FOSS
Research Centre for Sustainable Energy

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PV Technology

# Introduction to Nearly Zero Energy Buildings

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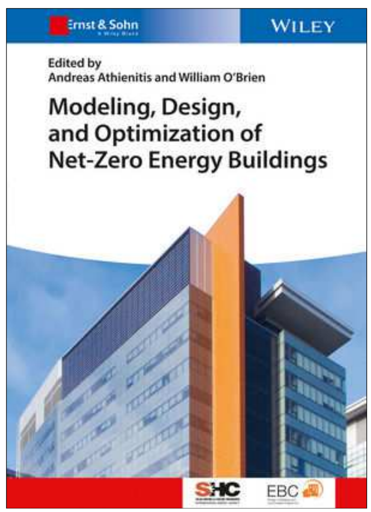
# Introduction

- **Nearly Zero Energy Building (NZEB)** → very high energy performance.
- Low amount of energy required comes mostly from **Renewable Energy Sources (RES)**.
- EU **Energy Performance of Buildings Directive** (EPBD):
  - All new buildings to be NZEBs by 2020.
  - All new public buildings to be NZEBs by 2018.


NZEB (office building) in Portugal

# Reference books

- A. Athienitis and W. O'Brian, Modeling, Design, and Optimization of Net-Zero Energy Buildings, 1st Edition, Wilhelm Ernst & Sohn (2015).
- Ministry of Energy, Commerce and Industry of the Republic of Cyprus, Technical Guidebook for NZEBs, 2015.




# Motivation: Energy Efficiency & NZEBs

Why are we interested in Energy Efficiency and NZEB?

- Buildings responsible for approx. 40% of the total annual energy consumption in Europe.

Buildings → major contribution to:

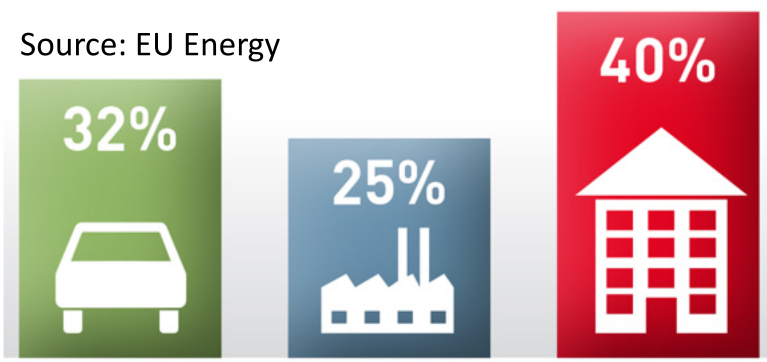
- **final energy consumption** (>40% EU, 37% CY)
- **GHG emissions** (>30%)

↳ High financial & environmental cost

Significant potential for:

- **energy savings**
- **GHG emission reduction**

Source: EU Energy




50% for heating/cooling

# Motivation: Energy Efficiency & NZEBs

- By 2050 energy use in buildings and related emissions may double/triple.
- Trends:
  - Increased access to adequate housing, population growth, migration to cities, household size changes, increasing levels of wealth, lifestyle changes.
    → **significant increases in building energy use!**
- Sustainable solutions needed:
  - Energy Efficiency (EE) & NZEBs, RES, sustainable mobility, sustainable cities.
- Cost-effective best practices, technologies and behavioural changes.
  → Reduction in energy requirements in buildings (x10 in new buildings, x4 in existing).
- **This is why EE and NZEBs are very important today!**

# Motivation: Energy Efficiency & NZEBs

- Building evolution and need for EE → **building energy regulations & standards**
- First EE regulations from northern European regions (1950s-60s):
  - To improve EE and comfort.
  - First real insulation requirements for U-values*, R-values** and specific insulation materials or multi-glazing.
- Oil crisis (1970s) → catalytic in developing EE requirements for buildings.
- Today: **mandatory minimum energy efficiency requirements** in the form of building codes or standards exist in most developed countries.

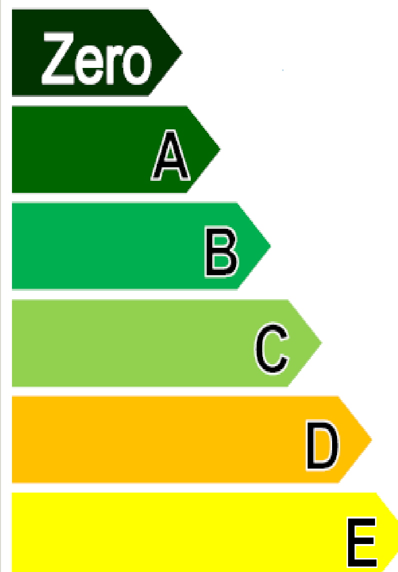
Energy efficiency "definition":
Using less energy to provide same service (*Lawrence Berkeley National Lab*)

** **U-value (Thermal Transmittance)**: how much energy passes through one m² of a construction by a difference of a degree in temperature, measured in W per K per m².*
*** **R-value (Thermal Resistance)**: how well a construction or insulation material resists the penetration of heat, measured in K * m² per W. The (U-value) = 1 / (R-value).*

# NZEB definition

**EPBD Directive (2010/31/EU, Annex I):**

- A building that has a **very high energy performance**.
- The nearly zero or very low amount of energy required should be covered to a significant extent by **energy from RES**, including energy from RES produced **on-site or nearby**.



# NZEB definition

- What are the main energy needs of buildings?

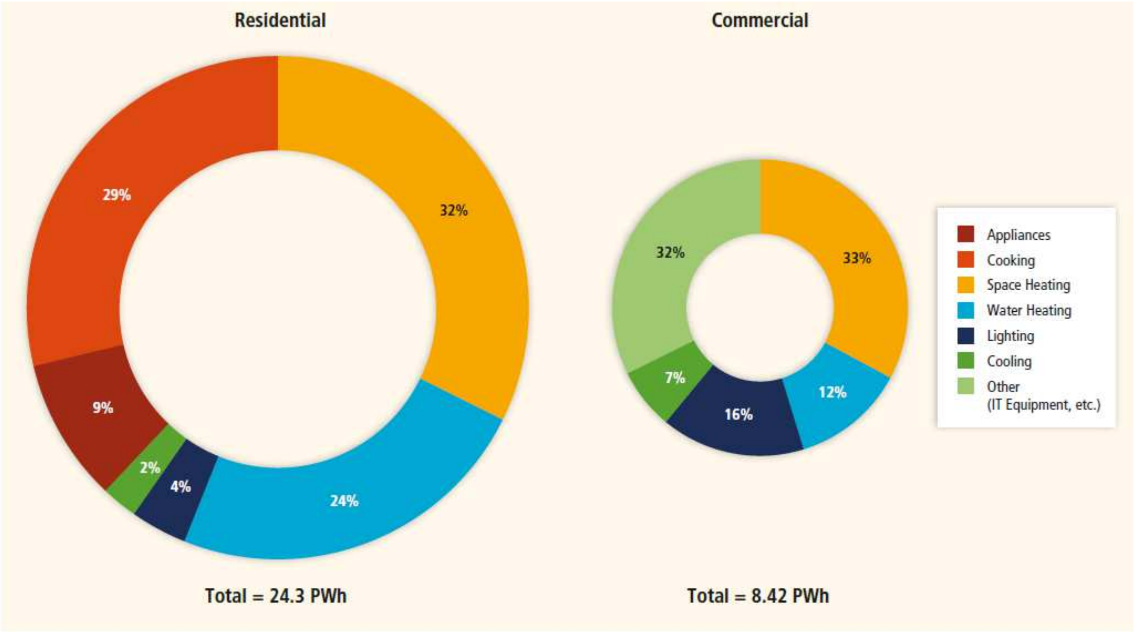
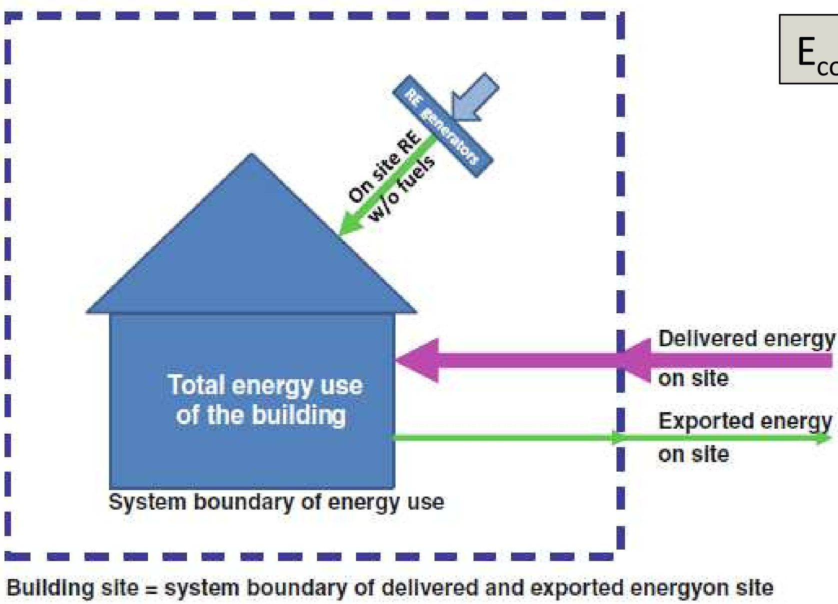



**Figure 9.4** | World building final energy consumption by end-use in 2010. Source: IEA (2013).

# NZEB definition

- Grid-connected building




$E_{consumed} = E_{delivered} - E_{exported}$

↓

RES + Grid

Target:

- $E_{consumed}$ → very low
- $E_{delivered}$ → mostly RES
- Self-consumption

→ E balance = 0

# NZEB definition

Main methods to achieve NZEB:

- Renewable systems for on-site electricity production
- Architectural Design
  - Climate and microclimate, building morphology
  - Size and orientation of building openings
  - Room arrangement in building
- Building Envelop
  - Insulation
  - Thermal bridges & thermal capacity
  - Building openings & shading
- Systems for HVAC, domestic hot water
  - Heating, cooling, Domestic Hot Water
- Energy efficient systems and appliances

# NZEB definition

Table 1.1 Challenges for smart Net ZEBs

| Building systems, design and operation | Current buildings | Smart Net ZEBs |
|---|---|---|
| Building fabric/ envelope | Passive, not designed as an energy system | Optimized for passive design and integration of active solar systems |
| Heating, ventilation and air conditioning (HVAC) | Large oversized systems | Small HVAC systems optimally controlled; integrated with solar systems, combined heat and power; communities: seasonal storage and district energy |
| Solar systems/ renewables, generation | No systematic integration – an afterthought | Fully integrated: daylighting, solar thermal, photovoltaics, hybrid solar, geothermal systems, biofuels, linked with smart microgrids |
| Building automation systems | Building automation systems not used effectively | Predictive building control to optimize comfort and energy performance; online demand prediction/peak demand reduction |
| Design and operation | The design and operation of buildings are typically not considered together | Design and operation of buildings fully integrated and optimized together subject to satisfying comfort; integrated design of the above four building subsystems |

# Barriers

- Cost:
  - Initial investment & future running costs.
  - Lack of training to analyse buildings lifecycle costs.
- Construction developers not interested in future costs for building owners/residents.
- Cost structures and lack of capacity
  - Special equipment or expertise not readily available in all markets.
- Insufficient efficiency awareness among consumers, designers and banks.
- Regulation and appropriate implementation.

# Defining national energy frameworks

- EU Directive: Energy performance calculation and definition of NZEB to be expressed with numerical indicator of primary energy.
- If national energy framework is not based on primary energy:
  - Need to develop new framework and implement in building code.
  - Major effort from countries.
- In practice, different energy performance indicators (& combinations) used to determine NZEB status and calculate energy performance.

Maximum primary energy [kWh/m$^2$/year]

Non-dimensional primary energy use coefficient (reference building)

'quantitative/qualitative share of RES'

Passive house

'on-site RES'

Carbon emissions

# Defining national energy frameworks

| Country | Status of the definition | Main reference(s) | Year of enforcement | | nZEB definition for new buildings: EPBD scope of nZEB definition [1] | Numerical indicator | Maximum primary energy [kWh/m²y] | | Share of renewable energy | Other indicators | nZEB definition for existing buildings: Status of the definition | Maximum primary energy [kWh/m²y] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Public | Non-public | | | Residential buildings | Non-residential buildings | | | | Residential buildings | Non-residential buildings |
| **Austria** | ✓ | OIB Guidelines 6 | 1/01/2019 | 1/01/2021 | ✓ [7] | ✓ | 160 | 170 (from 2021) | Minimum share proposed in the draft of OIB guidelines for all buildings | EP, $CO_2$ | ✓ | 200 | 250 (from 2021) |
| **Belgium - Brussels** | ✓ | Amended Decree of 21/12/2007 | 1/01/2015 | 1/01/2015 | ✓ | ✓ | 45 | ~90 [2] | ✓ Qualitative | EP, OH | ✓ | 54 | ~ 108 [2] |
| **Belgium - Flanders** | ✓ | Regulation of 29/11/2013 | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 30% PE [5] | 40% PE [5] | ✓ Quantitative [4] | EP, OH | Under development | | |
| **Belgium - Wallonia** | Under development | Consolidated report to EC | 1/01/2019 | 1/01/2019 | ✓ | Under develop-ment | | | Quantitative | EP | Under development | | |
| **Bulgaria** | Still to be approved | National nZEB Plan, BPIE study | 1/01/2019 | 1/01/2021 | ✓ | Still to be approved | ~30-50<br>Included in the calculation; building needs to comply with class A | ~40-60 | Quantitative | EP | As for new buildings | ~30-50<br>Included in the calculation; building needs to comply with class A | ~40-60 |
| **Croatia** | ✓ | Regulation OG 97/14, National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 33-41[3] | Under de-velopment | Minimum share in current requirements for all buildings | EP | ND | | |
| **Cyprus** | ✓ | Decree 366/2014, Law 210(I)/2012 | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 100 | 125 | ✓ Quantitative | EP | ✓ As for new buildings | 100 | 125 |
| **Czech Republic** | ✓ | Regulation 78/2013 Coll. | 2016-2018 depending on size | 2018-2020 depending on size | ✓ | ✓ | 75-80% [2,5] | 90% [5] | ✓ Quantitative | EP, TS | ✓ As for new buildings | 75-80% [2,5] | 90% [5] |
| **Denmark** | ✓ | Building Regulations 2010 | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 20 | 25 | ✓ Qualitative | EP, OH, TS | ✓ As for new buildings | 20 | 25 |
| **Estonia** | ✓ | Regulation 68:2012 | 1/01/2019 | 1/01/2021 | ✓ [7] | ✓ | 50-100 [2] | 90-270 [2] | ✓ Qualitative | | ✗ | | |
| **Finland** | Under development | Consolidated report to EC | 1/01/2018 | 1/01/2021 | ✓ [7] | ND | | | ND | | ND | | |
| **France** | Definition of Positive Energy Buildings under development [8] | Thermal Regulation 2012, National nZEB Plan | 28/10/2011 | 1/01/2013 | ✓ | ✓ | 40-65 [2,3] | 70-110 [2,3] | ✓ Quantitative [4] | EP, OH, TS | ✓ | 80 [3] | 60% PE [2] |
| **Germany** | Under development | KfW Efficiency House, National nZEB plan | 1/01/2019 | 1/01/2021 | ✓ | Under develop-ment | 40% PE [5] | | Minimum share in current requirements for all buildings | EP | Under development | 55% PE [5] | |
| **Greece** | Under development | Law 4122/2013 | 1/01/2019 | 1/01/2021 | ND | ND | | | Minimum share in current requirements for all buildings | | Under development | | |
| **Hungary** | Under development | Amended decree 7/2006, study by University of Debrecen | 1/01/2019 | 1/01/2021 | ✓ | Under develop-ment | 50-72 [2] | 60-115 [2] | ✓ Quantitative | EP | Under development | | |
| **Ireland** | ✓ | Draft definition in National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 45 | ~60% PE [5] | ✓ Quantitative [4] | $CO_2$ | Under development | 75-150 | |

*Source: Buildings Performance Institute Europe (BPIE) factsheet 2015, 'Nearly Zero Energy Buildings Definitions across Europe'*

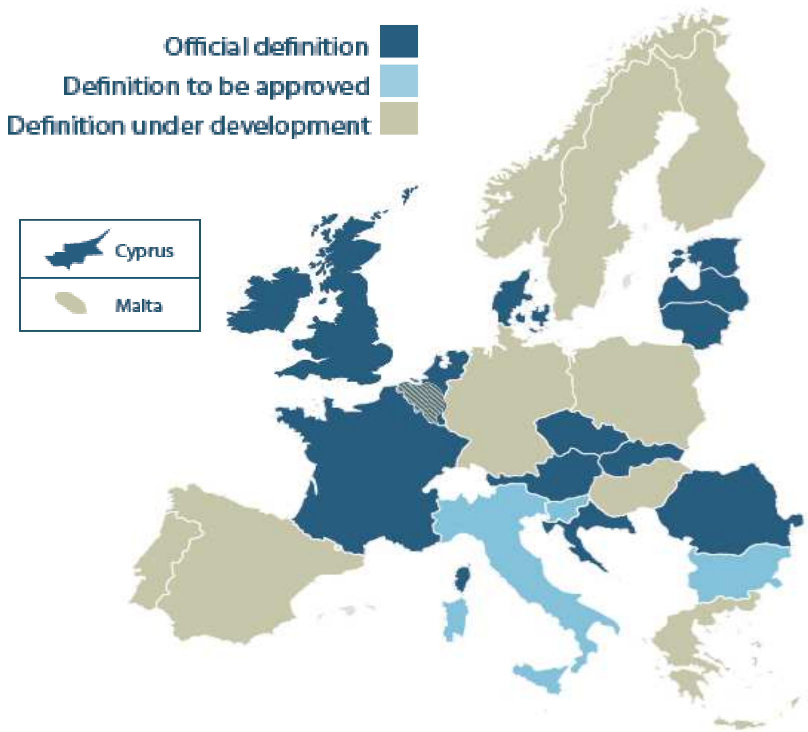
# Defining national energy frameworks

| Country | Status of the definition | Main reference(s) | Year of enforcement | | nZEB definition for new buildings: EPBD scope of nZEB definition [1] | Numerical indicator | Maximum primary energy [kWh/m²y] | | Share of renewable energy | Other indicators | nZEB definition for existing buildings: Status of the definition | Maximum primary energy [kWh/m²y] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Public | Non-public | | | Residential buildings | Non-residential buildings | | | | Residential buildings | Non-residential buildings |
| **Italy** | Still to be approved (under publication) | Draft of the new EPBD decree | 1/01/2019 | 1/01/2021 | ✓ | Still to be approved | Included in the upcoming updated version of the National nZEB Plan [2,3] | | Quantitative | EP, TS | ✓ As for new buildings | Included in the upcoming updated version of the National nZEB Plan [2,3] | |
| **Latvia** | ✓ | Regulation 383/2013 | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 95 | 95 | ✓ Quantitative | EP | ✓ As for new buildings | 95 | 95 |
| **Lithuania** | ✓ | Regulation STR 2.01.09 :2012 | 1/01/2019 | 1/01/2021 | ✓ | ✓ | Included in the calculation; building needs to comply with class A++ | | ✓ Quantitative | EP | ✓ As for new buildings | Included in the calculation; building needs to comply with class A++ | |
| **Luxembourg** | ✓ Details to be fixed | National nZEB Plan | 1/01/2019 | 1/01/2021 | ✗ [6] | ✓ | Included in the calculation; building needs to comply with class A-A-A | | ✓ Qualitative | EP, $CO_2$ | ND | | |
| **Malta** | Under development | National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | Current values to be revised | 40 | 60 | Qualitative | EP | ND | | |
| **Netherlands** | ✓ | National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | ✓ | Included in the calculation; building needs to comply with energy performance coefficient = 0 | | ✗ | EP | ND | | |
| **Norway** | Under development | Presentation by Research Centre on Zero Emission Buildings | 1/01/2021 | 1/01/2021 | ✓ | Under development | | | Minimum share in current requirements for all buildings | $CO_2$ (main indicator), EP, TS | ND | | |
| **Poland** | Under development | Consolidated report to EC | 1/01/2019 | 1/01/2021 | ✓ | Under development | 60-75 [2] | 45-70 [2] | ✗ | | ND | | |
| **Portugal** | Under development | Law 118/2013 | 1/01/2019 | 1/01/2021 | ✓ | In current requirements for buildings | | | ✗ | | ND | | |
| **Romania** | ✓ | National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | ✓ | 93-217 [2,3] | 50-192 [2,3] | ✓ Quantitative | $CO_2$ | ND | | |
| **Slovakia** | ✓ | Decree 364/2012 | 1/01/2019 | 1/01/2021 | ✗ [6] | ✓ | 32-54 [2] | 34-96 [2] | ✓ Quantitative | EP | ND | | |
| **Slovenia** | Still to be approved | Official Journal 17/14, National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | Still to be approved | 45-50 [2] | 70 | Under development | EP | Still to be approved | 70-90 [2] | 100 |
| **Spain** | Under development | Decree 235/2013 | 1/01/2019 | 1/01/2021 | ✓ | Under development | Included in the calculation; it is foreseen that buildings will need to comply with class A | | Minimum share in current requirements for all buildings | $CO_2$ (main indicator) | Under development | | |
| **Sweden** | Under development | National nZEB Plan | 1/01/2019 | 1/01/2021 | ✓ | Under development | 30-75 [2,3] | 30-105 [2,3] | ✗ | | ND | | |
| **UK (England)** | ✓ Details to be fixed | National nZEB Plan, presentation by Zero Carbon Hub | 1/01/2018 (from 2016 for residential buildings) [9] | 1/01/2019 (from 2016 for residential buildings) [9] | ✓ | ✓ | ~ 44 (2)<br>Included in the calculation; building will need to comply with carbon emissions ~ 0 | ND | ✓ Qualitative | $CO_2$ (main indicator), EP, TS | ND | | |

*Source: Buildings Performance Institute Europe (BPIE) factsheet 2015, 'Nearly Zero Energy Buildings Definitions across Europe'*

# Defining national energy frameworks

- At country-level.
- Harmonization of EPBD and national policies & implementation → **Not straightforward**
  - ‘very high energy performance’?
  - ‘very low amount of energy’?
  - ‘significant extent’?
  - ‘on-site or nearby RES’?
- **Lack of clarity & coherence** for NZEB definitions across EU.
- Some NZEB definitions still under development (or not approved).



# NZEB example in Denmark

- Green Lighthouse:
  first public carbon-neutral building in Denmark
- Consumption:
  - 30 kWh/m$^2$y
    (calculated without considering RES production)
  - 3 kWh /m$^2$y
    (with RES production, Solar Thermal and PVs)

*Source: http://www.buildup.eu/en/practices/cases/green-lighthouse-denmarks-first-public-carbon-neutral-building*

# NZEB requirements in Cyprus

**<u>Regulation 366/2014</u>**: Requirements for NZEB in Cyprus

- Follow the **minimum requirements from Regulation 432/2013**
- Have the following **technical requirements** and characteristics:

| Number | Requirement | Limit |
|---|---|---|
| 1 | Energy efficiency class on the energy efficiency certificate of a building. | A |
| 2 | Maximum primary energy consumption for buildings used as residences such as this is calculated by the building energy performance calculation methodology. | 100 KWh per $m^2$ per year |
| 3 | Maximum primary energy consumption for buildings not used as residential properties such as this is calculated by the building energy performance calculation methodology. | 125 KWh per $m^2$ per year |
| 4 | Maximum energy demand for heating for buildings used as dwellings. | 15 KWh per $m^2$ per year |
| 5 | At least 25% of the total primary energy consumption as calculated by the building energy performance calculation methodology comes from renewable energy sources. | - |

| Number | Requirement | Limit |
|---|---|---|
| 6 | Maximum average thermal transmittance value (U) of walls and elements of the load-bearing structure (pillars, beams and walls) which are part of the building shell. | 0.4 $W/m^2/K$ |
| 7 | Maximum average thermal transmittance value (U) of horizontal structural elements (flooring, canopy floors, roofs) and ceilings which are part of the building shell. | 0.4 $W/m^2/K$ |
| 8 | Maximum average thermal transmittance value (U) of frames (doors, windows) which are part of the building shell. Shop extensions are excluded. | 2.25 $W/m^2/K$ |
| 9 | Maximum average installed lighting power for buildings used as offices. | 10 $W/m^2$ |

# NZEB example in Cyprus - American Medical Center

- Designed to:
  - Implement energy saving techniques.
  - Utilize natural lighting.
  - Utilize efficient technologies for heating, cooling and lighting.
- 100 KWp roof-top PV system.

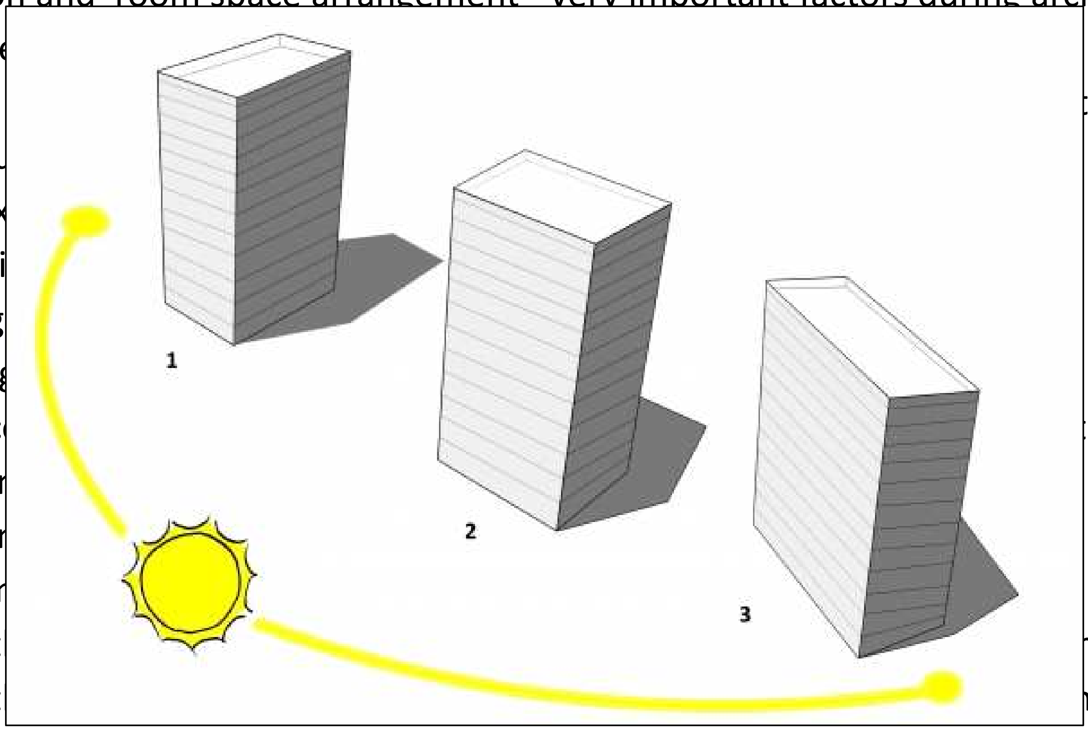
# NZEB example in Cyprus - New Nicosia Town Hall

# NZEB example in Cyprus - New Nicosia Town Hall

- Bioclimatic architecture building:
  - Natural ventilation design principles & very low energy consumption.
  - Dedicated openings & stack chimney ventilating central core of building.
- Energy performance:
  - Total primary energy demand (for heating, cooling, ventilation, hot water): 29 $KWh/(m^2y)$
- Thermal insulation level and features of building envelope:
  - External walls: $U = 0{,}36\ W/(m^2K)$
  - Roof: $U = 0{,}23\ W/(m^2K)$
  - Windows: $U_g = 0{,}7\ W/(m^2K)$ (triple glazing)
- Solar panels for DHW & heat pumps for top-up heating and cooling.
- 12 KWp roof-top PV system on-site.

# NZEB architecture & morphology

- Building orientation and room space arrangement - very important factors during architectural design.
- Optimize natural r
- Must consider the ... ions of the site.
- Orientation of a bu
  - Increase the ex
  - Increase exploi
  - Increase daylig
- Design the building
- As climatological c ... ect must consider:
  - The energy de
  - The energy de
  - Lighting deman
- Building surfaces t ... he North hemisphere.
- Building surfaces t ... misphere



# NZEB architecture & morphology

- Building morphology parameters important for energy requirements:
  - Building envelop exposure degree.
  - Extent of building openings.
  - Selection of roof.
- The Building Envelop Exposure Degree to weather is given by the equation:

$$\textit{Building Envelop Exposure Degree} = \frac{Building\ exposure\ area\ of\ walls\ (m^2)}{Building\ floor\ area\ (m^2)}$$

- Typical recommendation:
  - In a one floor building the building envelop exposure degree should not exceed 1.
  - For two-floor buildings between 2.5 – 3.

# NZEB architecture & morphology

- Building openings - challenging architectural issue
  - Increase of heat losses
  - Increase of solar irradiance exposure therefore
  - Thus decreasing the need for heating in the winter but increasing the need for cooling in the summer

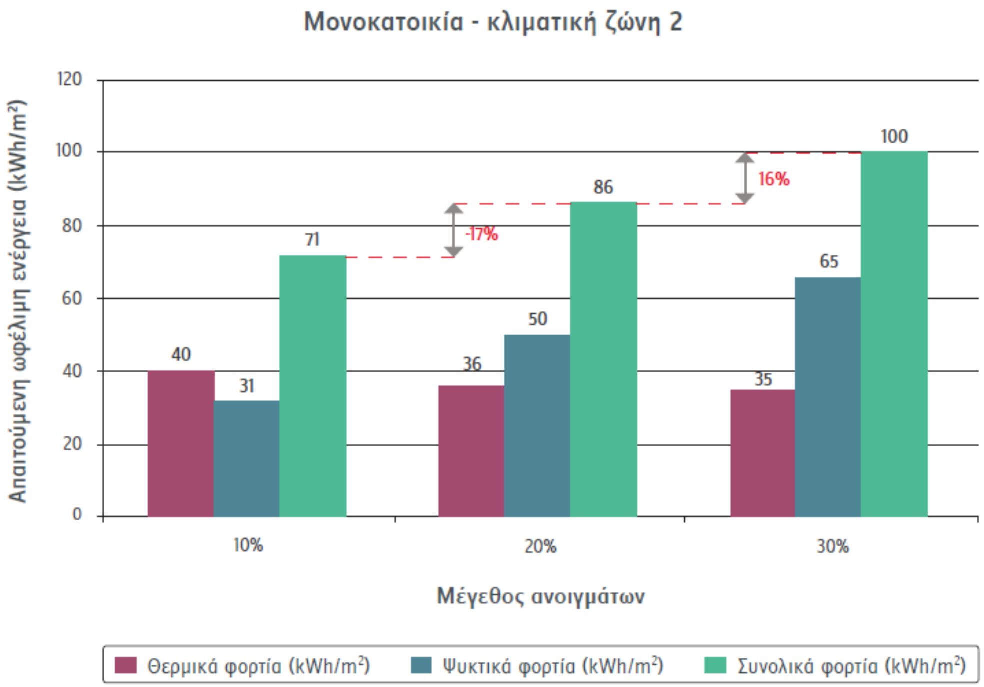
    → **Openings affect the building's energy demand for heat and cooling**.
- The Opening factor is given as:

$$Opening\ Factor = \frac{Area\ of\ building\ openings\ (m^2)}{Total\ area\ of\ building\ envelope\ wall\ surfaces\ (m^2)}$$

- The Opening factor must be decided so as in total the heating and cooling requirements of the building are kept as minimum as possible.

# NZEB architecture & morphology

Example of openings and total demand for heating and cooling for a typical house in Cyprus.



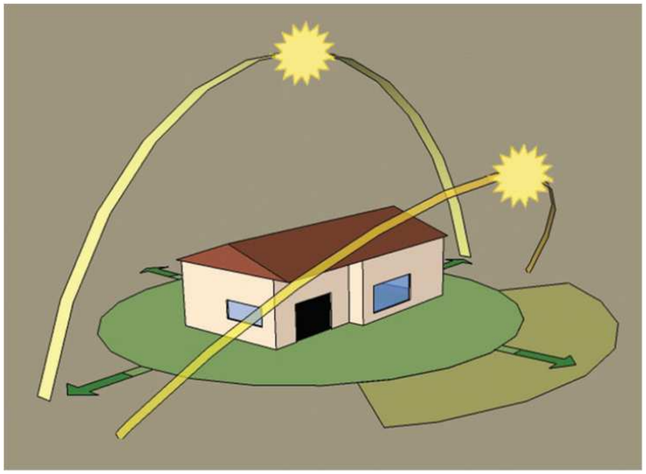

**As we increase the Openings there is a small decrease in heating loads but a large increase of Cooling loads.**

# NZEB architecture & morphology

- Effective empirical approach to optimally size and position the openings in a building is to do this **according to the orientation**.
- For building residences (Northern Hemisphere)s it is recommended that:
  - In the South orientation large openings should be placed for the exposure to sunlight of the building's internal during the winter, that of course would have shadings to minimize sunlight during the summer.
  - In the East and West orientation, medium sized openings are placed because sunlight of the building's internal is not for long duration. The openings are important for cooling so must be shaded.
  - In the North orientation the openings should be relatively small since there is no gain in sunlight their and these openings are responsible for losing heat.

# NZEB architecture & morphology

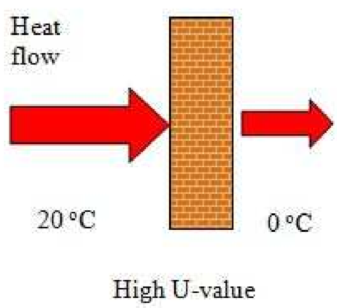
- Room arrangement in a building:
  - Important design topic
  - Linked to the comfort within the building.
- The South side of the building is more insolated than other sides therefore is more pleasant (warm/light) than other areas of the building.
- In this side it is recommended that the rooms of most occurrence are placed, assuming of course that measures for shading are taken for the summer period.
- Example: this room in the South area can be the living room in a residence.

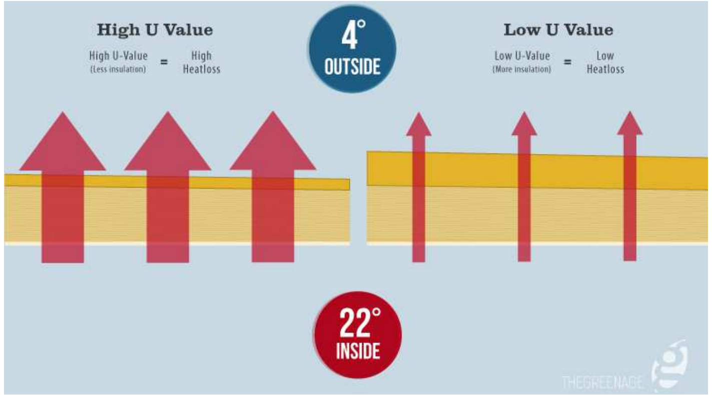


# NZEB architecture & morphology

**Thermal transmittance coefficient ($U$-value):**

- The $U$-value is a measure of the heat that is transmitted from the front side of a facade to the inside, assuming an area of 1 $m^2$ and a temperature difference of 1 K (or 1 ºC).
- It consists of heat transfer from air on one side of the element, thermal conductivity within the structural element and thermal transmission from the other side of element to the air.



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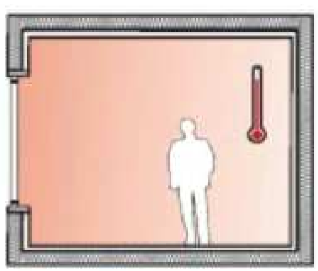
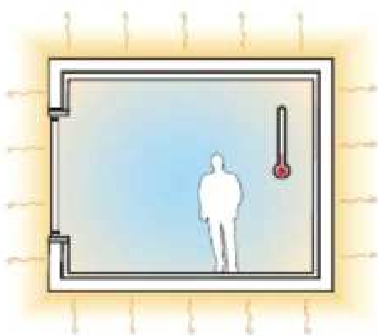
# Insulation

- Building envelop insulation is the protection of the internal from the outdoor environment and has an important part in **balancing the temperature** between them.
- Suitable insulation can decrease heat losses significantly and hence decrease energy demand for heating (Report from CEA reports up to 50 % benefit from reduced heating loads for a house with insulation over a year).

Without insulation



With insulation



# Insulation

- What is required for good building envelope insulation?
- The thermal conductance $\lambda$ $({}^{W}/_{mK})$ denotes the conductance of a material e.g. brick, to the flow of heat. Therefore the lower $\lambda$ of a material then less heat is allowed to flow through the material.

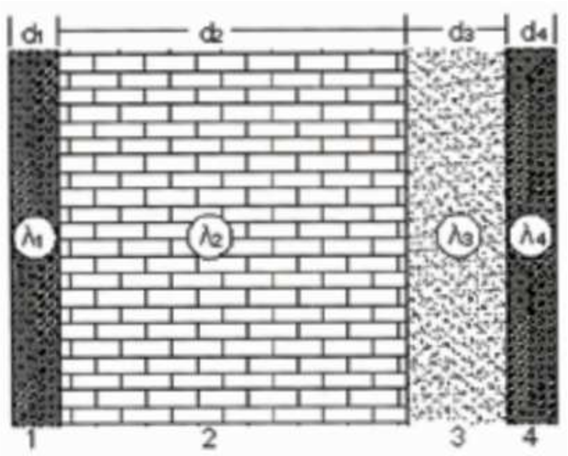
  → **Bricks with low $\lambda$ have an advantage**
- The $U$-value $({}^{W}/_{m^2K})$ denotes the resistance of a material to heat flow in accordance to its thickness $d$.

  → **Therefore walls with low $U$-value are preferred**

# Insulation

- The thermal resistance $R$ $(^{m^2K}/_{W})$ denotes the heat property by which an object or material resists a heat flow. Thermal resistance is the reciprocal of thermal conductance $\lambda$ $(^{W}/_{mK})$.

$$R = \frac{d}{\lambda}$$



# Insulation

- For the opaque building envelop materials (walls etc.) that separate the internal from the external living environment the thermal transmittance coefficient $U$-value ($W/_{m^2K}$) can be calculated as:

$$U_i = \frac{1}{R_{si} + \sum \frac{d_i}{\lambda_i} + R_{se}}$$

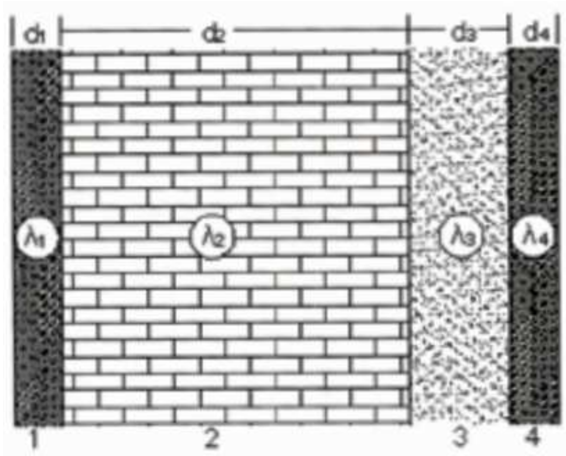
- Where:

  $R_{si}$ ($^{m^2K}/_W$) is the internal thermal resistance (common value 0.13 $^{m^2K}/_W$)
  $R_{se}$ ($^{m^2K}/_W$) is the external thermal resistance (common value 0.04 $^{m^2K}/_W$)
  $d_i$ ($m$) is the material thickness
  $\lambda_i$ ($^W/_{mK}$) is the thermal conductance of the material

# Insulation

- For the example below:

$$U_i = \frac{1}{R_{si} + \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_3}{\lambda_3} + \frac{d_4}{\lambda_4} + R_{se}}$$



# Insulation

- In cases where air is trapped between opaque materials then the thermal transmittance coefficient $U$-value can be calculated as:

$$U_i = \frac{1}{R_{si} + \sum \frac{d_i}{\lambda_i} + R_a + R_{se}}$$

- Where:

  $R_{si}$ $\left({m^2K}/{W}\right)$ is the internal thermal resistance (common value 0.13 ${m^2K}/{W}$)
  $R_{se}$ $\left({m^2K}/{W}\right)$ is the external thermal resistance (common value 0.04 ${m^2K}/{W}$)
  $R_a$ $\left({m^2K}/{W}\right)$ is the air thermal resistance
  $d_i$ $(m)$ is the material thickness
  $\lambda_i$ $\left({W}/{mK}\right)$ is the thermal conductance of the material

# Insulation

The most popular insulation materials in the market:

- Extruded polystyrene
- Expanded polystyrene
- Glasswool
- Polyurethyne
- Foam glass
- Rockwool
- Aerated concrete
- Thermal bricks

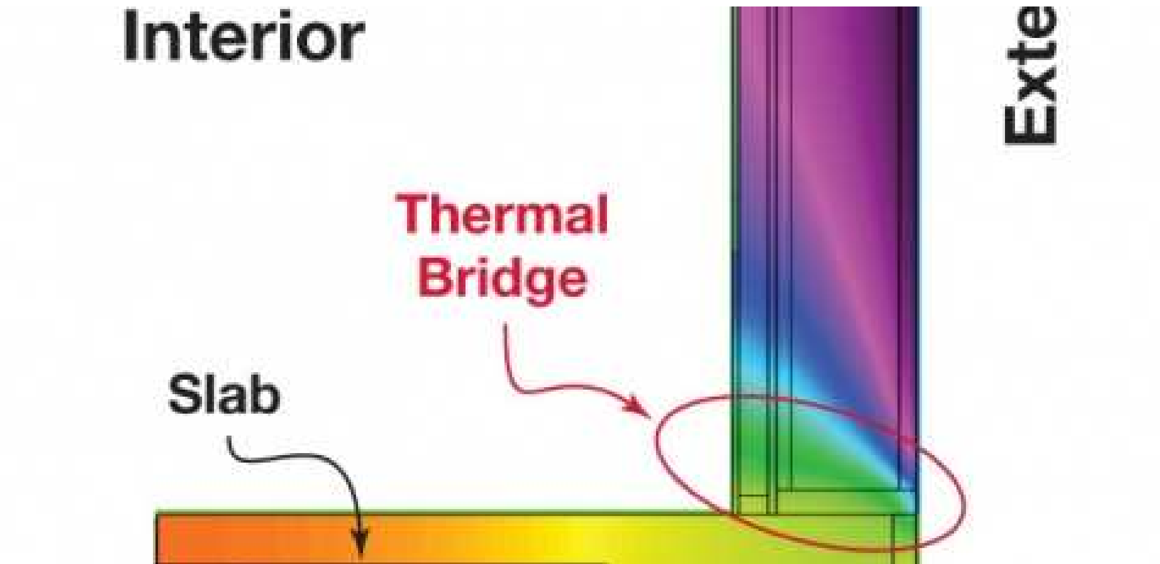

Thermal brick

Extruded polystyrene


Expanded polystyrene


# Thermal bridges

- Effectiveness of the insulation dependent on the avoidance of creating thermal bridges.
- Thermal brid
- Thermal brid
  - At the cor
  - At the geo
  - At points
- For the avoid
  - The level
  - Avoiding b ... cessary.
  - Insulate extruding building envelop materials such as balconies etc.



# Thermal capacity

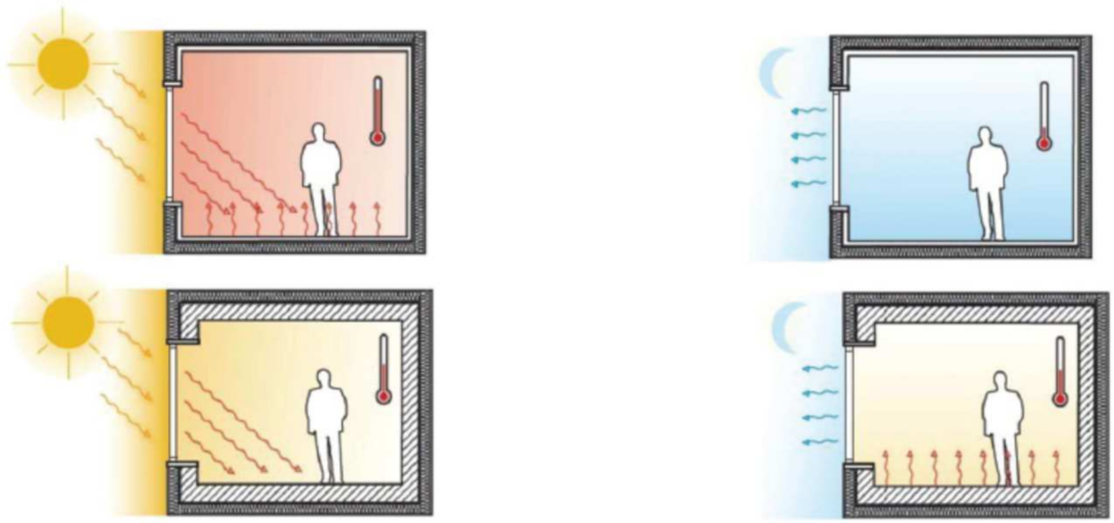
- The position of the insulation with respect to the building material affects its thermal capacity capability.
- It is preferable to achieve high thermal capacities, in line with good insulation so as to minimize the temperature variations within the building and ensure a comfort living environment.
- The effective thermal mass capacity $c_m$ ($J/_{m^2K}$) of a material is evaluated as:

$$c_m = \sum_j \sum_i d_i \times \rho_i \times c_{p,i}$$

- Where d is the material thickness ($m$), the density $\rho$ ($kg/_{m^3}$) and the specific thermal capacity $c_p$ ($J/_{kgK}$).
- Materials with high thermal capacity capabilities have effective thermal mass capacity over 1.2 $MJ/_{m^2K}$.

# Thermal capacity

- As a rule for NZEB the building envelope materials should have a low $U$-value and high effective thermal capacity $c_m$.
- This is achieved by insulating the external of buildings while installing interior materials with a high effective thermal mass capacity.

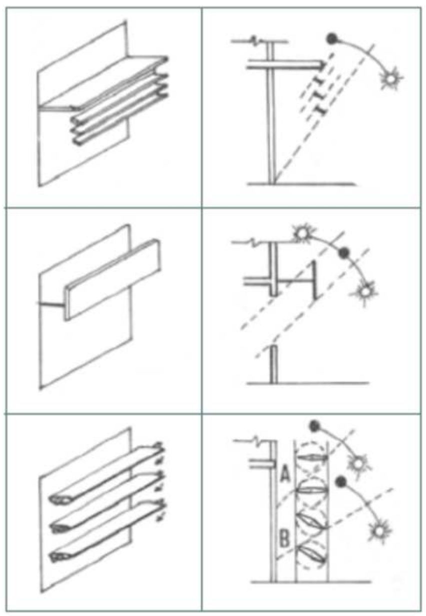


# Building openings & shading

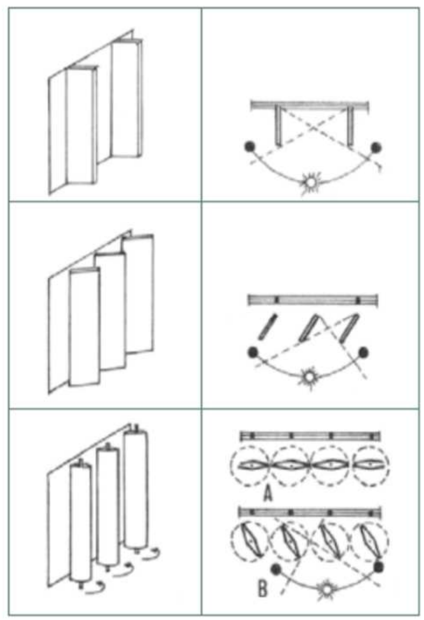
- Building openings must decrease the thermal and cooling loads at the same time.
- Openings are areas where heat can escape but also light can enter and light up areas of the household (natural lighting).
- For this reason the following must be considered:
  - The U-value of the opening
  - The light transmittance factor of the opening
  - The solar irradiance transmittance factor
- The light transmittance factor is a glazing parameter. Decrease of the U-value is usually associated with decrease in the light transmission.
- The controllable shading of the building's envelope is important as it can allow full exploitation of sunlight depending on the season.
- Building Management Systems (BMS) now also exist for automated shading.
- When the position of the Sun is high in the sky then the use of horizontal shading systems is effective.
- When the Sun is low in the sky (e.g. early the morning, late afternoon) vertical shading systems are more effective.
- The use of shutters is very effective for households as it can open widely during the summer so as to obtain full ventilation and shading while it can close for thermal insulation in the winter.

# Building openings & shading

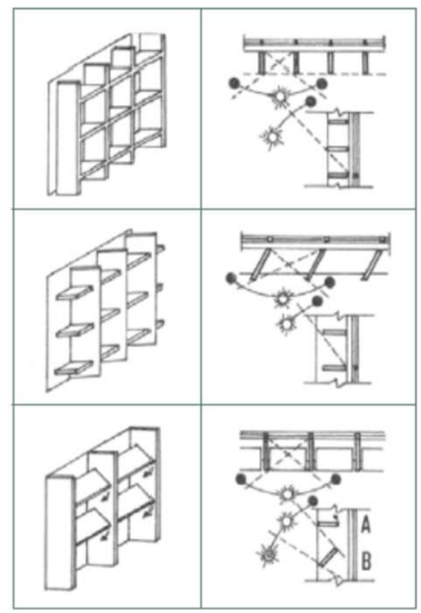
- Examples of shading systems.



Horizontal shading



Vertical shading



Shutters

# Heating and cooling

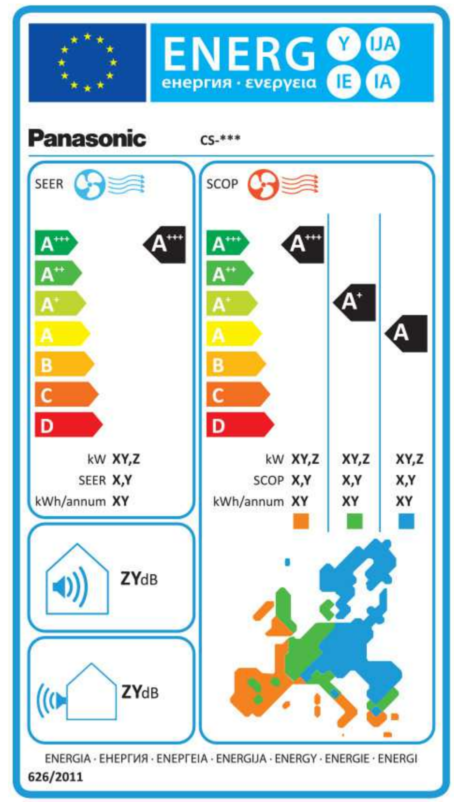
- For the heating of NZEB some of the recommended ways include:
  - High efficiency boiler oil/natural gas with efficiency >92%
  - High efficiency heat pumps in preference with an efficiency >3.5.
  - Solar thermal heating in conjunction with a boiler or heat pump system. Thei use can provide 50% conservation of conventional fuel used for heating and 80% for the use of DHW.
- Guidelines for improved efficiency and decrease of heating consumption:
  - Maintain the boiler (commonly every start or end of winter season).
  - Select a 20 ºC setting for the temperature.
  - Have in mind that for every degree you decrease the thermostat you can achieve 2% reduction of heating consumption for every 8 hours of operation of the heating system.
  - Use thermostats and timers to make use of heating only at the hours of the day necessary.

# Heating and cooling

- **Seasonal Coefficient of Performance (SCOP)** - This is the overall coefficient of performance of the unit, representative of the entire heating season designated (the value of SCOP corresponds to a determined heating season). It is calculated by dividing the reference annual heating demand by the annual consumption of electricity for heating.
- **Seasonal Energy Efficiency Ratio (SEER)** – This is the overall energy efficiency ratio of the unit, representative of the entire cooling season. It is calculated as the annual cooling demand divided by the annual consumption of electricity for cooling.

| SEER | |
|---|---|
| A+++ | SEER ≥ 8.50 |
| A++ | 6.10 ≤ SEER < 8.50 |
| A+ | 5.60 ≤ SEER < 6.10 |
| A | 5.10 ≤ SEER < 5.60 |
| B | 4.60 ≤ SEER < 5.10 |
| C | 4.10 ≤ SEER < 4.60 |
| D | 3.60 ≤ SEER < 4.10 |
| E | 3.10 ≤ SEER < 3.60 |
| F | 2.60 ≤ SEER < 3.10 |
| G | SEER < 2.60 |

| SCOP | |
|---|---|
| A+++ | SCOP ≥ 5.10 |
| A++ | 4.60 ≤ SCOP < 5.10 |
| A+ | 4.00 ≤ SCOP < 4.60 |
| A | 3.40 ≤ SCOP < 4.00 |
| B | 3.10 ≤ SCOP < 3.40 |
| C | 2.80 ≤ SCOP < 3.10 |
| D | 2.50 ≤ SCOP < 2.80 |
| E | 2.20 ≤ SCOP < 2.50 |
| F | 1.90 ≤ SCOP < 2.20 |
| G | SCOP < 1.90 |



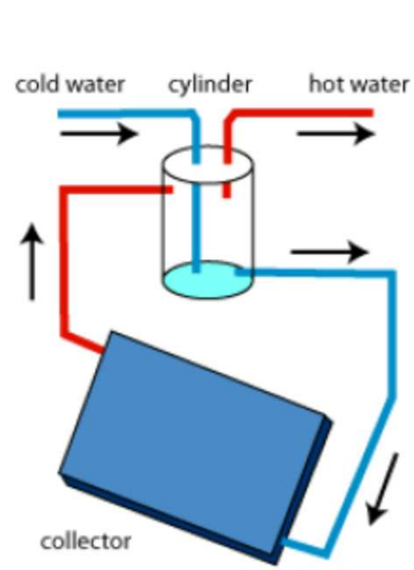
# Domestic Hot Water (DHW)

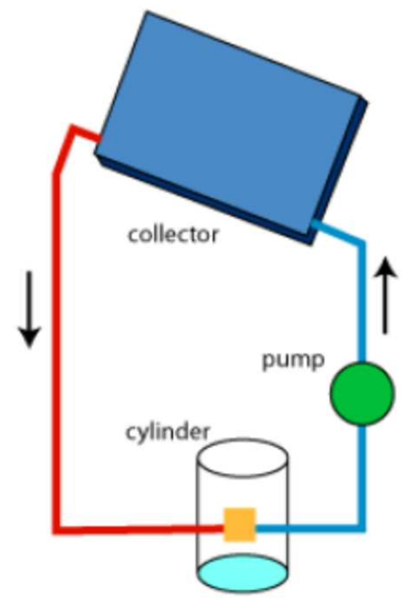
- Solar-thermal technologies make use of sunlight to heat a medium for either the provision of space heating or DHW.
- Important for NZEBs in order to minimize electricity used to heat the space of the building or DHW.
- In Cyprus almost all residential buildings have a solar-thermal system for DHW.
  - The use of DHW in new buildings is also obligatory for new buildings used as households.

# Domestic Hot Water (DHW)

Two main types of solar thermal systems for DHW, depending on the way the medium is circulated:

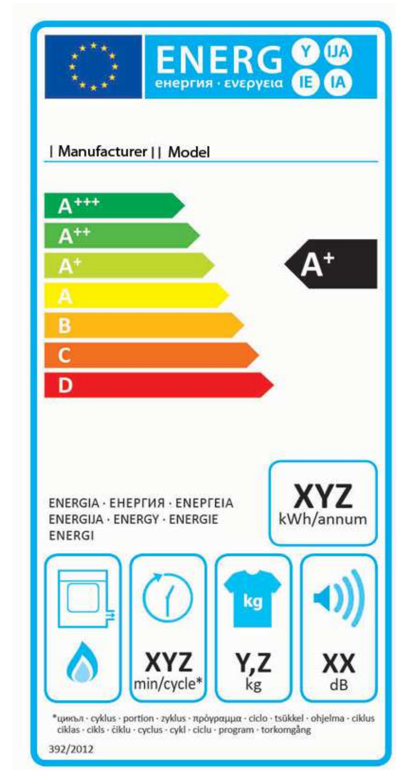
- Active in circulation
  (with electrification for pumps)
- Passive in circulation
  (thermosiphon)



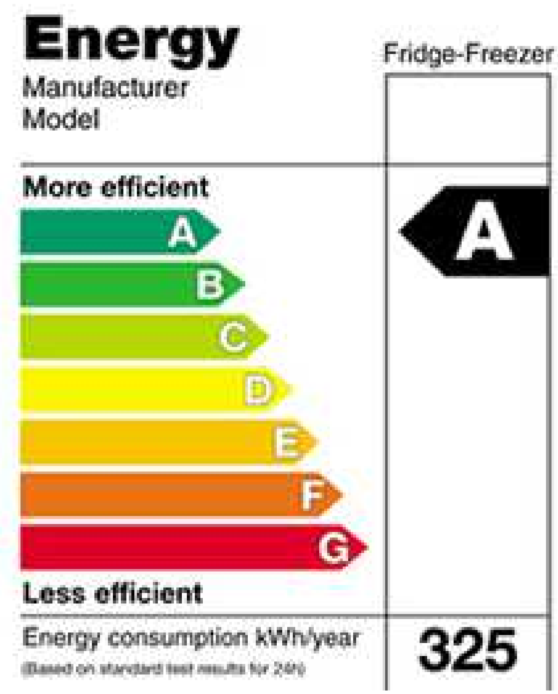
# Energy efficient appliances

- Appliances can account for up to 30% of a household's energy.
- Lot of appliances for cooking, heating/cooling, refrigeration etc.
  - Choosing energy-efficient appliances becomes more and more important.
- National standards for EE improve the performance of appliances all the time.
  - Upgrading to a more efficient appliance can save energy and money.
- Energy Rating Labels to help select the most efficient appliance.
- Products carrying an EU Energy Rating Label:
  - Washing machines and tumble dryers
  - Fridges, freezers and fridge freezers
  - Dishwashers
  - Electric ovens
  - Energy-saving light bulbs
  - Air conditioners



# Energy efficient appliances

- Energy ratings not comparable across different products, because each is calculated using a specific test defined by the EU and appropriate to that appliance.
- In order to conserve energy form all loads of a NZEB it is important to use high energy rated appliances e.g. A+.

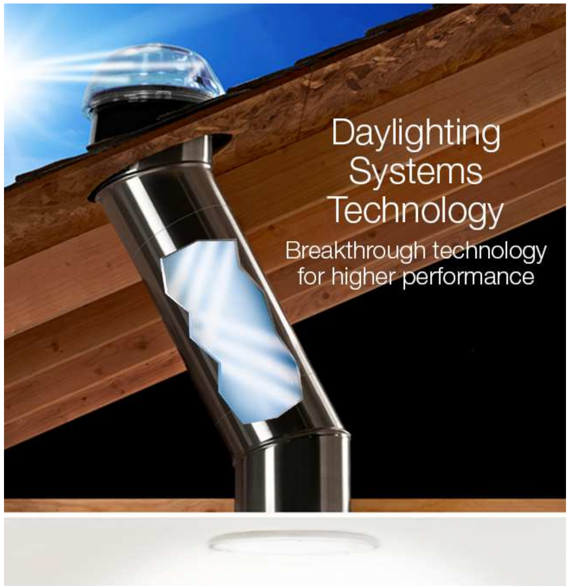


# Energy efficient appliances - Lighting

- For a well insulated building the consumption for lighting can be 50% of the total consumption (heating, cooling, ventilation, domestic hot water and lighting loads).
- Energy consumed for lighting is the result of installed lighting units in conjunction with daylighting mechanisms.
- Important to install and use light units in a minimal way without compromising the comfort of the people living/working in the building.
- For NZEBs in Cyprus the regulation imposes for offices that the installed lighting units shall not be >10 $W/m^2$.
- In winter the sunlight that streams through your windows adds free solar heat that lowers your heating bill.
- In summer you want to prevent direct sunlight from overheating interiors.
- The needs for lighting depend both in quality and quantity per building room area.
- Accordingly the natural light depends on the:
  - Geometry of the room (height/width)
  - Location of the window
  - Type of window
  - Shape of window

# Energy efficient appliances - Lighting

- For basements, stores and buildings where no other openings can be made another method for providing natural lighting is with light tubes.




Source: Solartube.com

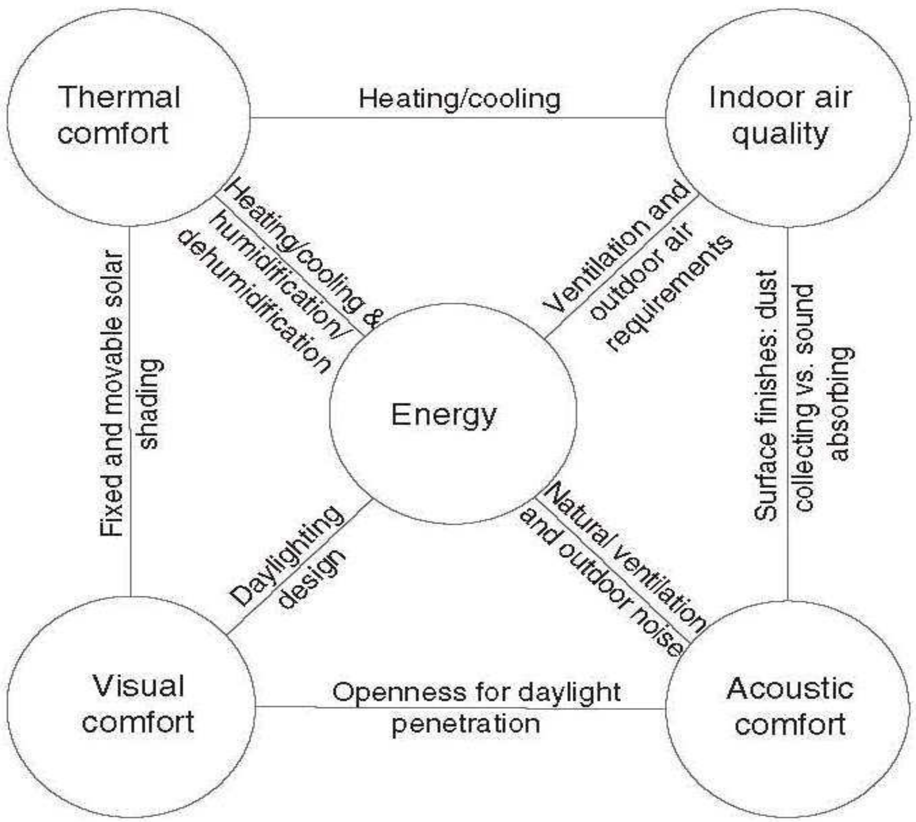
# Energy efficient appliances - Lighting

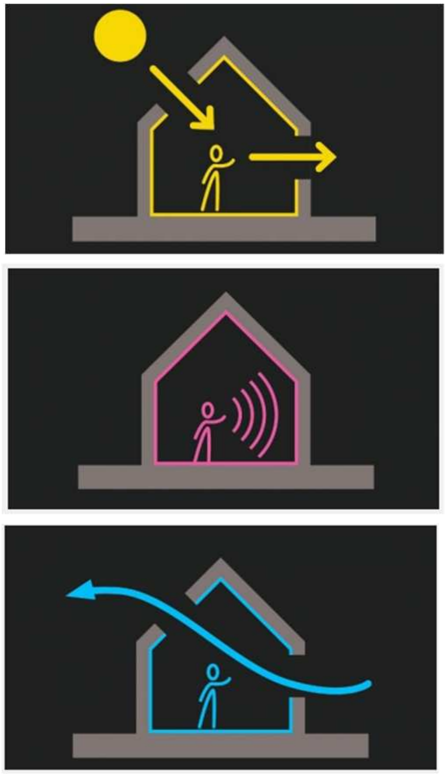
| | Light Emitting Diodes (LED) | Incandescent Light Bulb | Compact Fluorescent Bulb |
|---|---|---|---|
| Life span | 50,000 hours | 1,200 hours | 8,000 hours |
| Watts of electricity used (equivalent to 60 watt bulb) | 6-8 Watts | 60 Watts | 13-15 Watts |
| Sensitive to humidity | No | Some | Yes |
| Turns on instantly | Yes | Yes | No - takes time to warm up |

# Comfort considerations

- Primary goal of buildings: Provide shelter, a place to live and engage in activities to facilitate provision for a comfortable environment.
- Buildings should efficiently provide a comfortable environment while meeting the NZEB energy targets.
- **Comfort is tightly linked to energy performance.**
- If occupants are not provided with comfortable conditions they often adapt in the most convenient and responsive way rather than in energy conserving ways.
- Comfort should be critically assessed throughout the design and operation of NZEB.
- The focus is on the four main categories:
  - Thermal comfort
  - Visual comfort
  - Acoustic comfort
  - Indoor Air Quality

# Comfort considerations



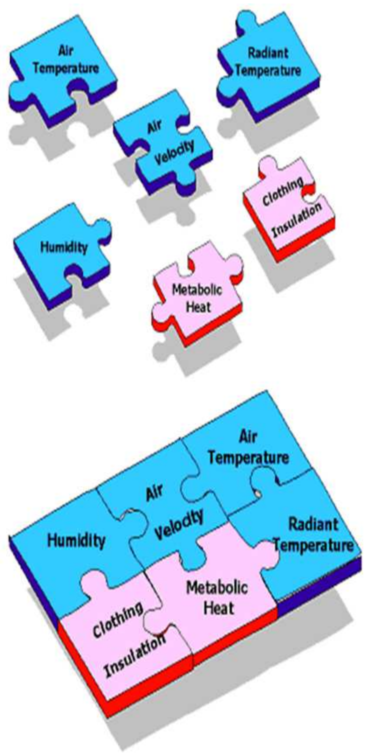



# Comfort considerations

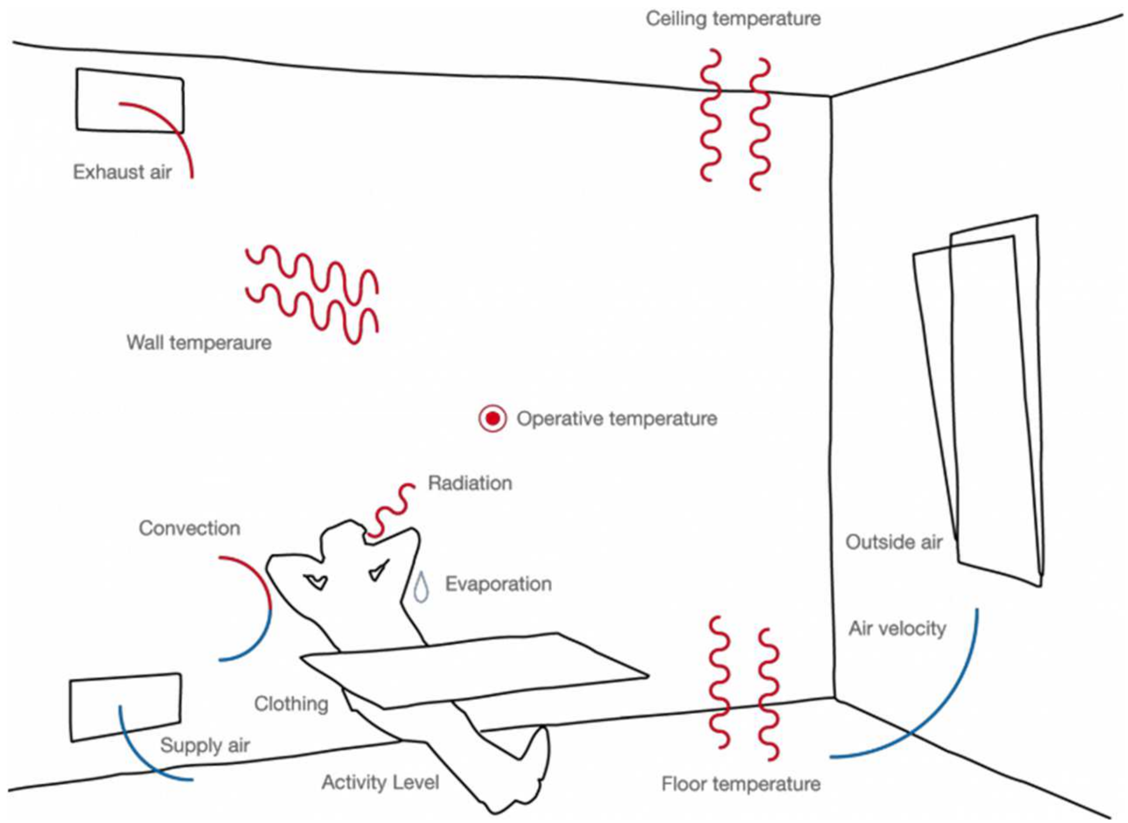
- Buildings are designed for people and people trying to accomplish a task:
  - Raising a family, running an office, or manufacturing a product.
- The building needs to keep people comfortable, efficient, healthy and safe during their task.
- Energy-efficient buildings are only effective when the occupants of the buildings are comfortable. If they are not comfortable, then they will take alternative means of heating or cooling a space such as space heaters or window-mounted air conditioners that could be substantially worse than typical Heating, Ventilation and Air Conditioning (HVAC) systems.

Thermal comfort

- Function of 4 environmental variables:
  - Air Temperature
  - Mean Radiant Temperature
    (weighted average of all the temperatures from surfaces surrounding an occupant)
  - Relative Humidity
  - Air Speed
- Also a function of 2 personal variables:
  - Metabolic activity
    (energy generated by the human body)
  - Clothing level

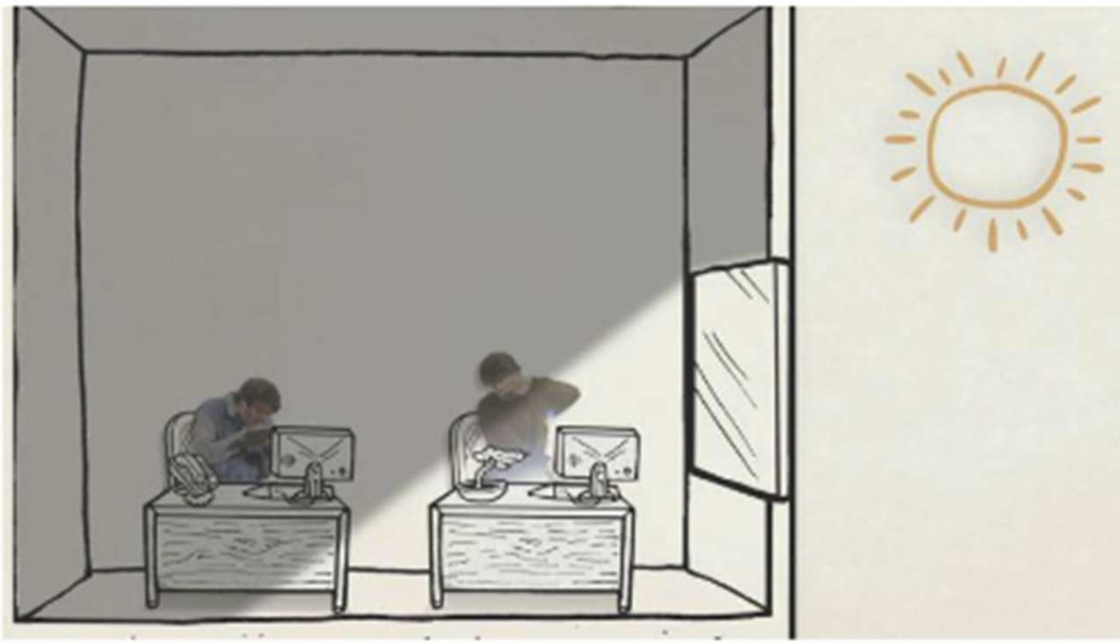


# Thermal comfort

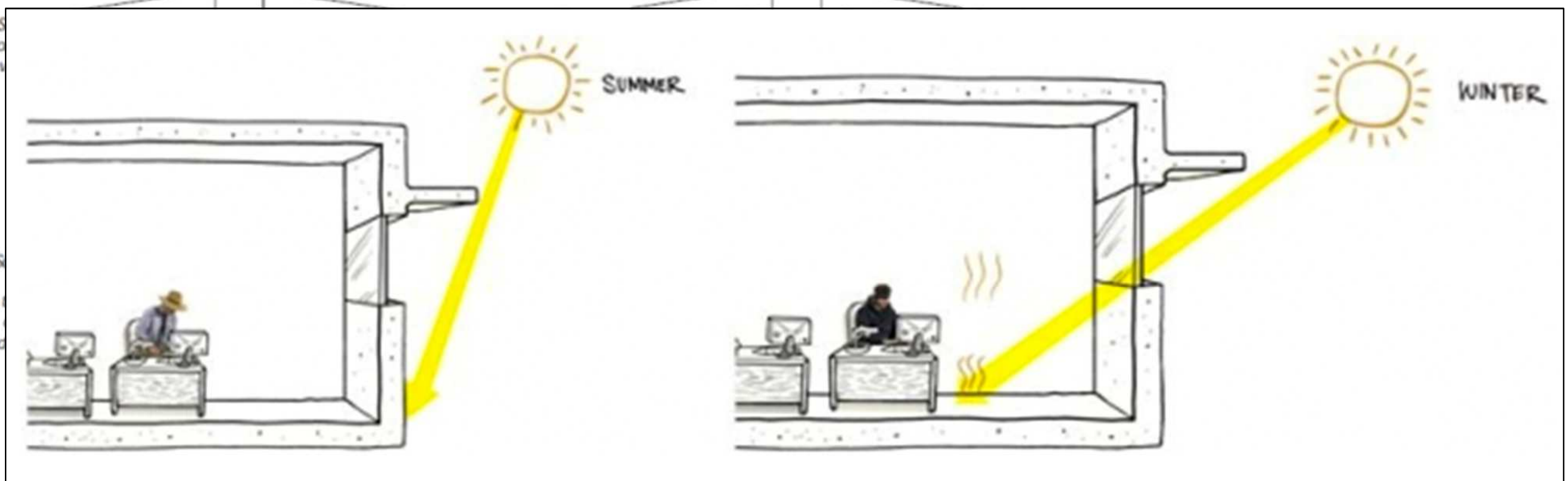


# Visual comfort

- Ensure people have enough light for their activities, the light has the right quality and balance and people hav
- Natural light be
- Perspectives of
  - Renewed er ergy use for NZEB
  - Daylight's in
  - Predominar eskwork)
- Visual comfort
  - Geometry o
  - Interior geo
  - Location of
  - Type of win
- Shape and size of window.



# Visual comfort




*An overhang shades in summer but lets heat in during winter*

*Lawrence Berkeley Lab's "Tips for Daylighting With Windows"*

# Acoustic comfort

- Having the right level and quality of noise to use the space as intended.
- People are more productive and happy when not distracted by noises from outside or from surrounding spaces and occupants, especially important for schools and office buildings.
- Acoustic comfort is often neglected during the design of NZEB because it can conflict with good daylighting and natural ventilation design.
- Recent evaluation of low-energy buildings revealed that these buildings score poorly on acoustic comfort.
- Poor acoustic comfort can compromise energy-conserving strategies like natural ventilation because occupants are faced with choosing between thermal comfort and having quiet indoor environment.

# Indoor Air Quality

- In addition to air that has the right temperature and humidity for thermal comfort, it is important that air is clean, fresh, and circulated effectively in the space.
- If air is too stale or is polluted, it can make people uncomfortable, unproductive, unhappy, and sick.
- Fresh air helps people be alert, productive, healthy, and happy.

# Conclusions

- The primary goal of buildings is to provide shelter, a place to live and engage in activities to facilitate provision for a comfortable environment.
- Buildings should efficiently provide a comfortable environment while meeting the NZEB energy targets.
- Comfort is tightly linked to energy performance.
- If occupants are not provided with comfortable conditions they often adapt in the most convenient and responsive way rather than in energy conserving ways.
- Effort (worldwide) in recent years to further NZEB deployment.

FOSS Research Centre for Sustainable Energy

DIEGO Development of quality system through EnerGy Efficency cOurses

Erasmus+

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# Thank you for your attention!

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