HI-SMART

HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #2

CHAPTER 2: HIGH PERFOMANCE WINDOWS FOR NEARLY ZERO ENERGY BUILDINGS

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1.1 WINDOWS IN THE BUILDING ENVIRONMENT

Near zero energy buildings are meant to respect very high energy performance requirements. These buildings will typically encompass a high level of insulation, very energy efficient windows, a high level of air tightness and balanced mechanical ventilation with heat recovery to reduce heating/cooling needs. Although the nearly zero or very low amount of energy required should be covered to a significant extent by energy from renewable sources, the quality of built materials and elements plays the most important role to conserve the energy supplied to the building.

No doubts that for the energy savings a right selection of window type can be crucial. Therefore choosing high-performance windows with appropriate properties can dramatically decrease building´s energy use and operational costs. Windows, or window systems represents an important integral part of the building´s thermal envelope, which also directly impacts other mechanical systems. The key properties that should be observed are as followed:

- energy properties : - U values ($W.m^{-2}.K^{-1}$)

  - g value (-) also known as solar heat gain coefficient (SHGC)

- optical properties: - LT – light transmittance

  - Rt – light reflectance

Nowadays an early design stage building simulation can tell us if the desired ratio between opaque and transparent constructions can lead us to the energy effective design or not, parallel with maintaining the requirements for visual tasks or hygienic criteria. Modern simulation software tools enable us to change this ratio as a parametric input and therefore give an important piece of information for architects to define the shape and architectural expression.

As modern buildings that find inspiration in nature through organic architecture rely in large content on transparent constructions, not only the proper selection of the materials but also fabrication of these systems are very important.

The following issues can affect the performance of the windows systems:

- Thermal Bridging

- Thermal and Visual Comfort

- HVAC and Lighting

- Acoustics properties

- Water intrusion

Where thermal bridges are connected mostly with right composition of each window element and its installation, they must also include the thermal breaks in the installation of window frames, the absence of which can lead not only to energy loss (linear thermal bridges) but also to condensation and maintenance issues.

Thermal comfort is mostly connected with radiative heat that penetrates building which needs to be balanced with interior heating and cooling loads. Heat that comes through windows is favorable when it is needed during heating period, but in excessive measures can hugely impact cooling loads and also produce the discomfort for occupants.

Design for daylighting is an effective strategy which cannot be neglected. Large glass areas are chosen to maximize the visible light to penetrate, but needs to be tinted in the final steps in many cases. The lack of or inappropriate shading devices can cause glare. Therefore an optimal balance needs to be achieved between visual comfort and light transmittance. A minimum of LT=60% is required in Slovakia.

Proper design in terms of daylighting can save on artificial lighting needs and can reduce the size and energy need for HVAC systems since high-performance windows and glazing system affect building´s peak heating and cooling loads.

Acoustic properties are becoming crucial when building is located close to the source of noise such as busy traffic areas, technological facilities or airports. Right composition of glazing system including different thicknesses of panes needs to be calculated, often with combination of additional ventilation units, since these windows are designed to be operated without being opened.

Water intrusion is a problem in all building structure components and is mostly the matter of proper detail design. While glazing system itself have a high resistance to vapors in general, the framing design and its connection to adjacent envelope elements can produce weak spots enabling rainwater channels. The result is not only a deterioration of internal finishes, but it also decreases indoor air quality and affects the energy performance of affected adjacent structures.

Windows are part of passive energy efficiency solutions that include:

- the building envelope solutions – all the elements such as walls, roofs, etc.

- passive strategies for cooling, such as natural ventilation, shading, etc.

This passive solutions present the core of the building structure and equipment. Since their lifespan is designed along the economical usage of the building they need to be selected also with the aim of easy maintenance and not to be replaced in near future.

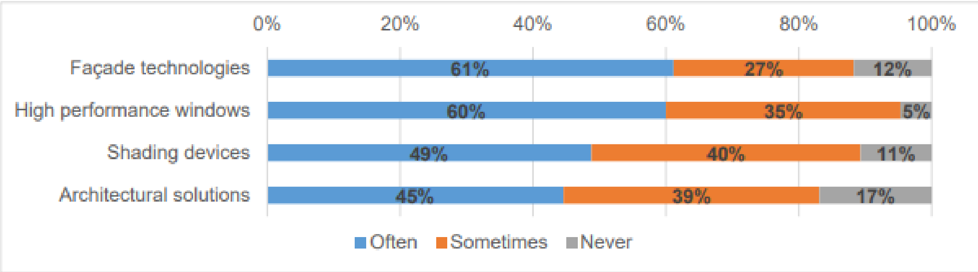


Fig.X Percentage of passive solutions used in nZEBs. (ZEBRA 2020)

According to surveys the professionals used mostly the façade technologies and high performance windows in realization of nZEBs. The architectural solutions such as natural lighting and passive cooling was less selected among the options.

1.2 SOLAR RADIATION AND WINDOWS

Solar radiation is a general term for the electromagnetic radiation emitted by the Sun. As the sunlight passes through the atmosphere, some of it is absorbed, scattered or reflected by water vapors, dust, pollutants and other components of the atmosphere. This results in diffuse solar radiation.

The solar radiation that impacts Earth´s surface without being diffused is called direct solar radiation. The sum of direct and diffuse radiation is called global solar radiation. The atmospheric conditions can reduce the radiation that impacts building in various amounts. The spectrum of solar radiation is close to that of a black body with a temperature of about 5800K. About half of this radiation (43%) is in the visible part of the electromagnetic spectrum (400-700nm) and the rest is mostly (52%) in the near-infrared part (700-2500nm) with some (5%) in the ultraviolet (300-400nm) part of the spectrum.

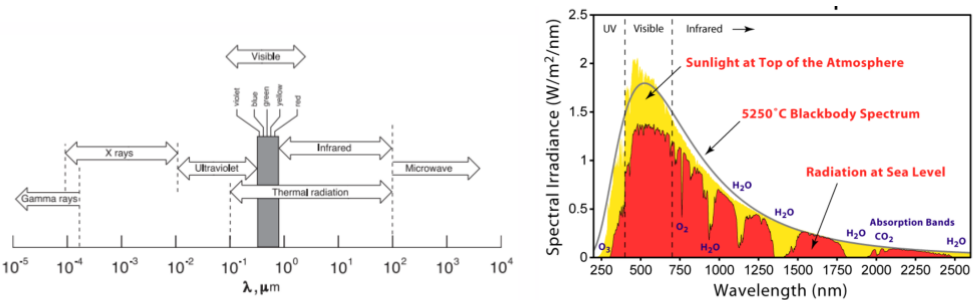


Fig. X Electromagnetic spectrum and solar radiation spectrum

As the solar energy from invisible part of the spectrum comprises more than 50 % of the solar energy, controlling the invisible solar spectrum using different glazing materials and coatings can play a significant role for nZEBs design.

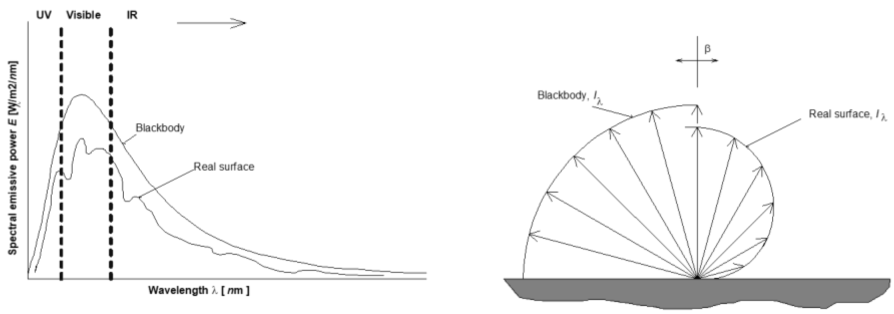
When hitting the Earth's surface the radiation in dependence of its wavelength and direction, and also the nature of the material, to which it is incident, gets reflected, transmitted, or absorbed by it. In semitransparent materials (e.g. glass pane, water) all three phenomena occur, i.e.

$$\rho \text{ (reflection)} + \tau \text{ (transmission)} + \alpha \text{ (absorption)} = 1 \qquad (1)$$

In opaque materials the transmission drops out and applies that

$$\rho \text{ (reflection)} + \alpha \text{ (absorption)} = 1 \qquad (2)$$

The absorbed radiation raises the temperature of the material (mass), which in turn removes the excess heat energy by radiation. The amount of emitted energy is dependent on the emissivity (surface radiation), ε, which is one of the characteristics of material. The emissivity is defined as the ratio of the radiation emitted by the surface of the material to the radiation emitted by a black body at the same temperature. Black body is a perfect absorber and issuer of radiation, whereas the spectral distribution of the intensity of solar radiation according to wavelengths is approaching the spectral distribution of the intensity of blackbody radiation at a temperature of 5800 K.



(a) (b)

Fig. 1: Comparison of blackbody and real surface emissions. (a) Spectral distribution, (b) Directional distribution (I_λ = radiation intensity, β = radiation angle) (Incropera & DeWitt, 1996)

The emissivity of a given material depends on the temperature of its surface and the wavelength of the emitted radiation. But also depends on the direction of the radiation. The spectral distribution of the absorbed radiation and subsequent emission may differ, e.g. in the case of glass (ordinary glass “converts” the absorbed shortwave radiation into longwave radiation).

Opaque materials and structures are characterized by thermal conductivity factor (λ). In case of transparent materials we focus on the properties connected with transmittance of solar radiation. We distinguish two main types of these properties - solar and visual. The solar properties integrates, more or less, the entire spectrum of sunlight and are intended mainly for energy simulations. The visual properties refers to the visible part of spectrum only and are intended mainly for daylighting calculations.

In addition to the characteristics listed above a global characteristic of the solar properties in form of the total solar energy transmittance coefficient, so-called solar factor (solar heat gain coefficient (SHGC)), or the g-value is widely used.

The solar factor (SHGC), g, is defined by EN 410:1998 as the sum of the direct solar transmittance, τ_{sol}, and the secondary heat transfer factor, q_i, of the glazing towards the inside. The secondary heat transfer factor is caused by convection and long-wave infrared radiation of that part of the incident solar radiation, which has been absorbed by the glazing. The respective equation for the g-value is then:

$$g = \tau_{sol} + q_i \tag{3}$$

The solar direct transmittance, τ_{sol}, is a glazing property. It is the portion of incident solar radiation that passes through the glazing layer and can be described as primary heat gain, g_1, divided by the total incident solar heat flux, φ_e. The secondary heat transfer factor, q_i, is dependent on the absorption factors of glazing layers, their emissivities (long-wave infrared radiation), ε, and thermal conductance, Λ, including the cavities and surfaces heat transfer. It is the absorbed portion of incident solar radiation that is converted into conductive and radiative heat flow towards the inside, and can be described as secondary heat gain, g_2, divided by the total incident solar heat flux, φ_e. Hence, another equation for the g-value is:

$$g = \frac{g_1 + g_2}{\varphi_e} \tag{4}$$

The solar factor is one of the most important characteristics of glazing systems because it allows an immediate and reliable assessment of the future performance of the glazing system in terms of solar heat gains.

Modern glazing systems are equipped with highly modified glass panes. The most frequently used treatment of glass in terms of improving solar properties is so-called coating or plating. This method is based on reducing the emissivity of the glass by applying an extremely thin layer of metal oxides. The producers adopted different technologies of manufacturing, mainly:

- **CVD** (chemical vapor deposition) – "hard coat" an on-line process where the coating is applied in the bath. This type has limited ability to achieve high-perfomance solar control levels.

- **Spray Pyrolysis** – an on-line process where coating of metal oxides is sprayed on surface where the reaction creates a durable layer. This type may influence the color of substrate glass and increase reflecivity, thus reduce light transmission.

- **MSVD** - Magnetron Sputter Vacuum Deposition – an off-line process where coating is applied in vacuum chamber to ready-made pre cut glass panes. This type enables lower emissivity and better solar performance. Since the nature of the coating layer most of them should be sealed inwards or laminated to avoid its damage. Most of solar control low-e glasses are made using this technology.

Using these methods we can reduce the glass emissivity from about 0.95 (clear glass) to 0.2 or less. This group of glazings is called low-emissivity or "low-e"glazing.

The position of low-e layer is very important. A typical low-e glass can work as:

-**Solar control low-e**: blocks solar radiation to reduce solar gains resulting in reduction of cooling costs.

-**Passive low-**E: transmits solar radiation

Only one low-e coating should be installed in one airspace for best performance. Besides those two basic types, there is also tinted, reflective, anti-reflective or other types of special glasses.

Besides coating technology, there is also a possibility of application of reflective films with special desired spectral properties (also known as spectral selective films). The main advantage of this technique is, that this films can be also applied after window installation, or during retrofitting of the older buildings.

Disadvantage of these treatments, aimed at the solar properties of glazing, is, that it also affects the visual properties of glazing systems. And therefore the huge reduction in solar factor (reduction of external heat gains) can result in reduction of light transmittance which can lead to increased use of artificial light (increase of internal heat gains).

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