« Smart Natural Energy Management »

NATURAL LIGHTING • SHADING • VENTILATION • QUALITY OF AIR • COOLING

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Gestion des Energies Naturelles //

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Proven efficient solutions for demanding buildings

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General Director of Adexsi

While energy consumption is a continuous issue when building, the traditional speech tends to change towards a more global and systemic one. The reason is simple: buildings are designed to receive people.

While comfort, quality of life or use and productivity are the main features, they really depend on the atmosphere created when designed. The criteria for quality are well known: temperature, light and ambient air. The challenge is to develop natural and sustainable solutions that are multipurpose, adaptable and economic – as much on the investment as the operation costs.

As the government is working on the upcoming 2020 Environmental bill (RE 2020), all agents – industrials, contracting authorities, general contractors, professional organizations – are working together on the "Positive Energy and Carbon Reduction – known as E+C-" reference document.

This voluntary initiative is supported by the Ministry for the Ecological and Inclusive Transition and its goal is to promote energy efficiency, reduce the carbon footprint during the building lifecycle (50 years) and promote the spread of renewable energy.

Do natural solutions fit in this initiative? Yes! Because they answer the question of energy sobriety and system efficiency on account of their reactivity to the natural cycles and events. As examples, we can speak of the free energy input by direct sunlight orientation or a double façade posing as a "buffer" and ensuring preheating of the air. The operation of concepts like natural ventilation (known from Antiquity) adapted to modern requirements under the names of "free-cooling", "night-cooling" and "adiabatic cooling".
This guide will educate you about the significance of adopting the regulations and control of equipment.

What is the point of these alternatives (natural lighting and ventilation) compared to the super-technical classic solutions' presented daily to contracting authorities? They essentially offer an intuitive management of the building's systems while improving the well-being of its occupants. Moreover, they meet the requirements of the RT2012: a sustainable concept, the reduction of energy consumption and the control of the summer comfort ambient air.

Now, these solutions also offer more affordable investment, installation and operation costs: environment-friendly and economy are now complementary concepts. They promote new arguments to meet the performance goals companies and their managers are looking for.

1 BUILDING COMFORT: THE BASICS

What is the notion of comfort?
It is the balance between humans and the atmosphere – visual, thermal, airflow and acoustics – of the occupied space. Which requires us to take into account six factors: light (fig. 1.1), temperature, humidity, air flow, radiation and physical activity.

Figure 1.1 - Light, one of the main factors of comfort.

What are the fundamental goals for visual and thermal comfort?
Lighting must enhance the interior of a building, which requires a level of lighting sufficient and adapted to the occupants' needs, avoid glare and help people safely interact within the building (with volumes, forms, shades).

The correct appropriation of the space is mainly subject to the attributes of natural lighting. It is recognized that natural lighting has a beneficial physiological influence on your health: regulation of biological cycles (wakefulness and sleep, mood, etc.), security when working, improvement of focus and learning capacities, and it highlight the building's aesthetics.

Technically, natural light also enables you to benefit from external sources of energy to lower the use of artificial lighting and reducing considerably the energy consumption of the building.
Environmental considerations of new projects summarize such benefits.

Thermal comfort is to maintain thermoregulation – the warmth of the skin is 36,7°C and the skin's surface temperature is from 33°C to 34°C – also to ensure good air quality by renewing it. Evacuating humidity and pollutants (carbon dioxide, odors, volatile organic compounds [VOC]...).

What role do partitions/walls play?
Walls, exterior joinery and roofs compose the building's envelope and protection against natural conditions: cold, heat, wind, rain, etc. But its function can be impeded through a cold wall sensation during winter, or overheating – during any season depending on the orientation –, accumulation of heat with a nocturnal phase difference effect in summer, humidity, etc.

Comfort: which temperature setpoint or light flux?
During winter, statutory instruments (articles R. 241-25 to R. 241-29 of the national Energy Code) set the heating system temperature setpoint at 19°C.
During summer, discomfort starts at wind-chill 26°C during 5 consecutive days. This threshold of Indoor Comfort Temperature is mentioned in the RT 2012 (articles R. 131-29 and R. 131-30 of the Construction and Housing Code).
Minimal luminous flux must be 200 lux. However, it is recommended to reach 300 lux during 50% of the time and on 90% of the surface.

How to control temperature homogeneity?
To answer our physiological needs, the horizontal stratification of the temperature must be less than 1°C/m and have a maximum difference of 3°C between the floor and ceiling (at 2,5m).
The cold wall sensation – or vertical stratification – is perceived as soon as the difference between the walls' surface temperature and the room temperature reach and/or exceed 5°C, and as soon as the difference between the glazed partitions temperature and the room temperature reach and/or exceed 10°C. Discomfort can physically appear with people shivering or sneezing.

Why does relative humidity greatly influence the notion of comfort?
Indoor atmosphere must be maintained within a narrow range: 40 to 60% or relative humidity, not 30% to 70% (fig. 1.2):
• A low level – less than 30 % – results in dry air with an increase of dust, breathing difficulties, etc.
• A high level – more than 70 % – degrades quality of indoor atmosphere: increase of germs, development of fungus, appearance of insects, chemical interactions, etc.

What is air renewal and how is it essential?
Ventilation has 3 main goals:
• maintening the building structure by evacuating the humidity to avoid degradation of the materials due to the condensation and of mold;
• ensure sufficient indoor air quality (IAQ) for the health of occupants: through breathing and perspiration, one person produces at least 50g of water per hour – and we can add the daily activities: cooking, hygiene (baths, showers, laundry, etc.);
• improve the indoor air quality: the air inside buildings is recognized to be more polluted than the outside air, and the CO_2 produced by the occupants is its first source of pollution.

To remain comfortable, the airflow "sweep" of indoor air must be of 0,2 m/s. Discomfort linked to highl speed can be real during winter, particularly during periods with a temperature lower than 25°C where the heating system is on.
Yet, it is not true anymore for temperature superior to 25°C. In this case, by facilitating evapotranspiration and eliminating the "dermal moistening", faster air flows on the skin improve the comfort sensation: know as "summer breeze".
As of an example, if the speed of the air flow is equal to 1 m/s, the wind-chill temperature will be equal to the room temperature - 4°C.
The occupants of the building can accept temperature variations depending on the seasons and their physiological adaptation.

What is the operative temperature?
To estimate the room temperature, we must calculate a temperature called "dry resultant" or "operative". This temperature takes into account the air temperature and the radiant temperature of all walls. Its simplified formula is:
Operative temperature = (air temperature walls temperature) / 2

$$to = \frac{(ta + tmr)}{2}$$

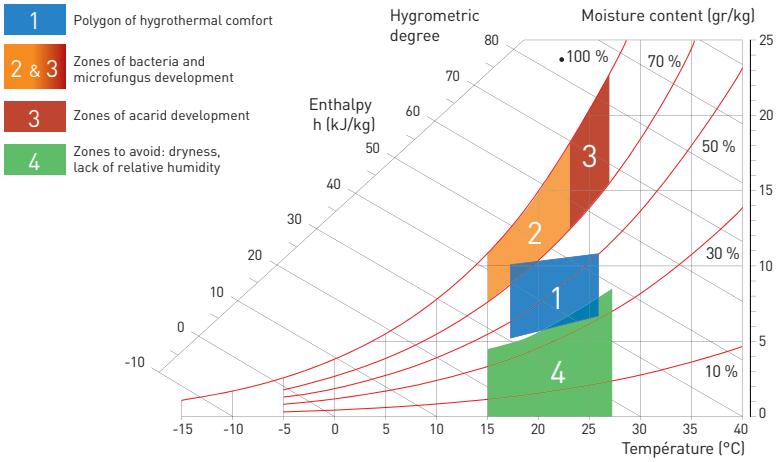


Figure 1. 2 – Link between room temperature and humidity degree to locate the comfort zone.

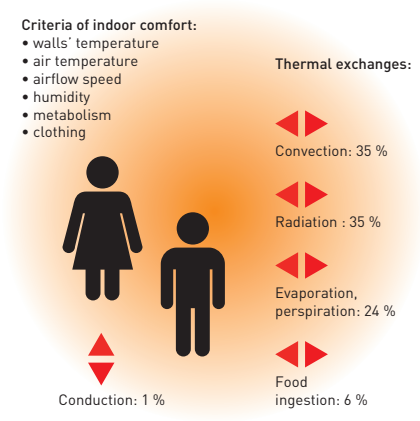
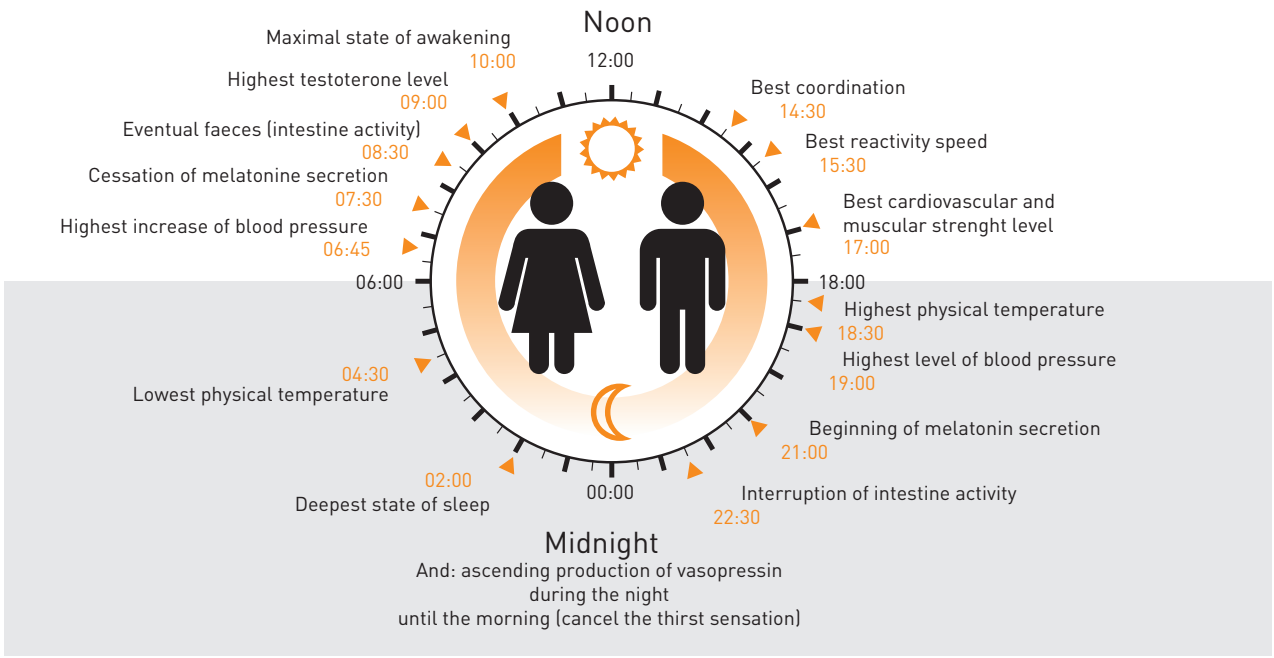


Figure 2.2 – The occupants and their indoor environment.



The circadian cycle: Exposure to natural light enables to follow natural biological rhythms

Identified in the 70's, the circadian cycle defines the physiological and biological rhythm of living organisms – vegetal or animal – during a 24 hours period. It is mainly highlighting a wakefulness/sleep alternation, and emphasizing peak, regular and off-peak periods while awake. It enabled to distinguish the attention variations.

Researches highlighted the impact of the environment on the circadian cycle, and in particular the light variations. Natural light plays a key role as a point of reference, and artificial light, due to its difference of wavelengths in relation to the human eye, is now recognized as disruptive: the blue tint of the LED confuse the production of melatonin – called sleep hormone - plays an important role in the regulation of sleep-wake cycles.

This theory was the point of reference of more extensive studies on time difference and its effects on health: they vary from stress to seasonal depression and could explain a predisposition to cardiovascular diseases.

2 COMFORT MANAGEMENT NATURAL TOOLS

The eye: reference for visual comfort.
Our eyes perceive tints from violet to red, that is to say the ones with wavelengths value from 400 mm to 700 mm. Peak of vision is within the green-yellow around 550 mm.

Natural light follows an emitted tint distribution curve very close to the one of the eyes with a peak of light matching the one of the eye maximum sensibility for a total adaptation (fig. 2.1).
On the other hand, light emitted from artificial sources are completely different: former incandescent lights emitted wavelengths within high orange-redish, and current LED lights (also called "cool white") emit wavelengths within blues (± 450 nm). Reduction to the exposure of these sources limit the effects on the body behavior: eye fatigue, depression, etc.

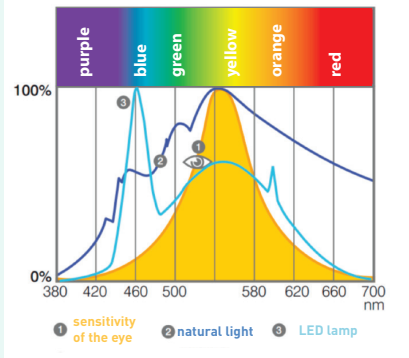


Figure 2.1 - Natural light and artificial light

Figure 2.1 – Natural light and Artificial light.

The body: in direct contact with ambient air.
More than half of body warmth loss is due to the convection with indoor air. For more than 35%, this transfer is done through radiation on the surface of the skin, evaporation and perspiration (fig. 2.2).

During a light activity, the maximal comfort temperature is centered around 20°C-22°C with ± 3°C; while sitting down and without any activity, the maximal comfort temperature is centered around 26°C with ± 1°C; while sleeping, this comfort temperature is 18°C with ± 3°C, etc.

To understand the concept of "thermal metabolism" (Mth), thermal engineers refer themselves to different situations. The standard is on the situation where sitting and resting: the "thermal power" of the body is evaluated at 58,1 W/m² of skin – or 1 met, specific unit relative to metabolism.

Nota: one person - 1,70 m and 70 kgs – presents a skin surface of around 1,8 m2 (approximatively 100 W) for 1 met.

While resting and laying down, the body emits approximatively 45 W/m2; while sitting with a light activity, we reach 70 W/m²; when standing up with a light activity, it increases to 95 W/m²; standing up and a more intense activity, for example working on a machine, the body emits 115 W/m²; standing up and with an intense activity, it increases to 175 W/m² – 3 met. Another example: in a night-club, the body of a person dancing (moderately) would be approximatively 250 to 265 W/m².

Clothing: naturally taken into account in the calculations.
Inside houses or offices, occupants accommodate themselves to the room temperature by adapting their clothing to the type of activity they have. If needed to be reminded, clothes create a thermal barrier between the skin and the environment.

Thermal engineers have standardize the level of clothing with the unit "clo" (1 clo equal one thermal resistance surface of 0,155 m².°C/W) (chart 2.1).

- 1 clo refers to the winter clothing type with pants, shirt and pull-over.
- 1,5 clo refers to a complete and traditional urban outfit.
- In return, 0,7 clo refers to a light clothing style; 0,5 clo, the summer clothing type; 0,3 clo, a casual summer-type outfit – short and sleeveless shirt, etc. –; 0,1 clo, wearing a short; and 0 clo, for being naked.

Regulation: the essential tool.
Comfort is at the crossing between 3 questions:
The body and its physiology, the behavior (activities, clothing, etc.) and the equipment (heating/ventilation/lighting/etc. systems).
Satisfaction of the occupants of the building implies giving them the opportunity to manage the different equipment: heating/ventilation/lighting/etc. systems, windows, etc.
Different tests highlight discrepancies of sensations from one individual to another, a notion clearly identified in the international EN ISO 7730 norm about the Ergonomics of the thermal environment.

This norm suggests two indexes of satisfaction:
- PMV, for « Predicted Mean Vote » average feedback of a group of people about a situation;
- PPD, for « Predicted Percentage Dissatisfied » or predicted percentage of dissatisfied occupants.

Studies say that with a PMV equal to 0, 4 % of dissatisfied occupants remain (PPD).

Regulation tools – radiators' valves, decentralized probes management system, etc. – must be responsive, or even capable of anticipating the meteorological events: evolution at 24 or 48 hours (to preheat the buildings during winter, "over-ventilate" during summer, etc.), sunlight on the facades to activate sun-protection equipment, quick variation of temperature, humidity, sunlight and wind in case of storms, etc.

To be efficient, the occupants must claim this equipment and understand their roles/capacities.

Chart 2.1: Energetic metabolism for different types of activities (extract of the ISO 7730 : 2005 norm)

Activity	Energetic metabolism	
	W/m²	met
Resting, laying down	46	0,8
Resting, sitting down	58	1,0
Sedentary activity (office, home, school, laboratory)	70	1,2
Light activity, standing up (purchasing, laboratory, some industry)	93	1,6
Medium activity, standing up (salestaff, cleaning, operating machines)	116	2,0
Walking:		
- 2 km/h	110	1,9
- 3 km/h	140	2,4
- 4 km/h	165	2,8
- 5 km/h	200	3,4

Additional information regarding the energetic metabolism are given inside the NF EN ISO 8996 norm.
It is to be noted that older people can have an average activity less active than younder people.

Feedback

Involving occupants within the construction of buildings

« Natural lighting and ventilation contribute to the living comfort either in your home or office. Natural light is sought-after pleasant and energizing. Vocabulary associated with natural light is positive. Difficulties can appear with solar heat gain during summer, the overheating effects – particularly in well insulated buildings. Solar protection and the management of windows are essential but not always possible.

In regions in the South of France, this equipment is already culturally acquired; in regions in the North of France, it is completely different.
Also, some constraints can occur, such as noise pollution or security issues which prevent from opening the windows for example, especially for the nocturnal ventilation.

Clearly, ventilation has always been used within buildings. Difficulties can result from the awareness of ventilation systems; during the last years, projects have been developing very technical systems – this function being highly associated with building's energy efficiency. This "engineer's dream" caused issues in terms of operation: air-vents closed, default of maintenance of the filters, etc.

It is better to come back to the basics regarding the concept of natural ventilation, taking into account the input of the user to renew the air or refresh the indoor environment.

Another important question appears regarding ventilation and lighting functions inside a building: automation.

Automate everything – following the presence of people or the indoor pollution – can facilitate one's life. In reality, it can lose its original meaning! We must let the occupants take over. But we can't expect them to do it full-time.

These gaps are caused by the promotion of new technology or the regulations. We should listen to the people using the buildings.
Such an approach has been initiated with "introductory booklets" but they are not sufficient to support the occupants. Now, architects, social housing landlords, condominium associations and other actors within the industry go beyond and promote participant process: they listen to the needs of users, and then they work with them. Therefore, instead of explaining or training people on how to manage such equipment at the delivery of the building, professionals take into account the user's feedback and needs to decide which type of equipment to use and install – the goal being for the occupants to claim the equipment and solutions. It is a smart process which will take some time to take over. »

Gaëtan Brisepierre,
Sociologist specialized in the energy transition, habitat and environment

Strict environnemental labels

Most of the environment labels for eco-efficient buildings highlight using natural lighting setting up specific indicator:

• **BREEAM** label by setting up a specific indicator "Hea 01 Visual comfort". Two criterias are required: an average illuminance of daylight and a minimal illuminance at one specific point in daylight. Usually are required a Daylight Factor of 1,8% on 80% of the surface, with an annual lighting autonomy of 2650 hours at 200 lux, a uniformity of light in regards to the depth of the room, etc.
Also, this label offers three types of lighting autonomy: "Natural lighting", "Examplary Natural Lighting" and "International Natural Lighting".

• **LEED** label sets up the indicator "IEQ credit 8.1" relative to the lighting calculation simulation. It respects levels of brightness of 270 lux to 5400 lux at 9am and 3pm during a clear sky day at its equinox. Meeting this condition for 75% of the occupied room gives you 1 point and reaching 90% 2 points.

• **HQE** label (published in 2016) sets two goals: A Daylight Factor between 0,7 and 2% on 8% to 90% of the surfaces depending on the environmental performance targeted, and the Daylight autonomy – the daily daylight brightness on 80% of a reference surface must be at least equal to the level required for the type of activity following the EN 12464-1 norm.

• **WELL Building Standard** defines seven factors for the well-being of the occupants, and among them the light. The label aims to reduce the disruption of the circadian cycle for the body. Its requirements were based on the data acquired during last years about the light's impact on the organism and body: conception of the lighting, performance of windows, interior tints used, distribution and control of the artificial and natural lighting systems to improve moods and productivity of the occupants, etc.

• **Effinergie** labels (BBC, Bepos and Bepos+) are lean on the RT2012 regulation reinforced with the regulations of the E+C reference document which is the current work on the upcoming RE2020 environmental regulation. This future regulation will be the transposition to a national level of the European directive about the building's energy performance (directive 2018/844 of May 30th, 2018). Although this directive is highlighting the mechanical ventilation solutions, they mention reinforced requirements having a direct impact on the ventilation and lighting consumptions:
- individual houses, a Bbio max reduced by 20 % (coef. 0,8) and a Cep max - 20 % ;
- multi-unit housing, a variation of the Bbio max from a 0,6 to a 0,8-coefficient depending on the density of the project, and a Cep max - 20 %;
- service industry, a Bbio max - 20 % and a Cep max - 40 %.

For residential buildings, control of the ventilation must be done following the Promovent regulations and come with functional inspections.

For the service industry, there are three issues involved like the visual control, functional inspections and measure of air-tightness of the networks.

3 RE-DISCOVERING NATURAL SOURCES OF ENERGY

With regular reassessments of the thermal regulations, natural free inputs recover their place alongside the buildings' envelope and equipment. What are these natural free inputs? They cover the external/internal charges to the building. Already taken into account within the calculations, their impact is now better taken into account with the reinforcement of the new insulation and airtightness of the walls.

Two measures of the RT2012 demand to clarify their calculation.

First, the obligation, for natural lighting access, to use a minimal glazed partition of 1 m² for 6 m² of living area; Then, the restriction of the energy consumption for five main functions – among which are lighting and ventilation – to 50 kWh/m²/year.

In application for now 5 years, this regulation paved the way for the bioclimatic architecture.

Now, architects and engineers take into account typical elements of traditional vernacular constructions: orientation, shape, impact of neighborhood, external conditions (climate, vegetation and relief), material characteristics, dimensions and location of joineries, type of occupation (number of occupants, activity, daily use), etc.

The heat balance can be refined with the total of external inputs: heat input with direct solar radiation on the walls, roof/ceiling and floor, with direct solar radiation on the windows, with the air renewal and infiltrations, etc.

Calculation tools also take into account the internal inputs like heat radiations from the occupants or the artificial lighting systems.

LIGHTING

Build sustainable!

« The bioclimatic architecture is the only one to optimize the function of a building on resources (or pollutants) brought by the external environment (temperature, sun, light, air, etc.) »: this extract from Bio-tech "passive solutions for summer comfort" written by Arene Île-de-France and ICEB.

Architects now will aim to take full advantage of the natural sources of energy – light, heat, wind – to use them for heating, cooling, ventilation and natural lighting functions. The application of the RT2012 requires to take into account the bioclimatic data, the building characteristics and the usage scenario to calculate the building's bioclimatic coefficient – aka Bbio – real indicator for the quality of the conception and establishment of the project in regards to its energy needs.

Its formula adds up the needs in heat (coefficient 2), needs in cooling (coefficient 2) and needs in light (coefficient 5). The result – without unit – must be inferior to the Bbio value of reference within the geographic area of the building.

Lateral or zenithal: which solutions for natural lighting?

The industry now offers a large range of solutions to bring light to the service, industrial or logistic industry buildings:

• Windows and façades.

Glazed partitions – windows or glass-doors – will be chosen with a maximal glazed surface to let the maximum of light go through. Architects will also choose from all types of glass available: light, tinted, reflective; simple, double or triple following the thermal requirements and how to manage the direct heat input.

Figure 3.3 – Glass roofs enable architects to design highly thermal efficient buffer volumes.

What will be the thickness and how will be installed the joineries: flush mounted or front mounte? With what shape of window frame (straight, open)? With what height of lintel?

The choice of the windows will also be made by taking into account the walls opacity in which they will be installed.

The multitude of façades available on the market are often offered with technical information and numbers about the natural lighting potential of the solution.

• Zenithal solutions.

They exist in multiple shapes and types, the simplest and more common being roof windows. Installed on sloping ceilings, they are mainly used to bring light to attics.

Architects and engineers frequently use light wells. Technical solutions available – with reflectors or diffusers – will guarantee the distribution of natural light with wavelength adapted to the eye and beneficial in terms of global comfort.

Figure 3.1a – Vaults and running skylights are good solutions for large volumes: malls, warehouses, etc

Figure 3.1b – Types of light tubes are numerous and adapt to various situations.

In service, logistics, commercial or industrial industry buildings, simple or running skylight on a flat roof (Fig. 3.1a et Fig. 3.2) are technically simple solutions and bring some aesthetics to the project. Solutions offered by vendor now integrate glare and thermal insulation issues. Glass roofs also are now being used more often in recent projects – like the Hôtel-Dieu in Lyon – for their lightning and protection qualities.
They have been often used in the past in the modern commercial building in the XIX century with projects like the arcades of Paris.

Figure 3.2 -Skylights are a classic of industrial or tertiary roofing equipment

As for the roof sheds, typical equipment for the industrial building, their main characteristic is the possibility to orientate them towards the north – to manage the glare – and to be offered with any type of infill.

Optimizing the glazed surface – opaque walls ratio.
If the thermal regulation requires a minimal ratio of 1 m² of glazed wall for 6 m² of living area, the goal is to take the most of the natural light input and give more room for creativity in order to offer an optimal global comfort.
A simple formula enables the architect to elaborate a satisfying approach: The Daylight Factor.
Determined for a precise point – on one desk, on the floor, etc. -, it is the relation between the natural light received and the external light with a cloudy sky:

$$\text{Daylight Factor} = \frac{E\ \text{inside}}{E\ \text{outside}} \times 100\%$$

Composing with 3 basic rules.
Quality of light transmission, uniformity of lighting, autonomy of natural lighting, etc. can be respected by using a simple but rigorous approach:

1. Reach the minimal threshold of 300 lux during 50% of the occupation and on 90% of the surface.
Recommended for years at an international scale, this level of natural light autonomy is clearly indicated in the new EN 17037 norm relative to "natural lighting" for the buildings. To deal with the light variation according to the localization, it is possible to exploit the geographic database: for example, the information on www.satel-light.com.

But the level of natural light available will depends on the geographic location. We will take into account the level of natural light required based on the building's activity and its geographic location to determine the lighting surface necessary and the type of infill (glass, shading system, polycarbonate, etc.).

2. Uniformizing the natural light thanks to the materials used.
Diffusing or transparent, they help make the light diffusion coherent within the building and can resolve the classic discomfort situations: glare, shades, etc. Shading systems can be associated.

3. Geometric Area Light
Calculating the geometric area light (or SGL in French) – this ratio is based on the DayLight Factor related to the Light Transmission factor (or TV) of the infill (from transparent glass to opalescent material) – enable us to determine the opening surface necessary, essentially on the roof.
Its formula is:

$$SGL = \frac{2{,}3\ FLJ}{TV}$$

A large choice of tools to build better.
Support tools help projects' managers to optimize, analyze and practice the building's orientation – either in renovation or new projects. Architects and engineers have access to geographic localization tools, meteorologic events history, etc., it is therefore possible to anticipate and do pre-calculations for theirs projects.
The recent "Guide for natural zenithal lighting" realized by the industrial members of the GIF Light group (cf. « Further information » section) introduces an approach with several of these tools (calculation formulas, charts, exemples, etc.) to grasp realistic options.

Feedback

Providing a complete support for an easier job

« When we are working on new or renovation projects as gymnasiums, industrial workshops or warehouses, we think it is very important to raise awareness among clients about the exploitation of natural lighting. For everyone working in the building, it is a question of visual comfort. From our own experience, we know it even goes beyond: it is a way to give occupants a well-being sensation, energy, and take into account some forms of fatigue at work.

When working on a new RT2012 project and to reduce the Bbio coefficient, natural lighting gives several important advantages: in the calculation formula, artificial lighting systems consumption have a coefficient 5! Increasing the windows' surface, on the façade or roof, greatly improve the result.

We introduced this type of lighting system in one French industrial electronic components welding shop, who's activity request a lot of precision: The natural lighting was part of an essential study to avoid any glare effects; this system now offers the employees a real comfortable work environment.

Our safeguards, in relation to these solutions, are to avoid glaring effects by working on the simulation – in collaboration with lighting engineers, and free tools for visualization – and treating the thermal risks for overheating and heat loss. Among the available solutions, we particularly appreciate the light tuning vertical tunneling. These equipments are of interest for both lighting and thermal insulation for the building: they don't diffuse direct light because their concentration is associated to a diffusion and the air column between the exterior edge of the spot and the inside outlet guarantees a small thermal protection.
This characteristic also applies for both the winter and summer comfort, because these light tubes prevent overheating. »

Joséphine Ledoux,
engineer, co-owner of
Enera Conseil engineering agency.

Engineering agencies have a lot of software at their disposal to take into account the shape and height of buildings they are working on. We can name:
• Heliodon, which performs sun path diagrams and calculates the direct solar radiation depending the localization, date and time ;
• DL-Light and DL-Instant, plug-ins of Sketchup sofware to evaluate the natural light within projects and urban environments;
• Relux, Dial + Radiance or Archiwizard for a global and thorough projects approach.

The GIF Light reminds some adjustments' rules of the visualization tools to reduce the difference gap between simulation and reality after construction: complete walls' reflection factors in databases, indicate precisely the windows' translucent or diffusing properties and proceed a simulation on an empty building – not furnished.
Some Dynamic Thermal Simulation (DTS) tools like Pleiades-Comfie, Designbuilder, Virtual Environment, etc. or shade analysis on an annual cycle with applications like 3D BIM can also apply.

Key point: the most important usable data is the average DayLight factor on a surface of reference.

Controlling the sunlight input.
Performance of the natural light in residential or business premises comes from the control of its variations which can disrupt the comfort of the occupants – essentially glare or overheating effects.
The architects and engineers' approach is based upon the orientation of the constructions and the simulation of the technical equipments: dimension and adaptation of the windows, choice of glass' infill to optimize the light transmission, solar factor (light glass, with solar control, reflecting, etc.).

Project managers must complete this work with protection systems. We can distinguish different types of solutions:
• Environmental integration: vegetation or relief will be used to protect or illuminate façades according to the season;

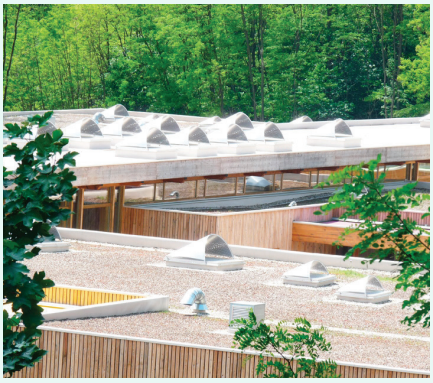
• The addition to the façade of edge trims, horizontal or vertical fixed solar shading, external mesh, green roof or façade; thicker buildings can be designed with patios, skylights or atriums, etc. these solutions are excellent for an environmental approach and break with monotony of traditional façades with a strict respect of the thermal regulation;

• Equipping the joineries with blinds with adjustable blades, internal or external blinds (sometime reflecting), drop-arm awnings, folding-arm awnings, venitian blinds or integrated blinds in double-glazed windows; electrochromic glass ensuring a dimming through electronic activation are now available.
For the roof, individual or running skylights, roof window, and north light roofs, can be equipped with diffusing infill, textile blinds – vertical or horizontal, etc.

Natural lighting: what are the benefits?
Choosing natural light has a human, technical and financial impact:
• By lighting up premises with a natural optimized and controlled solar source, project managers favor the basic physiological needs of the occupants. The natural light wavelength at 550 nm matches normal eyesight; artificial sources of light – LED or fluorescent – are generally shifted towards blue in the visible spectrum; it it now recognized that these lighting solutions disrupt the arcadian cycle.

Finally, being associated with a view of the panorama, natural lighting actively promotes the well-being of the occupants with a combination of visual, biological and emotional effects. Studies report a decrease in absenteeism, an improvement of the focus, etc.

• Exploitation of the natural light and thermal inputs impacts the heating and lighting entries.
Figure 3.4 – Natural light inputs through a skylight



on the roof.

In a business building, needs for lighting are from 7 to 40 W/m², or even 7 to 10 W/m².
Taking into account natural light reduces the need of electrical energy and equally limits the internal heat inputs. With the decree of March 22nd, 2017 about the existing buildings' thermal regulation, it is required for the new lighting installations in non-residential buildings to:
• a gradation of artificial light according to the natural light;

• a 1,6 W/m² maximum power for artificial lighting systems and an average lighting of 100 lux. An opportunity to complete the needs with natural input...

• finally, the financial impact of using natural light can be analyzed from different angles: an increase of productivity, a decrease of work-related accidents, an improvement of production quality, a reduction of energy consumption for lighting and heating.

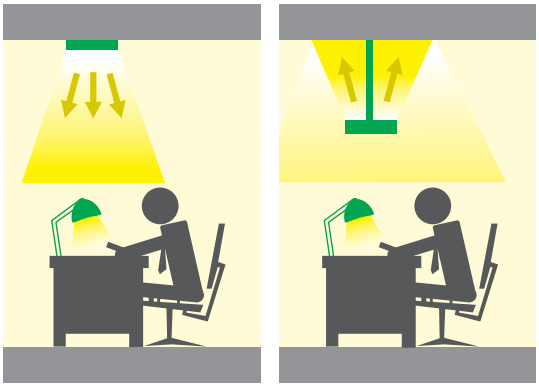
Also, the respect of 300 lux of natural light during 50% of the occupation time enables to reduce, starting at the conception phase, the primary energy consumption (PEC) by 10 to 20%.
And if by increasing the glazed surface you may increase the heat loss, natural lighting and thermal inputs can reduce the energy consumption by 20 to 60%.

Lighting, 1st energy expenditure for a RT2012 office building.

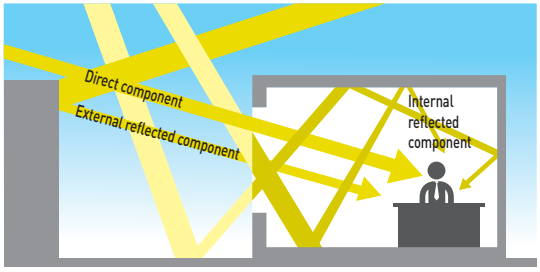
In the guide "Conception of bioclimatic offices", Cegibat quotes the numbers provided by the engineering agency Effilios about the energy consumption of existing or new buildings utilizing the RT 2012.
In ancient buildings, lighting represents 18% of the consumptions; in a new building, this part is reduced by half in accordance to the reduction of technical equipment (heating, cooling systems, etc.) consumptions.
But in a RT 2012 building, lighting represents 38% of the consumptions, against 14% for the heating, 21% for the cooling and 27% for ancillary equipments. "A level linked, according to Cegibat, to the duration of operation – a parameter hard to estimate as long as it is depending on the occupants' behaviors".

Vocabulary to better understand the light and the photometric range

1. **The Luminous Flux**: light power of a source. Its unit is the lumen (lm). One lumen is the flux of a radius 555 nanometers (nm) corresponding to a power of 1/683 W.
2. **The Luminous Intensity**: luminous flux of a source towards a fixed direction. Its unit is the candela (cd).
3. **The Illuminance: luminous** flux received by a surface. Its unit is the lux (lx). One lux equals 1 lumen on 1 m².
4. The Luminance: luminous intensity of a source in a fixed direction. Its unit is the candela per square meter (cd/m²).
5. **The Reflection**: change in the direction of the light on a surface. We distinguish:
- the specular reflection, or the radiation is reflected on a surface according to an angle identical to the radius.
- the diffuse reflection, or, on an irregular surface, the reflected radiation is not parallel to the incident ray.
- the luminous reflection factor or coefficient of a surface equals the luminous energy reflected in relation to the one received. Its unit is the **ρ** (rho).
6. **The Light Transmission**: luminous flux going through a material. We distinguish the directional light transmission, with an angle equal to the one of the incident ray, from the diffuse transmission (or specular). The Light Transmission coefficient (TL) is the ratio of the luminous flux conveyed on the incident ray. Its unit is the **τ** (tau).



Artificial lighting: exploiting the direct and indecent light.



Natural lighting: control the comfort by canceling the glare effect and shadows.

Illuminate the premises: norms and regulations

> Illumination of the work area is regulated by the **ministerial circular of April 11th, 1984** completing the decrees n° 83-721 and 83-722 from August 2nd, 1983.

This text requires a **minimal lighting level according to the type of activity**:
- **200 lux** for simple mechanical work, typing, office-related work;
- **300 lux** for the crafting activity, drawing or data-processing;
- **400 lux** for precision work, engraving, comparision of colors, detailed-drawing, fashion industry work;
- **600 lux** for precision engineering and electronics, control-management activity;
- **800 lux** for all difficult tasks within the industry or laboratories.

> More recent, **EN 12464-1 «the light and illumination of work»** premises norm published in 2006 and updated in 2011, gives a different approach of the illumination and its distribution on the work area. It is applied to offices, workshops, schools, hospitals and commercial premises.

1. It identifies **three illumination areas**:
- the work area: the office, the floor, etc. The surface on which a visual task is executed;
- the immediate surrounding area, an area of 50 cm around the work area; the level of light will be reduced by a factor of 1,5 to 1,66;
- the backrgound area, an area of 3 m around the immediate surrounding area... within the limits of the space (walls, partitions, furniture, etc.); the light level will be reduced by a third from the level of the previous area.

2. It prescribes an average of **level of illumination according to the activity**:
- **200 lux** in storage rooms;
- **300 lux** for commercial buildings, warehouses, sports halls, reception halls, offices;
- **500 lux** in industrial buildings, libraries or reading rooms, kitchens, schools or conference rooms, offices where people work on computer/screens;
- **750 lux** in technical/industrial drawing offices, etc.

3. It develops **two measures against glare**:
- The **UGR**, or « Unified Glaring Rate », to control the glare by associating several lights. This rate goes from 10 – not glaring – to 30 – very glaring. The UGR is mainly tied to the luminous flux, the lighting surface and the distribution of light.
- The **shield** angle is a maximal angle depending the luminance of the light: 15° for those < 50 kca/m², 20° for those from 50 to < 500 kca/m², 30° for those > 500 kca/m².

Lighting represents 12% of annual electric consumption

On the 475 TWh of electric energy annually consumed in France, 56 TWh are consumed by lighting:

- residential building represent 11 TWh;
- street lighting represent 7 TWh;
- public buildings' lighting (health, schools, sports, culture and administration) represent 15 TWh;
- private buildings' lighting (offices, pub, hotels, restaurants, shops and industries) represent 23 TWh.

Source: RTE, Ademe, Syndicat de l'éclairage (Lighting federation).

THE AIR

A constant need of air renewal.
Every building must be ventilated. When not occupied, micro-organisms naturally develop within interior environments, organic matter and odors deteriorate too, etc.
When occupied, the rooms accumulate the vapor released by the human body (from 50 to approx. 400 g/h according to the activity), the CO2 produced by breathing, the volatile organic compounds emitted by different products or activities: furniture, printers, industrial processes, etc. Air renewal maintains a healthy and pleasant ambiant air within these environments.

Depending on their use, the premises are subject to different regulations:

> Decree of March 24th, 1982 updated on October 28th, 1983
Individual housing or multi-unit buildings builders refer themselves to the decree of March 24th, 1982 updated on October 28th, 1983. It prescribes a general and permanent ventilation (chart 3.1).
Other types of buildings (service industry, industrial, commercial, sports halls) must refer to the Regional Health Regulations type (RSDt) or to the Labour Code.

> Regional Health Regulations type (RSDt) and Labor Code
Within the premises with non-specific pollution, a new airflow is introduced through mechanical ventilation according to the RSDt (chart 3.2).

Type of building /housing	Minimal total airflow		Kitchen		Bathroom		Restroom	
	Continuous airflow system	Airflow modulation system subject to technical approval	Minimal airflow	Peak airflow	Main	Other bathroom	If unique	If multiple
T1	35	10	20	75	15	15	15	15
T2	60	10	30	90	15	15	15	15
T3	75	15	45	105	30	15	15	15
T4	90	20	45	120	30	15	30	15
T5	105	25	45	135	30	15	30	15
T6	120	30	45	135	30	15	30	15
T7	135	35	45	135	30	15	30	15

Chart 3.1: Minimal extraction airflows (in m³/h) of the accomodations according to the decree of March 24th, 1982, updated on October 28th, 1983

Type of use of premises		New air flow in m³/h and per occupant
Schools	Classrooms, studies, laboratories (with the exclusion of laboratories with specific-pollution), kindergarten, primary/elementary and middle/highschool	15
	Classrooms, studies, laboratories (with the exclusion of laboratories with specific-pollution), highschool and universities	18
	Classrooms, studies, laboratories (with the exclusion of laboratories with specific-pollution), workshops	18
Accomodations: collective bedrooms (more than 3 people), dormitories, cells, fitness/sports centers		18
Offices and equivalent premises: reception halls, libraries, post offices, banks		18
Community premises: meeting rooms, spectacle/concert halls, religious buildings, community centers		18
Catering industry premises: cafés, bars, restaurants, canteen, dining room		22
Sports halls /centers	Per athlete in a pool	22
	Per athlete in other premises	25
	Per spectator	18
Premises with occasional presence (warehouse, archiving rooms, halls...); premises not permitting a ventilation through adjacent premises		0,1 l/s/m²

Chart 3.2 : New air flow to introduce within premises with non-specific pollution according to the Regional Health Regulations

The Regional Health Regulation requires:
• a limit of CO2 concentration of 1 000 ppm (with a tolerance up to 1 300 ppm) within non-smoking premises;
• a minimal ventilation when the building is not occupied, without reaching the maximal level of CO2 concentration, and which can be regulated or interrupted;
• the interruption of ventilation after occupation and after reduction of the CO2 pollution.

Within premises with non-specific pollution like offices and work-spaces, the natural ventilation through the windows or other types of openings is authorized by the Labor Code (Art. R 4222-5):
• if the physical work is light, the volume per occupant must be equal or superior to15 m³;
• if not, it must be 24 m³.

Regarding the conference rooms, concert halls, religious buildings, commercial buildings, etc. the RSDt allows the ventilation through opening towards the outside (doors and windows) provided that the minimal volume of 6 m³ per occupant is met (chart 3.2).

Within premises with specific pollution, architects and engineers determin the ventilation flow according to the nature and quantity of polluants. It can be premises containing gazeous, liquid or aerosol forms of pathogenic micro-organisms or harmful emissions sources (nuisances like odors). However, for bathrooms, toilets and kitchens, the airflow is indicated by the Regional Health Regulations type (RSDt) (chart 3.4).

Natural ventilation through doors and windows (chart 3.3) is authorized under certain conditions:
• a minimal toilets' surface of 5 m³ per potential occupant;
• and, for non-housing premises:
- that it is not necessary to capture polluants at production/emission point (welding smoke, painting, etc.) because of their aeraulic flows inversion risk,
- and that the extracted airflow is inferior to 1 l/s/m³ of premises.

Regulations are provided by articles R 4212-1 to R 4212-7, and R 4222-4 to R 4222-9 of the Labor Code. These regulations require:
• to ensure « air renewal at any point of the premises »;
• to not « cause, in the work areas, any nuisance resulting from speed, temperature and humidity of the

air noises vibrations »;
• to « not generate a significative increase of the sounds level resulting from the expected activities within the premises ».
Air flows required for a health-compliant air renewal within offices and non-housing premises are:
• offices, premises without any physical work: 25 m³/h per occupant;
• restaurants, commercial premises, meeting rooms: 30 m³/h per occupant;
• workshop and premises with light physical work: 45 m³/h per occupant;
• other workshops and premises: 60 m³/h per occupant.
To evacuate the heat load, the renewal air flow must be way higher: from 8 to 10 volume per hour.
Therefore, for 20 m² office with 2,5 m of floor height, or 50 m³, the renewal air flow must be 400 to 500 m³/h!

> Other sources.
Pending the evolution of the regulations, the Iceb (Institute for the Eco-responsible Design of Buildings) encourages, in its guide Bio-Tech "Natural and mechanical ventilation", a noticeable evolution of the renewal air flows to hygienic purposes:
• in classic non-residential (offices, schools): at least 30 m³/h.person and 1 volume/hour ;
• in residential: at least 30 m³/h.person et 0,5 volume/hour.

What concepts are available for natural ventilation?
Natural ventilation offers the advantage to enable the association of classic equipments and technical solutions both economic and architecturally non-restrictive.

> Walled and roof equipments
These solutions are now widely present in suppliers' catalogues:
• façade cladding (some even room-height) ventilation frames for a transverse ventilation by exploiting the pressure and flow exerted by the dominant winds,
• joineries equipped with controls for proportional opening,
• ventilation stacks using the principle of thermal draughts (certain models can be associated to vertical light tubes),
• skylights with manual or automatic opening controls...

> Natural and hybrid ventilation
Also called "assisted and controlled natural ventilation", the natural and hybrid ventilation is a mix of natural ventilation – extraction of the stale air by convection – and the technical support of mechanical ventilation – to maintain the airflow thanks to an extractor.

The advantages can be technical, energetic and financial:
• the air flows are guaranteed while being partially controlled;
• the cost of installation and operation are reduced;
• the equipment is limited to an extractor and its control, there is no specific sheath to install, and its maintenance is minimal;
• the equipment's energy consumption is low: approx. -30 to -35 % compared to a simple flux mechanical ventilation system...

> Destratification
Warm air rises, cold air goes down. This air-treatment solution through mixing of air is well-known: it is employed for big volumes and halls (airports, concert halls, gymnasiums, etc.)

Figure 3.5 – Fans dedicated to the destratification have been tested in industrial and logistics buildings.

Premises surface in m²	Surface of the windows in m²
10	1,25
50	3,6
100	6.2
150	8.7
200	10
300	15
400	20
500	23
600	27
700	30
800	34
900	38
1000	42

Chart 3.3: Surface of windows according to the surface of premises (except for schools) according to the Regional Health Regulations

Type of premises		Airflow
Rooms for individual use	Bathroom	15 m³/h/local
	Shared bathroom with toilets	15 m³/h/local
	Toilets	15 m³/h
Rooms for collective use	Toilets	30 m³/h
	Separated bathroom	45 m³/h
	Shared bathroom with toilets	60 m³/h
	Shared bathroom with toilets	(30 + 15 × N*) m³/h
	Bathrooms	(10 + 5 × N*) m³/h
	Dry cleaning rooms	5 m³/h/m²
Collective kitchen	Office	15 m³/h/repas
	< 150 meals served simualtemously	25 m³/h/repas
	150 to 500 meals served simualtemously	20 m³/h/repas
	501 to 1 500 meals served simualtemously	15 m³/h/repas
	> 1 500 meals served simualtemously	10 m³/h/repas

*N: number of equipments within the premises.

Chart 3.4: Minimal new air flow to introduce for bathrooms, collective kitchens and their nooks according to the Regional Health Regulations

The concept is to apply a pressure capable of causing an ample movement of air – from the roof to the external roofs then to the floor – which will homogenize the ambient air temperature and reduce cold wall effects, without being noticed by the occupants. For workshops and industrial/logistics buildings, some suppliers offer to install large diameter fans on the ceilings – from 2 to 10 m! – and with a slow rotation (Fig. 3.5). Their effectiveness is already proven.

> Geothermal systems (Canadian or Provencal)
This ancestral principle tempers the external air by making it travel through buried air ducts. This ducts network is buried between 1 and 3 m of depth and inhibiting the new air temperature in relation to the outside air. This type of installation is intended to warm the fresh air in the winter and to cool it in summer, but it requires a lot of structural work and maintenance.

> Adiabatic ventilation or cooling
From independent equipment, or associated to a simple or double flux air handling unit, this concept can ensure both ventilation or cooling functions (Fig. 3.6). The principle consists in humidifying the filtration system located within the air duct to reach temperature/humidity levels required within the space.
Such system permanently blows a renewed cooled air to control the ambient temperature during summer, to control the relative humidity (Fig. 3.7) – between 50 and 60 % – and to reduce the cooling function energy consumption and costs. It is use in numerous types of buildings: industrial, logistics, commercial, offices, sports centers, schools...

Figure 3.6 – Adiabatic ventilation systems ensure a permanent and efficient ventilation and a cooling function at a very low global cost.

> Ventilated façade, atriums and buffer spaces
These architectural solutions are unheated spaces in direct contact with the envelope of the building or with heated premises. They inhibit the external temperature during summer and winter, through air movement effects within the newly created space.

Architects distinguish:
• spaces where the fresh air only goes through the volume, without entering the main inside space, like attics;
• spaces where the fresh air introduced in the buffer space is used within the main inside space: ventilated façade, veranda/conservatory, etc;

Also, because of the difference of inputs, we can distinguish these spaces:
• exposed to the sun which envelope is composed – totally or partially – of windows (double façade, double windows, verandas, atriums, greenhouse, conservatory, etc.) and which benefit from a double free input – through the air and direct solar radiation (Fig. 3.8);
• non exposed to the sun because composed of opaque walls (attic, garage and parking, cellar, corridor, equipment room, etc.) and which exploit free inputs through the air.

These solutions offer a **triple advantage:**
• **thermal** because they correct the heat transfer and linear expansion coefficients of the walls of the heated rooms and therefore reduce the heat loss and prevent phenomenon of condensation on the surface of walls (precursory for mold development);
• **airflow and thermal** as the air is preheated during winter – in the northern regions of France, the level of natural free inputs is superior to the one in the southern regions as the heating period is longer – and is tempered during summer...providing the installation of sun protection, at the risk of overheating effect;

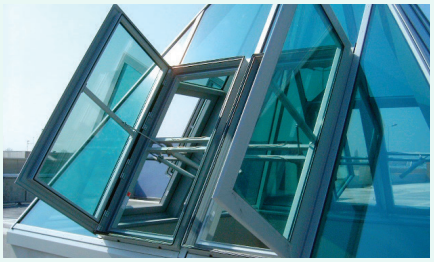


Figure 3.8 – Bay windows will be selected for their maximum glass surface.

• acoustic, because these spaces cancel the external noise levels in the occupied premises.

Challenges in tune with current environmental preoccupations.
While still not preferred by architects and engineers' reflexion, and too often not taken into account by the buildings' operators, natural ventilation is still being studied and its expertise still developed. Recently, the famous architect Renzo Piano, for the conception of the 200m of length and 3-stories building for Ecole Normale Supérieure of Paris-Saclay (fig. 3.9) chose to design a concrete floor for each level composed of thick cross-through casings enabling natural ventilation inside the class rooms, the offices and the central atrium.

Figure 3.9 – The ENS of Paris-Saclay in construction. On the façade, leafs regulate the natural ventilation of most parts of the building (Renzo Piano Architect).

This mode of ventilation's goal is to reduce the energy consumption and cost of the ventilation and air treatment functions, by canceling or reducing the energy consumption linked to ventilation equipments, or by optimizing the operation of double fux ventilation units with a complementary adiabatic unit. These solutions enable you to work comfortably even with doors and windows open during very warm days.

In numerous situations, these solutions can prevent using air conditioning systems, through a direct expansion system or other, which offers energetic and environmental advantages:
• equipments – joineries, fans, adiabatic cooling systems, etc. – are technically simple to install, operate and maintain.

• performance coefficients of these systems, like the adiabatic cooling system, can reach very high levels, generally above 50 kW of cooling for 1 kW absorbed, and up to 100/1 when added to an existing ventilation system;
• low energy needs implying a lower consumption of electricity;
• air flows can be controlled through remote controls and variable speed motors;
• operators are not subject to issues like refrigerant gas by choosing standard fluids: air, and water in adiabatic systems, sometimes even rain water. The water used not being lost or polluted by a natural evaporation principle.

These techniques of ventilation are also suitable to maintain the quality of the ambient air. The control of the air renewal by sweeping the room ensure the elimination of basic pollution (humidity, CO2) but also particles, volatile organic compounds, etc.

Imperative flexibility and precautions.
How do we calculate and anticipate natural ventilation system that are working in synergie with the building's envelope? It is a question that engineers tried to answer for 20 years. In 2003, the CSTB (Scientific and Technical Center for Building) published a technical guide about "Air conditioning systems with low energy consumption" (guide of the CSTB n° 3454).
The chapter "Technical solutions" of the guide Bio-tech "Natural and mechanical ventilation" from the Arene IDF and ICEB (2016) gathers technical conception elements for residential and non-residential buildings.
Recently, the Pacte – ex Rage program (Best practices – Grenelle Environment) – revisited numerous questions to comply with the regulations and best practices (www.programme-pacte.fr/catalogue) (See details in the section « Further Information »).

> Designing buildings compatible with natural ventilation
According to the Bio-tech guide from Arene IDF and ICEB (see the section « Further Information »), natural ventilation has some constraints:
• through the shape of the rooms:
- for a ventilation on only one side:
> with a unique window on the façade, depth must be limited to 2 times the ceiling height;
> with two windows placed at two different heights, the depth must be limited to 2,5 times the ceiling height, with a difference of 1,5 m height between the two windows;
(NB : the authors of the Bio-Tech guide « Natural and mechanical ventilation » suggest formulas to estimate the air flows.)
- cross-through ventilation: with one window on one façade and an other window on the other façade, the room depth must be inferior or equal to 5 times the ceiling height;
• through the orientation of the façades and the wind potential;
• through the building's environment (terrain roughness, masking effects...).
To limit the heat loss, architects and engineers also take into account the operation during winter.

> Appreciating the building's inertia
Effects of the natural ventilation and the regulation strategy can differ according to the buildings walls' characteristics for thermal inertia. Its performance can be estimated through multiple criterias: outside and rooms temperatures, room temperature setpoint and the internal free inputs.
A strong inertia, linked to the use of heavy materials and with a thick thermal insulation, translates to a steady room temperature regardless of the day and night variations ; this type of construction avoids overheating effects during summer and enables the building's operators to benefit from free natural inputs during mid-season and winter.
A low intertia is essentially due to the use of material with a low-absorption capacity of energy flux (wood, isolating materials) and to a strong variation according to the flux;
it requires a precise control to maintain a steady room temperature.

> Choose adapted natural ventilation solutions
Architects and engineers always face contradictory requirements: ensure the thermal comfort, the ambient air quality while controlling the energy consumption and having in mind the technical and economic questions.
Adapted windows, double façade, skylight, air blowing, chimneys, atriums, extractors for hybrid ventilation, adiabatic cooling systems, etc. The technical choices will be calculated and simulated on computers based on the air flows to reach and the comfort goals. Engineers will be taking the project in its globality – the envelope, the equipments and its occupants – in order to guarantee the results.

It is common to say "the air is lazy", that is escapes through parasite infiltrations disturbing the air flow. Builders and architects must therefore comply with the airtightness/regulation/air flow rules.

We put the emphasis on a rigorous simulation of the installation approach in order to deal with possible discomfort situations: condensation in summer, inertia of the envelope, difficulties to unload the heat storage during long hot summer waves, possibility for free-cooling during mid-season, night-cooling – also called temporary intensive ventilation – during summer to unload the heat stored during the day and benefit from the phase difference of the cool air accumulated during the night 8 to 12 hours later, pre-heating of the air during winter, etc. One of the answers to this need of quality is the definition of a regulation diagram.

Temperature (°C)

Relative humidity (%)	21	25	30	31	32	33	34	35	36	37	38	39	40	41	42	43
20											40	41	43	44	46	47
30			31	33	34	36	37	38	40	42	43	45	47	48	50	51
40		26	34	35	37	39	40	42	44	45	47	49	51	53	54	56
50	22	28	36	38	40	41	43	45	47	49	51	53	55	57		
60	24	30	38	40	42	44	46	48	50	52	54	57				
70	25	32	41	43	45	47	49	51	53	56	58					
80	26	33	43	45	47	50	52	54	57	59						
90	28	35	45	48	50	52	55	57	60							
100	29	37	48	50	53	55	58									

No discomfort
Discomfort
High discomfort
Danger – imminent heatstroke

Figure 3.7 – Calculation of the "Humidex" coefficient to anticipate the comfort according the meteorological events: temperature, humidity.

4. REGULATION, CONTROL AND MONITORING: A LARGE BUILDING'S EQUIPMENT.

Natural lighting and ventilation have multiple advantages: occupants' comfort, wide and accessible technical equipments, reduction of investment and maintenance costs, etc.
They also are of interest when considering their ease of use and how occupants can operate them. According to the building and its level of equipment, you can easily find a regulation control system.

Available solutions.
> Detection of presence
Linking a sun protection system and an artificial lighting system to probe is a common installation. The detection of presence can be associated to the lighting and shading systems as well as to a lighting gradation system in order to maintain an illumination level of the work area to the setpoint (300 or 500 lux).

> Temperature, humidity and CO2 probes
As for mechanical ventilation systems, different solutions of natural ventilation – hybride, adiabatic – operate efficiently with an adapted regulation system based on the basic comfort criterias.

Device manager.
> For natural ventilation
An intelligent natural ventilation system can be added to a traditional natural ventilation, hybrid ventilation or adiabatic cooling systems. Its advantage is to exploit equipment for natural smoke extraction and fire safety – which still have priority – to increase the comfort of the occupants: temperature, humidity, elimination of VOC and reducing CO2, etc. Without any heavy investment, this solution opens opportunities for natural heating and cooling systems (free cooling, night cooling, free heating). The exploitation of an annual meteorologic database can enhance the position and opening of the windows.

> For natural lighting
An intelligent shading solution can automate the sun-barrier equipment (blinds, external sun-breakers, etc.) and artificial lighting systems.
To increase the economy of energy according to the occupation of the building, its regulation system offer a devices' management through a daily, weekly and annual program.

> For double façades
To be efficient on the lighting, ventilation and thermal comfort functions, these double façades (Fig. 4.1) must be equipped with automated control systems to manage the windows in order to have a « smart bioclimatic façade » and exploit free natural inputs during mid-season and winter and avoid overheating effects during summer.
They also can be reinforced with natural lighting and ventilation management systems in their multizone version and with an interface accessible remotely online.

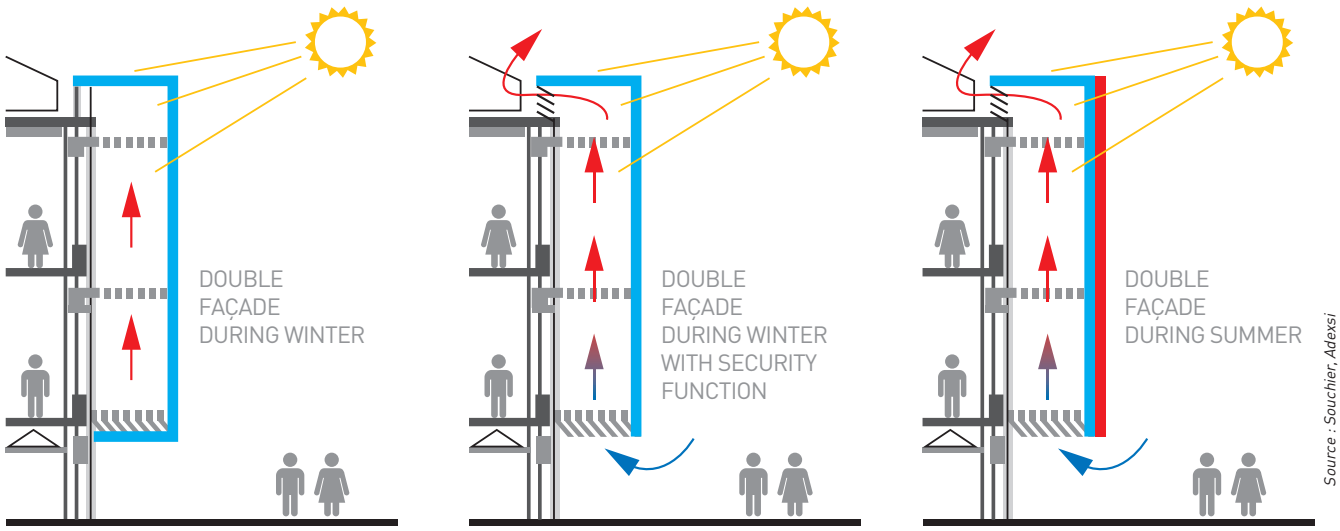
Building Management Systems (BMS).

> Solutions for new construction or renovation projects.
Control of the technical features of a building, whatever its size, is base on a global management. Global solutions with integrated calculation systems make their installation easy:
• Example 1: a meteorological station linked to an ensemble of probes (outside and inside temperature and humidity, CO2 and COV measure, detection of presence, wind or rain) manages the windows of the façade;
• Example 2: specially designed for natural ventilation and lighting of buildings with atriums, a solution associating a "wind and rain" station to multiple outside and inside temperature probes – which some can be radio and hard wired – to manage the windows and some chain actuators. This type of solution can operate destratification of wide volumes.
• Example 3: designed for industrial and logistics buildings, this other type of solution operate the same measuring equipment (meteorological station, temperature and humidity probes) to control the natural smoke extraction skylights, roof ventilation turrets, or windows on north light roofs or other equipment for sun protection. It is a sturdy (rare breakdowns) and very responsive to meteorological events. Based on classic equipment for these types of buildings, it is also very economic in its investment and operation while improving the comfort and reducing the lighting consumption spendings.

> "Classic" building application.
Such modes of operation find regulation and classic control systems for the non-residential buildings:
• EnOcean radio solution for renovation projects;
• Bacnet or Modbus communication protocols common solutions to integrate the natural lighting and ventilation functions within the building's global regulation system.
These solutions are perfect for the natural lighting and ventilation functions to blend in the Building Management Systems (BMS). They also give the engineers the opportunity to integrate the equipments of worldwide suppliers (Energy Management Solution or Ecos 5 from Sauter, programmable control systems, sensors and probes from Carel, Saia control systems from Honeywell, Synco

temperature regulation system from Siemens, etc.).

> How can we follow the performance of our equipment?
Whatever the technical solution chosen, the building's operator and occupants will want the control over the equipment and their operation.
Webservers give you a remote access to data, synoptics, alarms and defaults.
After integrating wireless and radio control systems, webservers and others, natural comfort solutions also lean towards web-connected devices. An essential path to follow to become more attractive.



1- Double façade during winter
Double façade closed: direct sun radition is used to heat the air stocked inside the double façade and store a maximum of solar heat.
> NB: windows on the façade of the building can also be used to let the warm air from the air conditioning system go through.

2- Double façade during winter
An automatic function can limit the excess of temperature inside the double façade by briefly, and if necessary, introducing fresh air from the outside (partial opening of the air inlets to avoid a too big increase of temperature which can damage the equipment).

3- Double façade during summer
To prevent the overheating of the ambient air by naturally ventilating the air stocked inside the double façade and avoid the warm air from the double façade to enter the building.
> NB: windows on the building's façade can also be used to let the cool air stocked within the double façade penetrates the building, and thus limit the need for air conditionning.

Figure 4.1 – Double façade: their operation during winter and summer

FURTHER INFORMATION

Regulations.
• European directive (UE) 2018/844 from May 30th, 2018, modifying the European Directive 2010/31/UE about the buildings' energy performance and the European Directive 2012/27/UE about energy efficiency European Union Official Journal of June 19th, 2018.
• Decree n° 83-721 from August 2nd, 1983 completing the Labor Code (2nd part) regarding the illumination of work premises, Official Journal of August 5th, 1983.
• Decree n°83-722 August 2nd, 1983 completing the Labor Code (2nd part) and setting the rules relative to lighting of work premises to which project managers willing to build or renovate building with an industrial, commercial or agricultural activity, Official Journal of August 5th, 1983.
• Decree n°2011-1728 of December 2nd, 2011 about the surveillance of indoor air quality in public buildings, Official Journal of December 4th, 2011.
• Decree of March 22nd, 2017 modifying the decree of May 3rd, 2007 about thermal characteristics and energy performance of the existing buildings, Official Journal of March 25th, 2017.
• Ministerial circular of April 11th, 1984 relative to the technical indications from the decrees n°s 83-721 and 83-722 of August 2nd, 1983 relative to lighting of work premises, Official Journal of May 11th, 1984.
• Circular DRT n°90/11 of June 28th, 1990 relative to natural lighting and outside view.
• Circular DRT n°95/07 Of April 14th, 1995 relative to work premises (circular non published on the Official Journal).

Norms.
• ISO 7730:2005 (November 2005): Ergonomie des ambiances thermiques - Détermination analytique et interprétation du confort thermique par le calcul des indices PMV et PPD et par des critères de confort thermique local (Thermal ambiances ergonomy – Analytics and interpretation of thermal comfort by calculating PMV and PPD coefficients and with local thermal comfort criterias).
• NF EN 17037 (September 2016): L'éclairage naturel des bâtiments (Natural Lighting of Buildings).
• NF EN 12464 1 (July 2011): Lumière et éclairage – Éclairage des lieux de travail – Partie 1 : lieux de travail intérieurs (Light and Illumination – Illumination of work premises – Part 1: interior work premises).
• NF EN ISO 7730 (March 2006) : Ergonomie des ambiances thermiques - Détermination analytique et interprétation du confort thermique par le calcul des indices PMV et PPD et par des critères de confort thermique local (Thermal ambiance ergonomy – Analytics and interpretation of thermal comfort by calculating PMV and PPD coefficients and with local thermal comfort criterias).
To follow: les travaux de la norme expérimentale NF X 35 103 sur les principes d'ergonomie applicables à l'éclairage des lieux de travail en tenant compte de l'âge des occupants, de la tâche visuelle et des situations à risques (experimental NF X 35 103 norm work about the principles of ergonomy applicable to the illumination of work spaces according to the age of the occupants, the visual task and the at risk situations).
• NF EN ISO 8996 (February 2005): Ergonomie de l'environnement thermique - Détermination du métabolisme énergétique (Thermal environment ergonomy – Determination of the energetic metabolism).

Projects.
• Le guide de l'éclairage naturel zénithal pour les bâtiments industriels, commerciaux et tertiaries (guide for natural zenithal lighting for industrial, commercial and office buildings), published by the GIF Light in collaboration with Ademe and the Light Association, led by Bernard Lepage, April 2018
• La ventilation naturelle en pratique (Natural ventilation in practice), by Jacques Gandemer, Instituto Arquitectura Tropical, PDF published in November 2015.
• Conception de bureaux bioclimatiques (Bioclimatic offices conception), technical guide written by Cegibat, ICO and Unsfa, Éditions Cegibat (2016).
• Bio-Tech guides published by l'Arene Île-de-France and l'Iceb, published in 2014 (http://www.asso-iceb.org/documents/guide-biotech/).
• Energy performance:
- Volume 1: les matériaux et procédés d'isolation (materials and insulation methods), by S. Bouché and A. Delaire, CSTB Éditions (2013).
- Volume 2: chauffage, ECS, électricité, ventilation (heating, ECS, electrical and ventilation systems), from the CSTB, CSTB Éditions (2016).
• Traité de construction durable (Building Sustainable Draft), under the supervision of Daniel Bernstein, Éditions Le Moniteur (2007).
• Le Guide de l'habitat sain (Guide for Healthy environment): Les effets sur la santé de chaque élément du bâtiment (effects over the health of each elements of the building), by Suzanne and Pierre Déoux, Éditions Médiéco (2002).

Sources.
> Basic concepts for building efficient buildings:
• Quality of Construction Agency and the « REX – Efficient Buildings » plan: http://www.programmepacte.fr/dispositif-rex-batimentsperformants.
The reader will be directed towards obervations and reports about lighting atmosphere and the educational tools: http://mallette-pedagogique-bp.programmepacte.fr
• Website of the Pacte program (Action Plan for Quality of Construction and Energy Transition): www.programmepacte.fr/catalogue
On this website, you can consult:
- professional recommendations « Verrières » (Glass Roofs) of September 2013;
- guide « Doubles fenêtres » (Double Windows) of April 2014;
- guide « Ventilation hybride » (Hybrid Ventilation of March 2015;
- guide « Façade multiple » (Multiple Façades) of February 2014;
- guides about « Puits climatiques » (Geothermal Systems) of March 2015 (conception, dimensioning, installation, operation and maintenance) ;
- work site notebooks « Puits climatiques en habitat individuel et en tertiaire » (Geothermal systems for residential and non-residential buildings) of January 2017.
• Effinergie website to download the BBC, Bepos Effinergie, Bepos+ Effinergie labels and E+C- project: https://www.effinergie.org/web/association
• Énergie Plus website, toolbox developed by the « Architecture and climate » department of the Catholic University of Louvain, in Belgium : https://www.energieplus-lesite.be
• « Guide Bâtiment Durable » "Building sustainable guide" developed by Bruxelles Environment in collaboration with specialized engeneering agencies: https://www.guidebatimentdurable.brussels/fr/
• Adexsi group website: https://www.adexsi.fr

> Thermal regulations:
• Thermal regulation in existing and new buildings: https://www.rt-batiment.fr
• Policy of energy consumptions reduction and comfort in the buildings: https://www.ecologiquesolidaire.gouv.fr/politiques/batiments-et-regles-construction
• Website about the future E+C- environmental regulation: http://www.batiment-energiecarbone.fr, with training modules within the dedicated "educational tools" area https://docs.google.com/forms/d/e/1FAIpQLSc0KtXR5Pgobvup B0ZpCQK102_3sjrdsW4IYQeRunyFXqD6WQ/viewform

> Natural lighting:
• GIF Light website : https://www.gif-lumiere.com
• French Association for Lighting website (AFE) : http://www.afe-eclairage.fr

www.adexsi.fr

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