorporating trivalent atoms, except that in this case, we have incomplete linking, and, there is an excess of holes (according to the symbolical definition here up). The impurity is called “accepter”.

So, when an electron is freed (under the action of temperature and/or light, *etc.*), it meets a hole in excess, it fills in this hole, but frees another hole.
Everything happens as there were free-positive charges, which explains a good conductibility.
When the electrons are in excess, we have a “n” semi-conductor (n for negative).
When there are holes, it is called “p” (for positive).
The usual introduced impurities rate is really tiny.

2.7.2.4 Energy bands in a crystal

We can distinguish two principal bands: the valence band, and the conduction band.
Between the two exists a forbidden band, where the electrons can’t be.
At the absolute zero, all the electrons are in the valence band.

If energy is given to the crystal, by temperature rising, or by illumination, the valence-band electrons can move to the conduction band. The passage of an electron from the valence-band to the conduction band is due to the break of a linking and the releasing of the electron.

For example, the necessary energy is the energy jump of crystal ΔE, which is of 1,09 eV for Si.
If the temperature is too high, the PV-module’s efficiency lowers heavily.

2.7.2.5 P-N Junction

A junction in a crystal is a low thickness area in which the conductivity goes from the p-type to the n-type.
This junction is generally obtained by diffusion of impurities so we obtain a n-region which is “rich in electrons”, and a p-region which is “rich in holes”.
We think that the electrons of the n-zone, during their excitement, will move to the p-zone where they will fill in the holes.

Therefore, in the n-zone, a “poor in electrons” area, near the junction, where many electrons are missing, is created.
That is why this area is positively-charged. Through the same reasoning, in the p-zone, we have a tight junction, where the holes are more filled in by the electrons, so, in average, negatively charged.
Between these two areas, charged of opposite signs, appears an electrical field, heading from p to n, that prevents the diffusion from continuing. See figure 2.7.3.

At the equilibrium, the field constitutes a barrier, called potential barrier, which plays an essential role in the photoelectrical way of work.

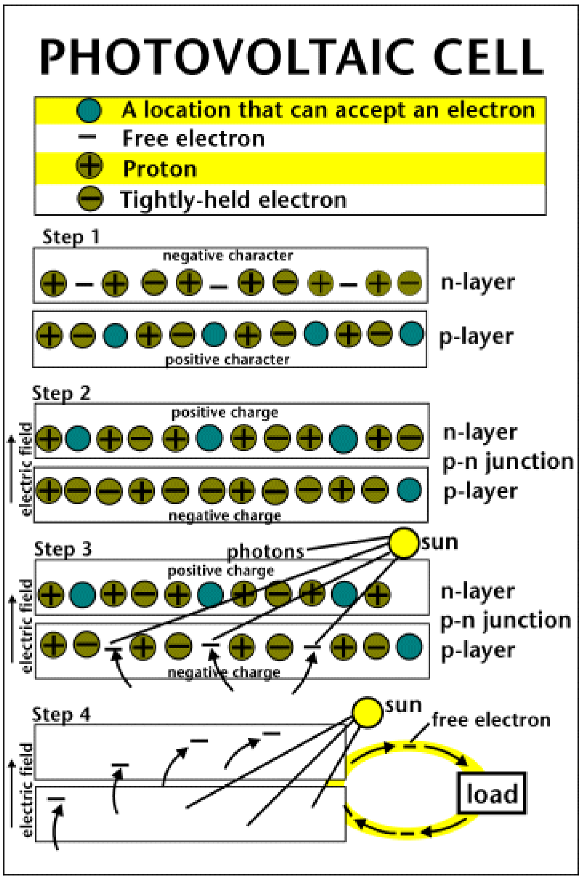


Figure 2.7.3: The way a photovoltaic cell works.

THE PHOTOELECTRIC EFFECT

When a photon of solar light has a sufficient wavelength ($\lambda < 1.1$ µm, for Si), it interacts with the Si atom, it excites an electron, and takes it off from its electronic structure.

This electron, attracted in the electrical field of the junction, produces a photocurrent, that we can easily measure by putting the cell in short-circuit. As

$$\lambda = \frac{v}{f}, \tag{2.7.2}$$

where:

1. λ is the wavelength (expressed in m);
2. v is the wave speed (expressed in ms^{-1});
3. f is the wave frequency (expressed in Hz),

the f frequency of the light wave must be **higher** than the f_0 limit frequency of the material (Si, here), $f > f_0$; then, an electrical tension is generated.
On the opposite, if the frequency of the light wave is **lower** than the limit frequency of the material, $f < f_0$, no tension is generated.

Practically, the PV cell is a diode made of a sheet less than 1 cm thick, and from 5 to 10 cm in diameter, which directly transforms the light into continued electrical power, of a low voltage (U lower than 1V). See figures 2.7.3 and 2.7.4.

Such a cell is able to produce 1 W (electrical watt, it means 1 J/s) when it receives a 10 W luminosity from sunlight; in these conditions, its conversion output equals from 10% to 20%.
As the electrical energy production is quite proportional to the PV cells receiving surface, the aim is to reduce the thickness, and to increase the number, to reduce the PV cells weight, therefore the cost in material in the photopile.
To increase the tension, the PV cells are serial-linked.

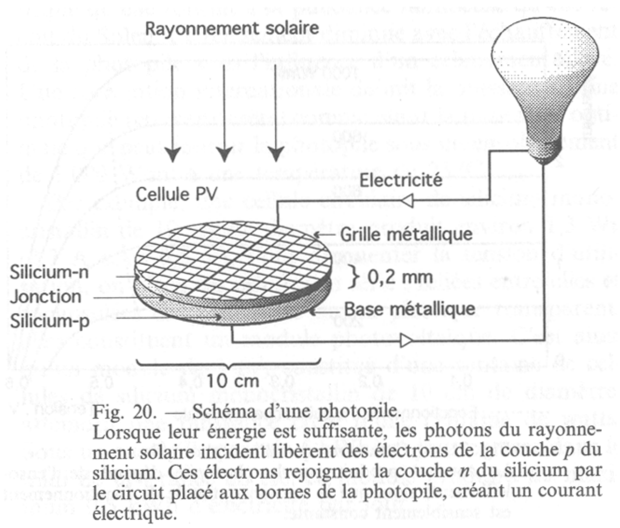


Figure 2.7.4: A photopile (French).

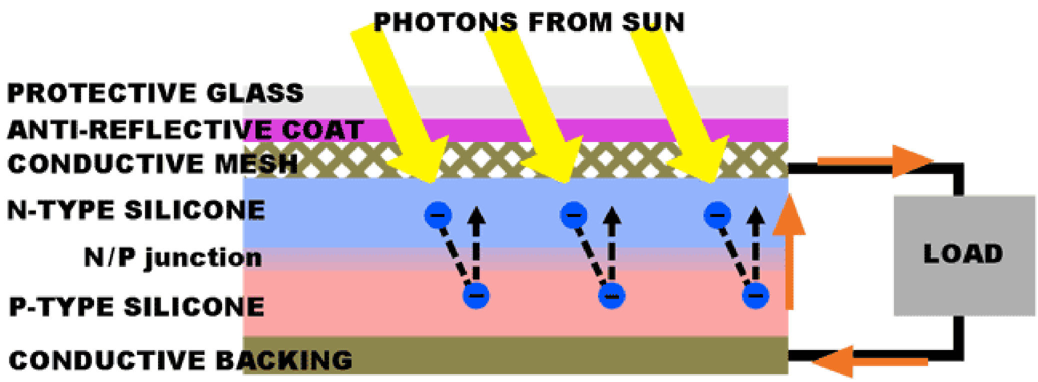


Figure 2.7.5: Composition of a photopile.

2.7.2.6 The photopiles power unit: the Watt-Peak

The performance of a photopile is measured by its capacity to transform solar energy in electricity.

Definition 2.7.1 (Output of a photopile)**.** We define the output of a photopile as the ratio of the electrical power that it gives, and light power that it receives from the Sun.

This output decreases with the warming of the photopile under a high insolation.
An insolation convention defines the photopile power (in watts-peak) as the optimal power that can give the photopile under an insolation of $1000\,\mathrm{W\,m^{-2}}$ under a 25°C temperature.
For example, a circular mono-crystalline Si-cell of 10 cm. of diameter products ± 1.3 *Wp* (2.7 Aunder 0.5 V).

2.7.2.7 The PV systems

To make them practically useful, the photopiles are mechanically and electrically assembled, linked and encapsulated under a glass or a transparent plastic, they constitute a PV module, which protects them from the bad weather for about ten years.
The PV modules are generally linked in "serial-parallel" to increase the voltage (U) and the intensity (I) at the output of the modules field. If many apparels use alternative current, an inverter is placed on the circuit (see figure 2.7.7, p.30).

That's why a $1\,\mathrm{m^2}$ module, constituted by a hundred of mono-crystalline Si-cells of 10 cm of diameter, will reach a peak-power of a hundred of watts.

Under a $5\,\mathrm{Wh\,(m^2\,day)^{-1}}$ insolation (like in the South-France, in summer), this module will produce a maximum of 0.5 kWh (= 3.6 MJ, or a 1 kW apparel which has worked during one hour) of electricity/day.

The more photovoltaic cells are connected, the more the voltage (U) of the produced electricity increases.

It is, on average, the same whatever the weather is, but the intensity (I) is quite proportional to the received rays. See figure 2.7.6, p.29.

The coupling between a discontinued electrical production (which follows the solar cycle and the weather's fluctuations), and the user's energy needs must also be assured.
As the perspectives of photopiles' costs-lowering are already important, the accessories cost will become largely preponderant if we do not relaunch the research and the development, in particular in the batteries domain.

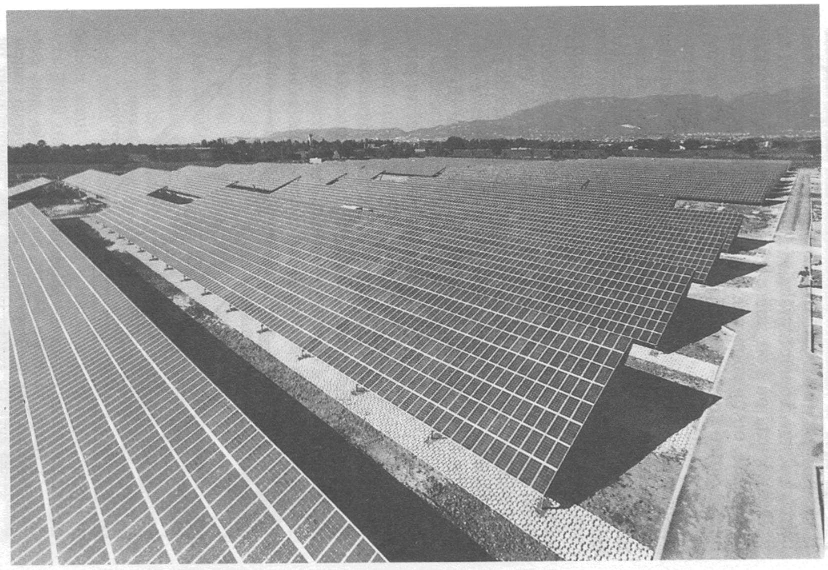


PLANCHE V. — Centrale solaire photovoltaïque de 3 MW en Italie.
@ IT Power.

Figure 2.7.6: A solar photovoltaic central, in Italy (French).

2.7.2.8 Advantages and disadvantages

See advantages and disadvantages of the passive house (summary draw, point 2.9, p.32).

2.7.2.9 Their future ?

The graph situated below details the worldwide PV market (in X, we have the years, in Y the MWp (Mega-Watt peak)). This market is answering more and more to the customers' needs, by producing more MWp, resulting of the rise of the PV panels' amount, and of their performances.

This is comprehensible, and it is explained by the lowering of the PV cells' price, the Government's incentives to make people use solar energy.

Many researches are also made on the PV cells.

Their price has already highly risen since 1988; in the future, it will certainly decrease, thanks to technical progress and public needs.
See figures 2.7.8 and 2.7.9.

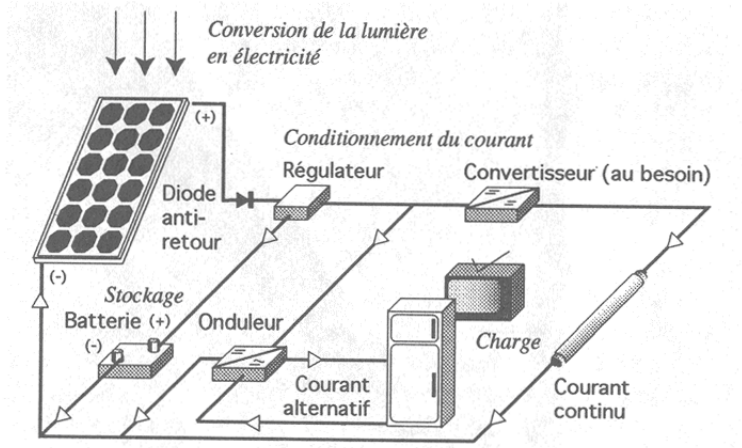
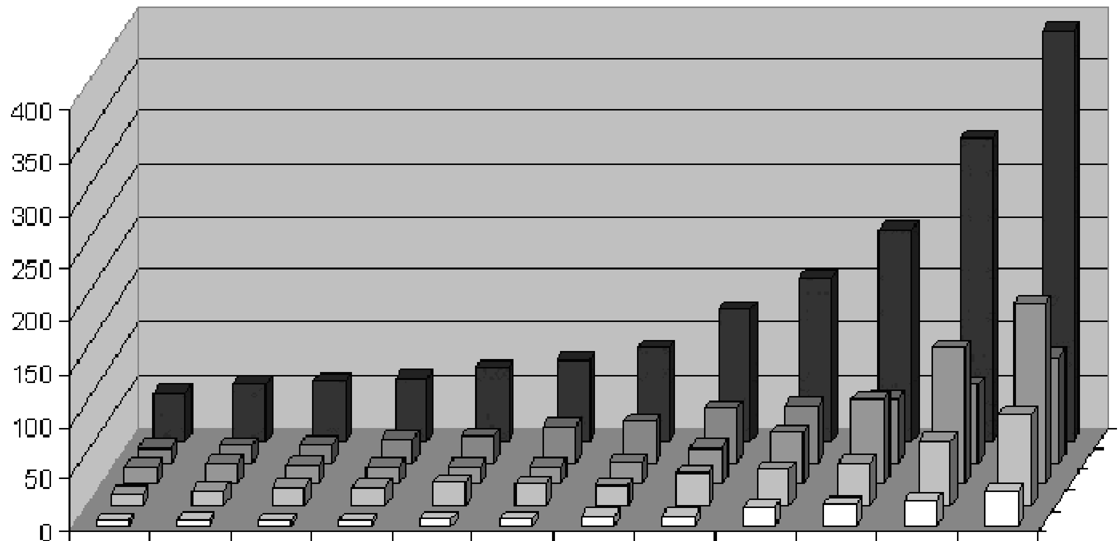


Fig. 25. — Un système photovoltaïque.
L'énergie électrique délivrée par les modules peut être stockée dans une batterie. Elle alimente en courant continu des appareils adaptés (ampoules basse consommation), ou après conversion en courant alternatif dans un onduleur, des appareils domestiques usuels.

Figure 2.7.7: A photovoltaic system (French).



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Rest of World	4.7	5	4.6	4.4	5.6	6.35	9.75	9.4	18.7	20.5	23.42	32.6
Europe	10.2	13.4	16.4	16.55	21.7	20.1	18.8	30.4	33.5	40	60.66	86.38
Japan	16.8	19.9	18.8	16.7	16.5	16.4	21.2	35	49	80	128.6	171.22
United States	14.8	17.1	18.1	22.44	25.64	34.75	38.85	51	53.7	60.8	74.97	100.3
Total	46.5	55.4	57.9	60.09	69.44	77.6	88.6	125.8	154.9	201.3	287.65	390.5

Figure 2.7.8: Worldwide PV market (data from PV News, ed. Paul Maycock).

2.8 Living in a passive house

Living in a passive house requires many personal changes in the inhabitant lifestyle, in regards to a traditional house.

A lot of habits will have to be lost, and, also created.
For example:

1. turning on the heating no more (there are no more convectors !);
2. opening the windows no more (the ventilation interferes);
3. warmer clothing (to endure temperatures included between 20°C and 22°C);
4. planning the energy's use (washing when there is a lot of sun, and drying the clothes outdoor);
5. lessening his demand in energy;
6. using low-energy-consumption apparels (buy preferentially AA class apparels) for the whole house (electrical dryer, fridge, and lighting);
7. setting mechanical ventilation;
8. managing the heat recuperators (the oven, the other electric devices);
9. thinking of a special room for the "passive apparels", because they could heat, and make noise !;
10. designing the house's architecture differently.

This lifestyle can seem disconcerting in the beginning, but it will prove to be particularly rewarding by its collaboration to the planet's future, and with the completed gain in money too.

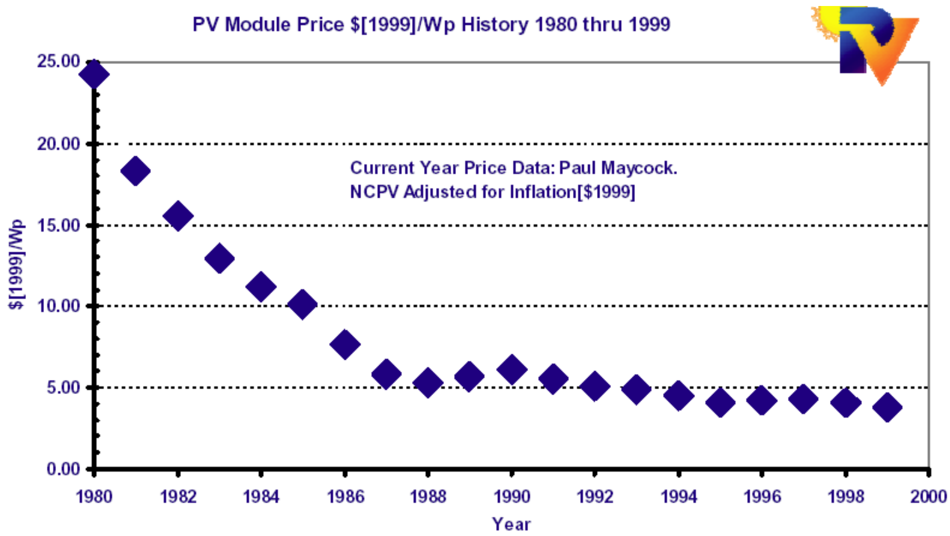


Figure 2.7.9: PV module price (1999).

2.9 Advantages and disadvantages of the Passive House

Without claiming exhaustiveness, we are going to try to class below the numerous advantages of the passive house and the disadvantages resulting most time of the use of sophisticated devices, but not always essential.

We have chosen a system of non-mutually exclusive categories, even if we have limited to the maximum repetitions.

Many advantages or disadvantages are included in "cost" and "performances" categories, both being linked.

Category	Advantages	Disadvantages
Health and **comfort** Thanks to : **-ventilation** system, well installed, and insulated. **-windows**	-No running or outdoor noises -Less thermal losses. -Thermal gain, if well oriented. -Windows are always closed, except in summer. -Air is "naturally" heated in winter, cooled in summer (thanks to the Canadian well). -Air is filtered → A healthier air is sent; → Suppression of intern/extern CO_2; → Suppression of dust and microbes; → Suppression of smells (if there are); → Keeps a 30% hygrometry (no	-Running noises if the system is badly insulated. -Can't hear birds singing. Risk of overheating. -Annoys our airing habits (except in summer). -A thermal exchanger and a regular maintenance are necessary. Air is too dry if hygrometry is below 30%.

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Category	Advantages	Disadvantages
	condensation on cold surfaces, such as mirrors and glasses. -No freshness sensation, because the average temperature in a room equals the sum of the temperatures of intern partitions and walls and the air's temperature. ($T_{avg.} = T_{partitions} + T_{air}.$) -Regulated air: temperature and debit. -Constant temperature: 20°C – 21°C everywhere. See figure 2.6.4, p.20.	-Freshness sensation, felt-temperature sometimes too low is aimless. -It requires an appoint convector in the bathroom. -The inhabitant must change his habits: no more curling up near the convectors, because they do not exist no more.
Pollution sometimes due to **insulating materials** and the **way** they are **treated**.	The solar energy: -Is clean: when working, it emits no CO_2 gas (it is a gas which causes the greenhouse effect). -No toxic waste. -Allows an environment-respectful recycling. -The Si pollutes a little bit (2^{nd} element after O, so 28% of the Earth's crust). -Natural recycling insulators do exist (wheat, inflated cellulose fibre, . . .). -More performing and thinner insulators exist.	Production of some materials to capture, amplify, and stock solar energy sometimes generates a pollution, depending on the kind of used-material (solar and thermal panels). -They require more walls' thickness, with a surface's loss. (see figures 2.5.6 and 2.5.7, p.15). -They are more toxic, non-degradable, because of their raw material, production, and treatment.
Output	-Although the luminosity is not high, there's anyway an energetic economy. -Solar energy is available everywhere, even in the farthest places, so it avoids the urban exodus; it can also be made in autonomy. -It avoids rural exodus; it is also a way of living in self-sufficiency. -In summer, thermal solar panels do entirely cover the energetic needs in SHW if there is an adapted behaviour from the users.	-A high luminosity is not always available, to optimize the output, and, furthermore, weather is unpredictable. -In winter, solar panels don't cover the thermal demand; an extra heat source is needed, to increase the temperature of the air, the water.
Surplus management	-Tanks accumulate *SHW*'s water, boilers.	-They take space, but necessary in every case.

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Category	Advantages	Disadvantages
	-Batteries allow electricity stocking. -The extern network retrieve electricity (re-injection).	-Batteries are polluting and expensive. -It is difficult to stock big quantities of energy. -There's a phase shift: the energy needs are higher in the evening, and lower during the day. It is the same with the seasons.
Cost	-Solar energy is direct and free, to heat greenhouses, walls, panels.	-It is not going to serve as substitute for fossil energies, because of the huge surfaces we would have to cover by solar (PV and T) panels to obtain the same energetic power.
	-The surplus of energy created can be re-sold to the network, at a higher price than the other alternative electricity prices. Re-sold energy can be re-bought by the seller. Supplementary benefices are brought by the "Certificats verts".	
	-The 2nd panels generation (a-Si) has a better price to performance ratio, although they are a little bit less efficient. In 8 years, the cost has lowered of 80%, and hasn't changed for 20 years. See figures 2.7.3 and 2.7.4, p. 26. -Thanks to technical progresses (thinner layers), and to their use's rising, their manufacture's cost will decrease. -For very competitive prices, natural insulators do exist, constituted by rubbish recycling. -Vacuum panels also exist, and they are thinner.	-Thermal solar panels are expensive (in their building too, because of the vacuum process), and it is not a well-developped solution, although the costs are decreasing. -The costs of an inverter and a counter must be added, for PV panels. -To reach the efficiency of the more expensive, thinner, and more polluting materials (polyurethane moss, glass wool), we must use thicker walls, which reducethe habitable area (or buy a bigger piece of ground).
	-A PV module payback is much less than its expected lifetime and it is even able to payback their proper replacement. <u>Other gains</u> -No need to build a fireplace to get rid of toxic combustion rubbishes (coming from gas or oil);	It costs a bit more than a traditional house (max. 15 %, and paid back within the 5 to 7 following years), depending on the insulating materials, the devices (which belong to the passive house), and the

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Category	Advantages	Disadvantages
	-Neither convectors, nor thermostatic vanes; -The whole floor surface can be used; -A passive house is less sensible to energetic costs; -10 years of payback for the whole passive house; -Economies from 75% to 90% on heating energy, in comparison to normal buildings (see table 2.4, p.37). -On the heating and *SHW* plans, a passive house costs 68% less than a traditional house (see table 2.4, p.37).	additional energy. (see phase shift and seasonal.) -An appoint convector can be placed, especially in the bathroom.
Knowledge	Sharp formations do exist, and are more and more frequent.	The solution is not well known by all the professionals yet (insulation, airproofness, installation, repair, maintenance).

Table 2.3: Advantages and disadvantages of the Passive House.

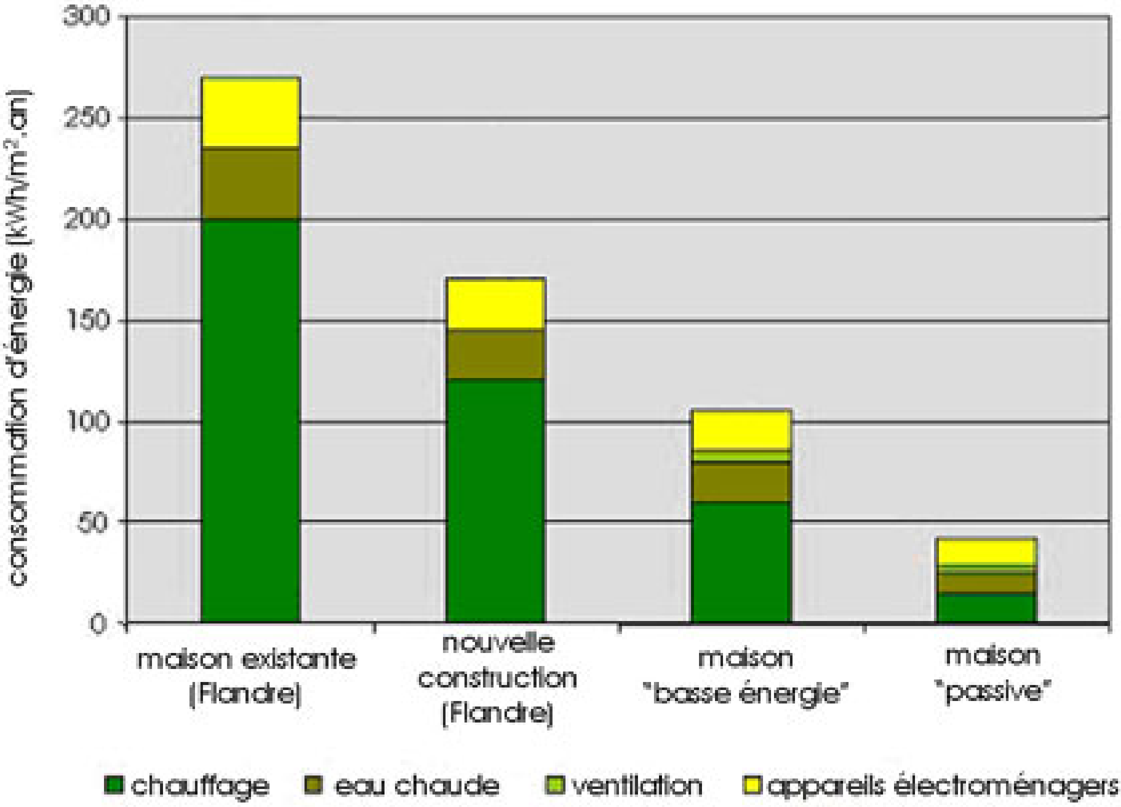

Figure 2.9.1: Energetical use, depending on the four kinds of buildings (French).

2.10 Comparison between a traditional and a passive house

After having analyzed advantages and disadvantages of a passive house, we are going to try to compare the costs of a passive house with a traditional house, at the two following levels: building (initial investment) and consummation (electricity, *SHW*, heating, etc.).

2.11 Heating's cost

The most important expense in the household's budget is the heating sector (57%, see figure 2.12.1, p.38), and the passive house covers 70% of the heating needs, as it is shown on the following draw (see figure 2.7.8, p.31), compared to a similar traditional house: 211 € (passive house) and to 773 € (traditional house).

The total gain equals 561.61 EUR, because 773 € − 211.09 € = 561.61 €. Furthermore,

$$\frac{561.91 * 100}{773} = 72.69\%. \qquad (2.11.1)$$

Month	Consumed kWh	Consumed kWh
	Neufchâteau – passive 2007 and 2008	My house – traditional 2007
January	320 and 321	
February	250	
March	50	
April	0	
May	0	
June	0	
July	0	
August	0	
September	0	
October	8.2	
November	201.7	
December	287	
Total	1116.90 kWh at 0.189 €/kWh 1116.90*0.189=211.09 € → gain = 773-211.09=561.91 €	4089 kWh =773 €

Table 2.4: Results of auxiliary heating consumption in Neufchâteau (passive house).

2.12 Electricity's cost

On the figure 2.12.1, the 18% of the electricity's cost (11% for electrical devices, 7% for the kitchen) are practically identical in a traditional house and, in a passive house, the saving will only be done through changes in the habits (AA household appliances, economical bulbs, a better management, . . .), see table 2.5.

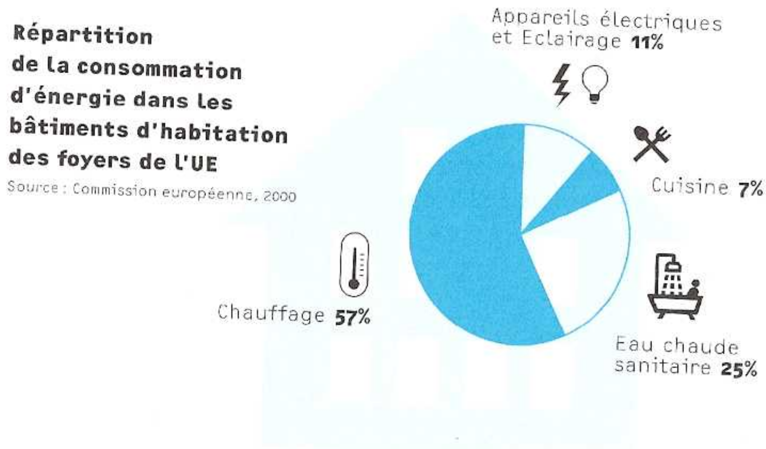

Figure 2.12.1: Repartition of the energetical use in the houses of E.U.. The heating percentage is often higher than 57%.

Month	Consumed kWh Neufchâteau – passive 2007 and 2008	Consumed kWh My house – traditional 2007
January	584 and 744	
February	500 and 372	
March	320	
April	198	
May	217	
June	201	
July	186	
August	161	
September	195	
October	275	
November	568	
December	676	
Total	4081	4304.2

Table 2.5: Total electricity demand (to the network) in Neufchâteau (passive house).

2.13 SHW's cost

25% of the budget for *SHW* (on the figure 2.12.1, p.38) represents an identical expense in both cases (traditional or passive house, see table 2.4, p.37), except if we use a solar panel, which can obtain a 70% return on the SHW use.

2.14 Building's cost

Seeing the possible savings, and the advantages/inconvenients, it is interesting to invest in a passive house, because the total overspend reaches a maximum of 5% to 15%, compared to a traditional house. See table 2.6.

Category	Passive house (real)		Traditional house[3]
Situation	Neufchâteau	Price (VTA excluded) [€]	
Researches, architect, setting up and security of the building site.		20,630.42	
Excavations, setting up of a sewerage system, foundations		31,009.41	
Structuring wood, insulation	Untreated wood (indigen wood)	91,526.05	
Roof and weatherboarding	Canadian wood. Clay plastering and bricks	39,697.34	
Doors and windows	Hemp wool, Pavatex, Fermacell, OSB Sterling	28,782.38	
Sanitary, plumbing, ventilation, thermal solar heater		17,745.01	
Indoor completion, electricity		25,802.60	
Outdoor completion		5,534.82	
(Area) : 290 m^2		Not comprised	Not comprised
Sliced-stores (8m60x2m60)		3,555.00	
Subtotal		260,728.03	240,342.77
+21% (VTA)		+54, 752.89	+63, 888.58
Subtotal (2)		315,480.92	304,231.35
		→ overspend of 4.5%.	
Incentives		-5,000	
Total		310,480.92	304,231.35
		+36 €/year	+heating maintenance +heating cost (for maintenance).

Table 2.6: Concrete example : cost of a passive house VS traditional house.

The cost of the passive house (315,480.92 €), compared to the traditional house's price (304,231.35 €) gives an overspend of 4.5 %.

2.15 Point of view of "passive" inhabitants

In Hanovre (Deutschland), a survey has been made between year 2000 and year 2001 with the inhabitants of passive houses. See table 2.7.

Point of view about ...	Note
Air temperature	After an adjustment phase, it is quite acceptable.
Air quality	Very good (95%)

Table 2.7: Point of view of "passive" inhabitants.

2.16 Incentives in Wallonia in Belgium

2.16.1 In Wallonia

The energy fund of Wallonia has incentives for everyone, and for every kind of building: new, under construction, and passive house.

Wallonia has also created a support plan, called "Solwatt", to help with the setting up of a PV system. There is also the "Soltherm" plan, for thermal solar panels.

The incentives' bestowing is linked to the respect of many criterions, about the building's envelope, and the systems detailed in the incentives-asking fill-in form.

We can ask for it at the Energy Desks.

You will find more information on: http://www.mineco.fgov.be, http://energie.wallonie.be, http://www.primerenovation.irisnet.be.

2.16.1.1 How to obtain incentives ?

1. Ask for the specific fill-in form: each incentive is the object of a specific fill-in form. It gives information about technical and administrative criterions that are important to respect (it is possible to fill them up online);
2. Make the investment and/or the necessary works (without the agreement): many incentives require to ask for an approved master-builder who has a regular access to the job;
3. Fill in the form and its technical appendices;
4. The incentives' asker must be the person who the incentive is addressed to;
5. Introduce the incentive demand in a four months time delay (from the bill date, or from the specified date in the form), either to the "Gestionnaire de distribution" (GRD), or to the "Division de l'énergie" of Wallonia;
6. Wait for the receipt confirmation of the incentive demand. Within 40 days (beginning the day after the receipt of the incentives' demand), the "Division de l'Energie" (or the GRD) sends an acknowledgment of receipt, specifying whether the file is complete, or, claiming, if necessary, for the missing documents. In this case, we have 70 days to transmit them; if this is not done, the file will be definitively closed;
7. Receive a decision relative to the file: the agreement. Within 120 days (beginning the day after asking's receipt), a letter will inform the incentive's asker whether his demand has been accepted or not. If the administration (or the GRD) does not send a letter within the 120 days (so, 80 days after point 6.), the file will be considered as being accepted;
8. Receive the incentive.

We have chosen the incentives having a link with the passive house, the insulation, the energetic audit, the ventilation, and the panels (photovoltaic and thermal).

N° de prime	Nom	Détail
		Primes à l'isolation
1	Isolation du toit	Si l'isolation est placée par un entrepreneur enregistré, la prime est de 8 € par m² de surface isolée. Si vous placez l'isolation vous-même, la prime est de 4 € par m² de surface isolée. Le maximum octroyé est de 10.000 € par an et par bâtiment.
2	Isolation des murs	Un audit enregistré doit être préalablement réalisé, en conformité avec le prescrit de la prime 15. La prime est de 25 € par m² de murs isolés en contact avec l'ambiance extérieure ou un espace non chauffé ou qui n'est pas à l'abri du gel. Le maximum octroyé est de 10.000 € par an et par bâtiment. L'entrepreneur doit être agréé et enregistré.
3	Isolation des planchers	Un audit enregistré doit être préalablement réalisé, en conformité avec le prescrit de la prime 15. La prime est de 25 € par m² de sol isolé. Le maximum octroyé est de 10.000 € par an et par bâtiment. L'entrepreneur doit être agréé et enregistré.
4	Remplacement du simple vitrage haut rendement	La prime est de 40 € par m² de vitrage placé. Lorsque le châssis est également remplacé, La prime est calculée sur base des dimensions extérieures du châssis. Le maximum octroyé est de 10.000 € par an et par bâtiment. L'installation doit être réalisée par un entrepreneur enregistré et agréé, disposant de l'accès réglementé aux activités de la menuiserie, et de la vitrerie.
6	Maison passive	La prime est de 6.500 € pour la construction d'une maison unifamiliale passive, présentant une consommation de chauffage très faible, inférieure à 15 kWh/m².an. Cette prime n'est pas cumulable avec la 5 (isolation d'une maison unifamiliale) et la 7.
		Primes à la ventilation
7	Installation d'un système de ventilation avec récupération de chaleur	Le montant de la prime est de 75 % de l'investissement global avec un maximum de 1.500 € par unité d'habitation équipée dans le logement.
		Primes à l'audit
15	Audit énergétique	Dans le cas d'une maison unifamiliale, la prime pour la réalisation d'un audit énergétique est de 60% du montant de la facture TVA comprise (ou de la note d'honoraires) et ne peut excéder 360 € par audit. Pour tout autre bâtiment, la prime est de 60% de la facture TVA comprise ou de la note d'honoraires, et ne peut excéder 1.000 € par audit et par bâtiment. L'audit doit être réalisé par un auditeur PAE (Procédure d'Avis Energétique), selon la méthode PAE.
16	Audit par thermographie	Dans le cas d'une maison unifamiliale, la prime pour la réalisation d'un audit énergétique est de 50% du

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Nº de prime	Nom	Détail
		montant de la facture TVA comprise (ou de la note d'honoraires) et ne peut excéder 200 € par audit. Pour tout autre bâtiment, la prime est de 50% de la facture TVA comprise ou de la note d'honoraires et ne peut excéder 700 € par audit et par bâtiment.
	Prime aux panneaux PV (grâce au Plan Solwatt)	
19	Installation de panneaux solaires photovoltaïques	La prime est de 20% des coûts éligibles, augmentés de la TVA si le demandeur n'est pas assujetti avec un maximum de 3.500 € par installation et par compteur EAN. Les coûts éligibles représentent le montant de la facture hors TVA relative au placement d'une installation photovoltaïque (les panneaux solaires, le générateur, le sectionneur de courant continu, l'onduleur, le compteur d'électricité verte, le disjoncteur de courant alternatif, les supports de fixation des panneaux, l'éventuel dispositif de suivi du soleil et le câblage nécessaire, ainsi que la main d'oeuvre relative à ces différents éléments). Ces coûts sont limités au produit de la puissance de l'installation exprimé en Wc, par : 7 €7 /Wc pour un système fixe; 8 € /Wc pour un système intégré; 9 € / Wc pour un suiveur solaire. Pendant les 15 premières années, le plan Solwatt octroie un revenu complémentaire sous forme de " Certificats verts ", en raison de la production d'électricité verte : - 7 "Certificats verts" / MWh pour les 5 premiers kWc de l'installation; - + 5 "Certificats verts" / MWh pour les 5 kWc suivants; - + 4 "Certificats verts" / MWh entre 10 and 250 kWc. Ces certificats verts ont une valeur minimale garantie de 65 €/pièce; ils peuvent être revendus et négociés à des producteurs d'énergie à un prix égal ou supérieur à 90 €. L'installation doit être réalisée par un entrepreneur disposant d'un accès réglementé pour les activités électrotechniques, à l'exception de placements des panneaux PV, qui doivent être réalisés par un entrepreneur disposant de l'accès réglementé pour les activités de la toiture et de l'étanchéité. La facture de solde doit être postérieure au 31 décembre 2007. Dispense de permis d'urbanisme pour l'installation des panneaux PV, en toiture, et sous certaines conditions (voir commune). Possibilité de prêt hypothécaire.
	Prime aux panneaux thermiques (grâce au Plan Soltherm)	
20	Installation d'un chauffe-eau solaire	La prime est de 1500 € pour les systèmes de $2m^2$ à $4m^2$ de capteurs. A cela, il faut ajouter 100 € par capteur supplémentaire, jusqu'à un plafond maximum de 6000 €.

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N° de prime	Nom	Détail
		Dispense de permis d'urbanisme pour l'installation des panneaux T, en toiture, et sous certaines conditions (voir commune), et en-dessous de $10m^2$ de surface totale.

Table 2.8: Incentives (French).

2.16.2 Federal Level

Many investments, helped by regional subsidies, can also benefit from taxes reduction (of physical persons), for investments in energy reducing. The taxes reduction equals 40 % for each type of billed expense, with a maximum per taxable period, and residence. If a person has more than one house, she can benefit from the reduction for each.

On average, a solar panel lives 25 years, the payback is done within 10 years, so 15 years of net benefit, which largely covers the following installation's cost. See table 2.9.

	Wallonia	Flanders	Brussels
Produced energy (per year)	2550 kWh		
Investment cost (6% VTA included)	19080 €		
Tax allowance	-2600 €		
Regional subsidy	Non included	-1908 €	-10%
Real cost	16480 €	14572 €	13480 €
Reducing of the electricity bill	434 €		204 € (no compensation)
Selling of "certificats verts"	1149 €		384 €
Payback time	10.5 years	9 years	23 years

Table 2.9: Federal level incentives.

2.17 Provincial level

The province of Liège offers a complementary incentive of 650 €; this incentive is subordinate to the preliminary bestowing of the 20th subsidy of Wallonia.

The provincial incentives are claimed at the same time with the communal, federal, and regional ones, if their total doesn't overcome 75% of the total investment.

2.17.1 Communal level

Many communes offer incentives varying from 125 € to 750 € for a thermal solar water heater.

This is for a minimal $2m^2$ individual area for the setting up of a minimal $2m^2$ area of solar thermal captors.

There are some communes that do not offer incentives for the setting up of a solar water heater.

Liège gives 250 €, and Herstal 200 €.

The communal incentives are claimed at the same time with the provincial, federal, and regional ones.

CHAPTER 3

CONCLUSION

A conclusion is simply the place where someone got tired of thinking.
– ANONYM.

As we detailed it previously, solar energies (PV panels, thermal, and impact of solar radiation throughout the specific glasses) will allow us to make serious savings after having recovered from the investment in the new building, or in the improvement works.

Directly, the purchase of such systems will also spare us from consuming non-sustainable and expensive energies; it will be an important gain for the wallet and the environment.

In sunny countries, the passive house will be able to answer to the energy asking, and people will even be able to reinvest in clean energy.

In our temperate regions, the weather does not allow us to completely cover our energetic asks for the whole year; an additional system will be sometimes necessary, but its consumption's cost will be ridiculous, compared to the money spent in heating a traditional house.

To conclude, the passive house asks for several conditions respecting the three following aspects: technological[1] (double-flux ventilation), physical (compact house [see figure 2.4.1, p.8], with a good insulation), and financial (a cost). Psycho-social aspect is not mandatory (living more in proximity and using semi-detached houses is simply good)

When these first difficulties have been overcome, we notice that there are three main satisfactions: a not-to-pollute and a better (healthier) living and also to spare at long-term.

The passive-house's inhabitant is also most implicated in his responsibility towards the environment, compared to the traditional house's inhabitant.

But we must not fall into the "paranoiac insulation", because a good, simple, and efficient insulation can already spare us money and can also diminish pollution.

You will on the following page a graphic (figure 3.0.1) which explains the cost-investment/ consummation energetic rapport, and another graphic (figure 3.0.2) which shows the energy economy, depending on the investment.

[1] thermal and PV panels are not obligatory

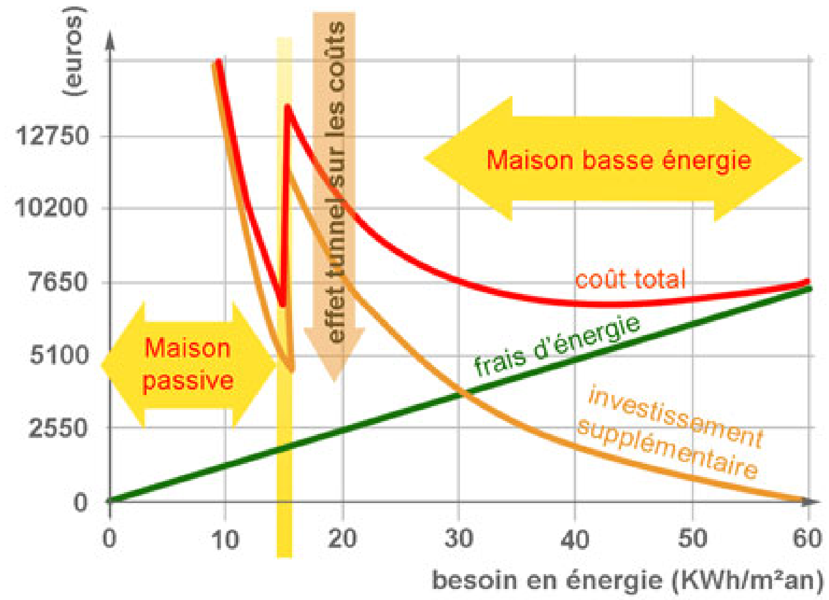

Figure 3.0.1: Conclusion graph (1/2) (French).

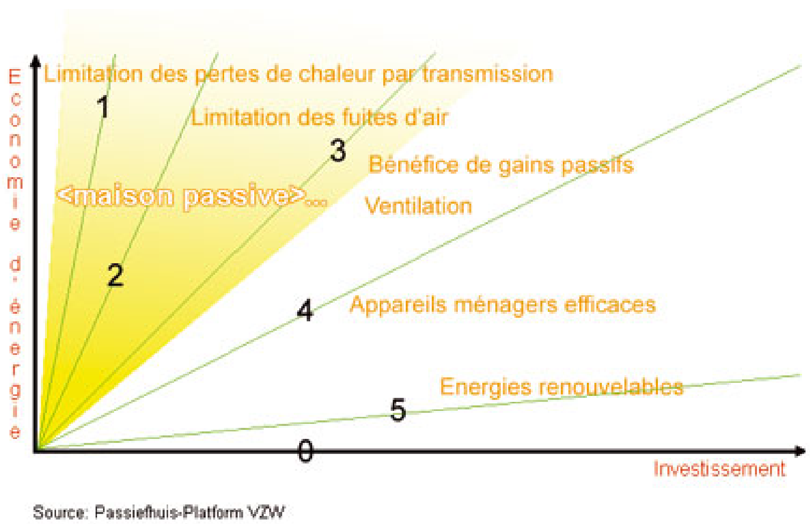

Figure 3.0.2: Conclusion graph (2/2) (French).

LEXICAL

We will define here the words which were often used in this document. They were in italic.

U factor It represents the rate of heat loss (as a flux) through a material ($1\,\mathrm{m}^2$ of layer, for a temperature difference of 1°C between indoor and outdoor).

ECV Electronic Controlled Ventilation.

SHW (Sanitary Hot Water.) Sanitary hot water. It also called SWW.

SWW (Sanitary Warm Water.) Sanitary warm water. It also called SHW.

Doping It consists in introducing small impurities in a semi-conductor, so it conducts the electrical current better.

p-doping When the doping makes the semi-conductor becoming poorer in electrons (more positive).

n-doping When the doping makes the semi-conductor becoming richer in electrons (more negative).

eV (electroVolt.) The energy acquired by an electron in an electrical field of 1 V; $1\,\mathrm{eV} = 1.6 \cdot 10^{-18}$ ergs.

Wp (Watt-peak.) The optimal power the photopile can give under an insolation of $1000\,\mathrm{W\,m^{-2}}$ under a 25°C temperature. According to the sun, the produced energy by a 1 kWp photovoltaic system will be around 850 kWh/year at Tournai, but would be around $1200\,\mathrm{kWh\,year^{-1}}$ at Nice. To calculate the necessary surface of photovoltaic panels to produce the total electricity needed for consummation, an easy formula can be used: 1 kWp = $850\,\mathrm{kWh\,year^{-1}}$ = $8\,\mathrm{m}^2$ of solar panels. For example, for an average consummation of $3400\,\mathrm{kWh\,year^{-1}}$ = 4 kWp = 4*8 m^2 = $32\,\mathrm{m}^2$ of solar panels (this is valuable for a 4 persons family in Belgium, for a normal use.). Knowing that the setting up of $8\,\mathrm{m}^2$ of solar panels to produce 1 kWp costs 6,500 to 7000 €, $32\,\mathrm{m}^2$ of solar panels to produce 4 kWp (= $3.400\,\mathrm{kWh\,year^{-1}}$) cost from 26,000 € to 28,000 €. To this amount, we must withdraw all the financial helps.

"Certificats verts" They are given by the Solwatt plan (of Wallonia), when "green" electricity is produced:

1. 7 "Certificats verts" / MWh for the 5 first kWc of the setting up;
2. +5 "Certificats verts" / MWh for the 5 following kWc;
3. +4 "Certificats verts" / MWh between 10 kWc and 250 kWc.

Appendices

APPENDIX A

FIGURES (PART ONE)

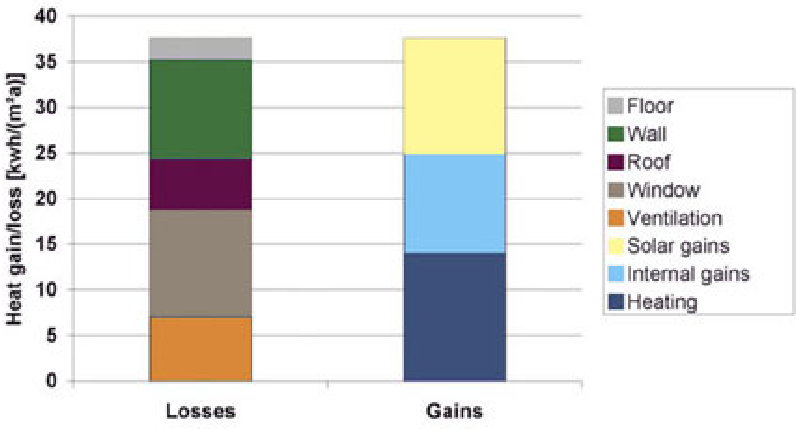

Figure A.0.1: Losses and gains.

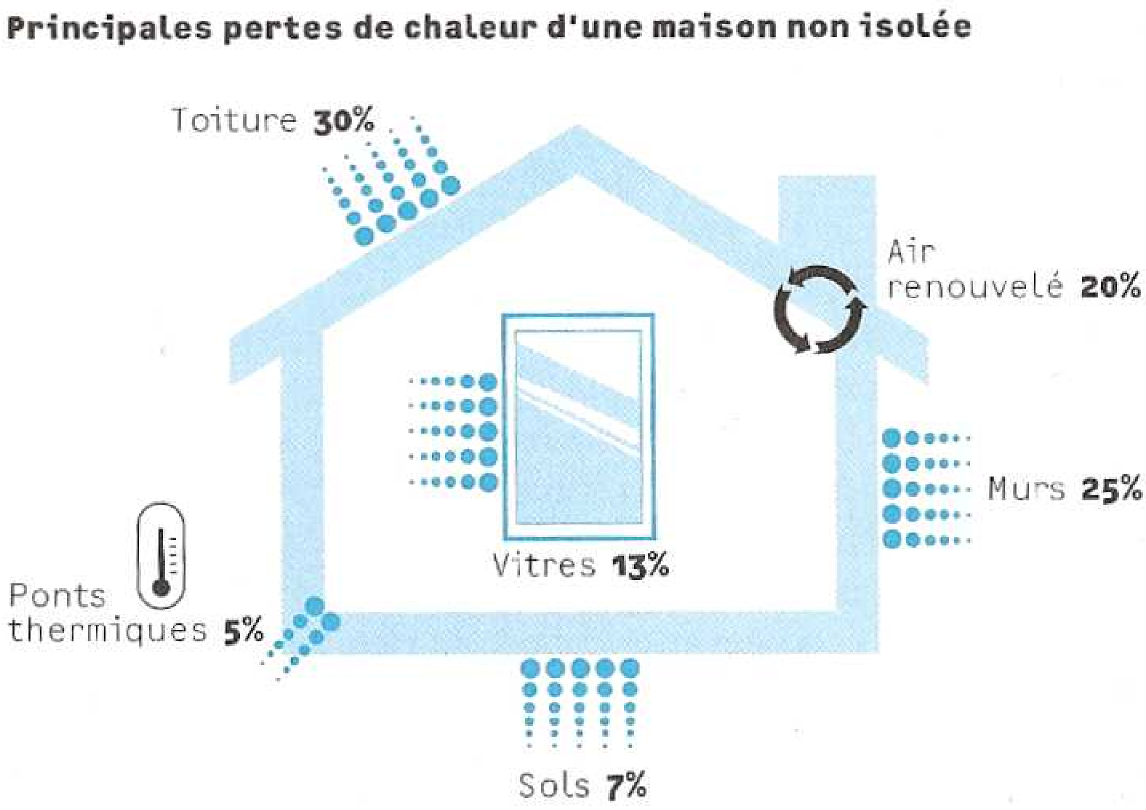

Figure A.0.2: Principal places where energy is lost (French).

APPENDIX B

WHEN IS A HOUSE CALLED PASSIVE AND "LIVEABLE" ?

When is a house called passive and "liveable" ?

For 40o - 60o Northern latitudes, a house is called passive when :

1. the principal part of the house is South-oriented (30%);
2. there are no shadowing trees, or buildings, in the hood;
3. it uses triple-glazed, to gain more heat than the losses;
4. the frames are perfectly isolated to avoid thermal bridges;
5. there's a high level of insulation on walls, floor, roofs, windows;
6. heat loss's reduced by extreme air-tightness of the building;
7. the thickness of the wall isolation is about 30 cm;
8. the thickness of the roof isolation is about 40 cm;
9. the thickness of the floor isolation is about 20 cm;
10. the air's quality's guaranteed by a mechanical ventilation system with highly efficient heat recovery (the air renewal for n50<$0.6\,\mathrm{h}^{-1}$), $30\,\mathrm{m}^3$ h/person of air pulsing;
11. the temperature gain is about $> 8°\mathrm{C}$;
12. the new air temperature is about $> 0°\mathrm{C}$;
13. the energy's demand is only $10\,\mathrm{W\,m}^{-2}$ or less;
14. the energy's demand is low, because of the efficient appliances used;
15. the habitant's energy demand (without primary energy use) is limited to $42\,\mathrm{kWh\,m}^{-2}\,\mathrm{year}^{-1}$;
16. the total final energy demand for heating, water cooling, and household appliances is limited to $42\,\mathrm{kWh\,m}^{-2}\,\mathrm{year}^{-1}$;
17. the annual energy need for heating doesn't overcome $15\,\mathrm{kWh\,m}^{-2}$ (max. W for the heating : $10\,\mathrm{W\,m}^{-2}$);

18. the total primary energy use (for all appliances), domestic hot water and space heating and cooling is limited to 120 kWh m^{-2} $year^{-1}$;
19. the appoint energies used are also called "at sustainable development";
20. the performance of the air/air exchanger is > 80%;
21. the used apparels are economical ones;
22. the "passive" apparels don't emit more than 25 dBa not to disturb the house's habitant;
23. the floor's temperature is 4 or 5 degrees above global room temperature.

APPENDIX C

FIGURES (PART TWO)

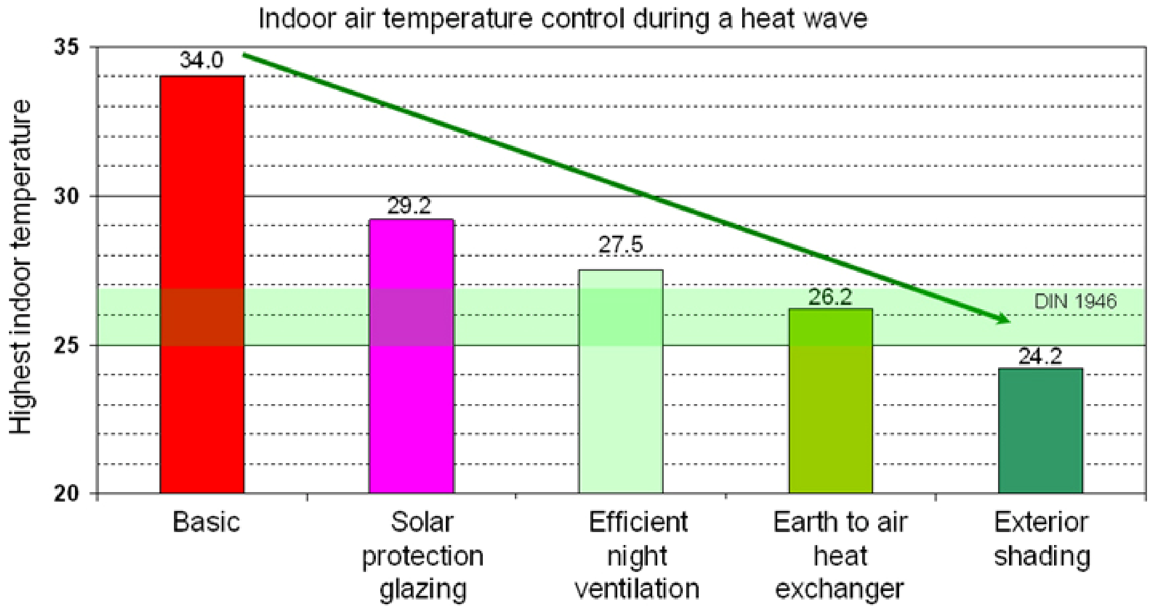

Figure C.0.1: Passive cooling by exterior shading is an efficient method for comfort in summer. Shading provides 50 - 60 % reduction in a buildings cooling energy demand even in warm Mediterranean countries. (VTT)

APPENDIX D

INFORMATION ABOUT PHYSICAL FACTORS

Information about physical factors

U factor ("Thermal Transmission by conduction, convection and rayonment".) Formerly called K factor, the U factor represents the rate of heat loss through a material. In the U.S., it is expressed in Btu/h.ft^2.F, and, in Europe, $\mathrm{W\,m^{-2}\,K}$. It represents the heat flux which comes through $1\,\mathrm{m}^2$ of a layer, for a temperature difference of 1°C between indoor/outdoor. When the U factor is high, the thermal transmission is high, so the insulation is low, and reciprocally. It is between 0.15 and 1.20.

R factor The R factor is the K (U) factor's reciprocal : it measures the insulation (resistance to heat loss).

g factor The g factor (formerly FS factor) of a window is the quotient between the total energy incoming in the local (through this window) by the solar incident energy.

SHGC (Solar Heat Gain Coefficient.) It measures how a product blocks heat coming from the solar rays. It is expressed between 0 and 1.

VT (Visible Transmittance.) It measures how much light (the visible part of the light spectrum : from 380 to 720 nm) comes through a product. It is expressed between 0 and 1, or in percent.

AL/L50 factor (Air Leakage.) It measures how much outside air comes through a product. It is situated between 0.1 and 0.3.

CR(F) factor (Condensation Resistance.) It measures how a product resists to the condensation's formation. It is expressed between and 100.

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