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Training for Renovated Energy Efficient Social housing

Intelligent Energy -Europe programme, contract n° EIE/05/110/SI2.420021

Section 2 Tools
2.1 Simplified heating load calculation

Tamas CSOKNYAI
BUTE

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Objectives and principle

- **Objective : decrease the heating energy consumption and the heat demand**
- **Principle : decrease of the transmission and ventilation losses, utilization of the solar gains and optimization of the equipments**
- **Example : „passive house labeling” in Germany, Minergie in Switzerland**
- **EPBD: European Energy Performance Directive on Buildings,**
  - in force since January 2006
  - Energy certification
  - Regular inspection of boilers and air conditionning systems
- **Tools : simplified energy balance, dynamic simulation tools (see section 2.2)**
- **European standards EN 832, EN ISO 13790**

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Heating energy balance of a building

$$\Phi_{tr} + \Phi_{vent} + \Phi_{sol} + \Phi_{\text{int}} \pm \frac{\Phi_{stored}}{T} - \left(\Phi_{H} - \Phi_{system\ losses}\right) = 0$$

$$\Phi_{H} = \Phi_{tr} + \Phi_{vent} - \Phi_{sol} - \Phi_{\text{int}} \pm \frac{\Phi_{stored}}{T} + \Phi_{system\ losses} = 0$$

Φ_{H}	**Heating load**
Φ_{tr}	**Transmission losses**
Φ_{vent}	**Ventilation losses**
Φ_{sol}	**Solar gains**
Φ_{int}	**Internal heat charges**
$\frac{\Phi_{stored}}{\tau}$	**Variation of stored heat in function of time**
$\Phi_{system\ losses}$	**Losses of the heating system (distribution losses)**

Heating load calculation

With other words
(according to Standard EN ISO 13790)

Heating load =
= heat losses – η . (solar + internal gains) + distribution losses

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Heat losses

- **Transmission losses through the building envelope**
  - Exposed surfaces: facade walls, roof, ground
  - Openings (windows, doors)
  - Thermal bridges
- **Ventilation losses:**
  - Opening of windows
  - Losses of mechanical ventilation system
  - In- or exfiltration of air
- **Depends also on the indoor air temperature (control, zones) and the outdoor conditions (latitude, altitude)**

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TRANSMISSION LOSSES

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Transmission through multi-layer structures

Transmission losses: $\Phi_{tr} = U \cdot A \cdot (\vartheta_i - \vartheta_e)$ [W]

- U-value: Air-to-air conductance (thermal transmittance)
- R: thermal resistance of a layer

$U = 1 / \Sigma R$ [$W/m^2/K$]

- A: Surface of the exposed elements [m^2]
- ϑ_i : Design indoor air temperature
- ϑ_e: Design outdoor air temperature

$$U = \frac{1}{\frac{1}{h_i} + \sum R_j + \frac{1}{h_e}} = \frac{1}{\frac{1}{h_i} + \frac{1}{h_e} + \sum \frac{d_j}{\lambda_j}}$$

- Total heat transfer through a building element is a result of
  - conduction,
  - convection
  - radiation

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Conductivity of materials

- polystyrene

λ = 0.04 W/mK

- reinforced concrete

λ = 2,1 W/mK

- wood

λ = 0.15 W/mK

- glass

λ = 1 W/mK

- steel

λ = 50 W/mK

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Convection+linearised radiaton

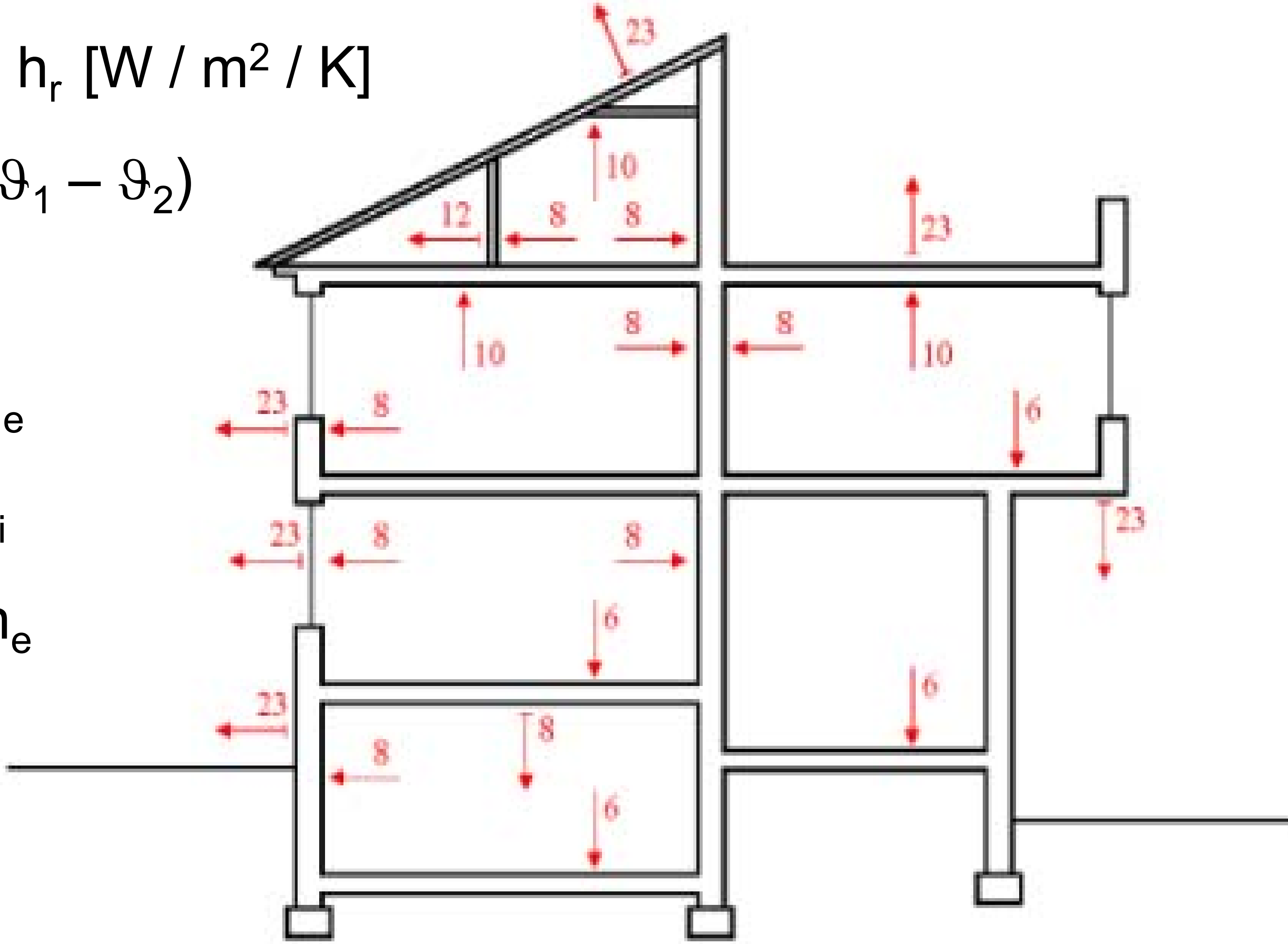
$h = h_c + h_r$ [W / m² / K]

$\Phi = h \cdot (\vartheta_1 - \vartheta_2)$

h_i and h_e

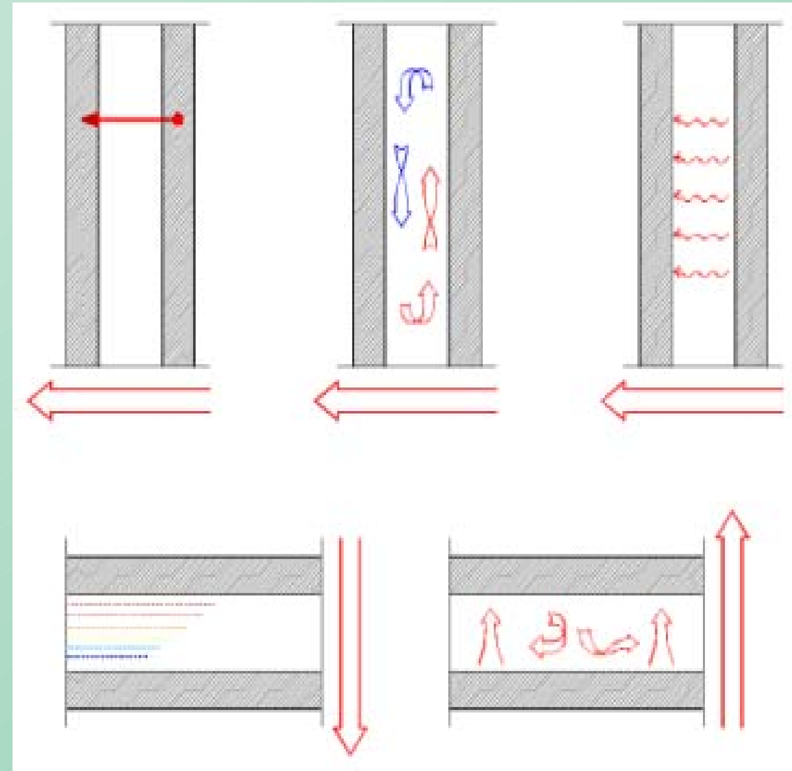
$R_i = 1/h_i$

$R_e = 1/h_e$



Special cases for determining U-value: Air layers

- **Air gap between two materials**
- **Thermal resistance depends on position, width and level of ventilation**
- **Thermal resistance in function of the width of air gap**



R = 0.11	0.13	0.14	0.15	0.16	m2.K / W
	0.7	0.9	1.1	1.3	**width** (cm)

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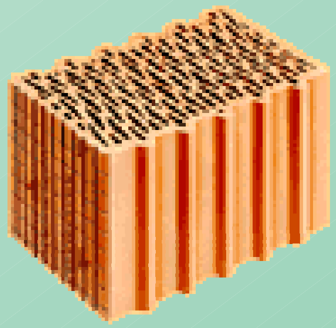
Special cases : Non homogeneous materials

Non homogeneous materials, average R (usually given by the producer)



Examples :

- **brick of 5 cm , R = 0.11 m^2.K/W**
- **insulating masonary blocks (bricks with holes) of 44 cm (« Phorotherm »), R = 2.57 m2.K/W**

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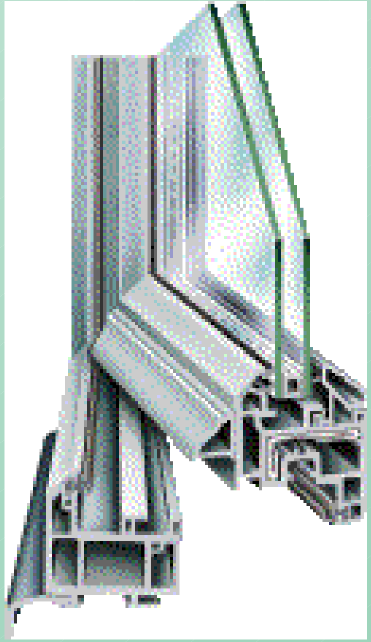
Walls, floor and roof

▸ Facades	Uf	Af	Uf . Af
▸ Floor	Ufl	Afl	Ufl . Afl
▸ Roof	Ur	Ar	<u>Ur . Ar</u>
▸ TOTAL			Σ (U . A)

- transmission heat losses :

$\Phi_T = \Sigma (U . A). (\vartheta_i - \vartheta_e)$ + windows, doors and thermal bridges

Doors and windows



- Single glazing : U = 5.5 W/m2/K
- Double glazing : U = 3.3 W/m2/K
- + low-emissivity coating : U=1.8 W/m2/K
- + argon filling : U = 1.1 W/m2/K
- Wooden frame : U = 2.4 W/m2/K
- PVC frame : U = 1.7 W/m2/K
- Average U-value: mean value weghted with proportion of area, e.g. 75% glazing, 25% frame + losses caused by spacer
- Door : according to thickness and material (R)

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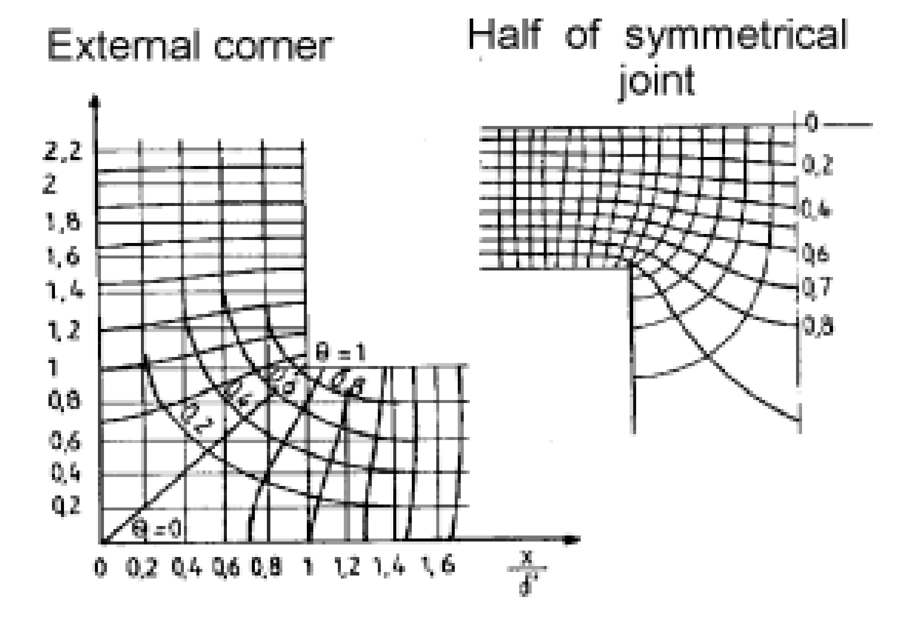
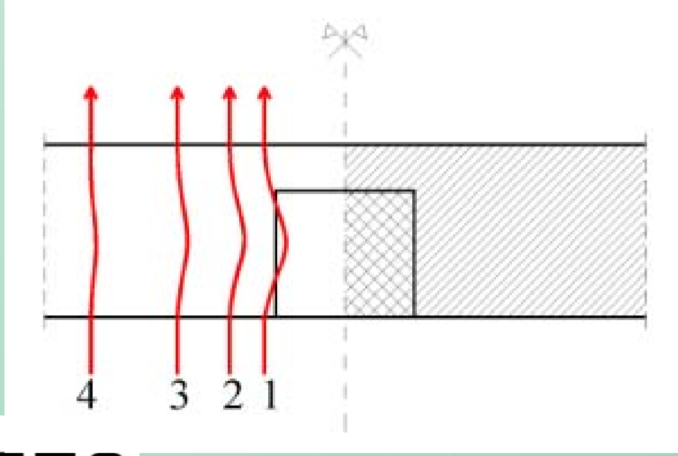
Thermal bridges





Ψ [W/mK]: Linear heat loss.

Can be determined using:

- Thermal bridge catalogues
- Thermal bridge calculation tools
- Some producers of complete construction systems publish their usual Ψ-values in catalogues

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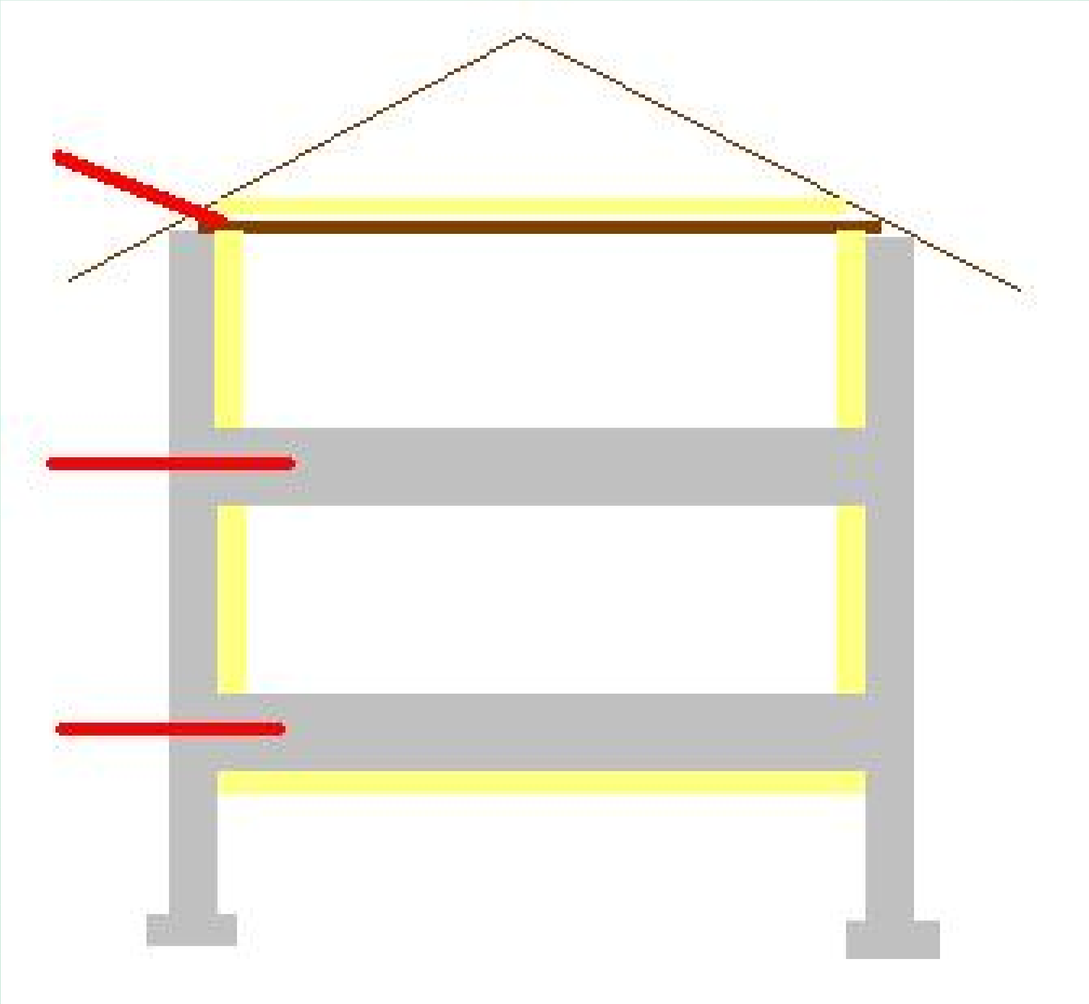
Thermal bridges (examples)

ψ= 0.05

Ψ= 0.8
-> 1

Ψ= 0.5
-> 0.7
W/m/K



TREES $\Phi = \psi \cdot L \cdot (T_i - T_e)$ **ψ in W/m/K**

VENTILATION LOSSES

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Calculation of ventilation losses

- Minimum ACH determined by:
  - Biological need (fresh air for breathing)
  - Required ACH for fabric protection
- 2 ways of determination of ACH:
  - Fresh air required per person : 30 m^3/h,person
  - Minimal air change rate: $n_{min}=0,5\ h^{-1}$
- Infiltrations (spontanous losses through window gaps, joints, shafts…)
- Ventilation losses : ACH .V .ρ .C .$(\vartheta_i - \vartheta_e)$

ACH: Air change rate [h^{-1}]

ρ : density of air, [m^3/h]

C : heat capacity of air = 1000 J/kg,K

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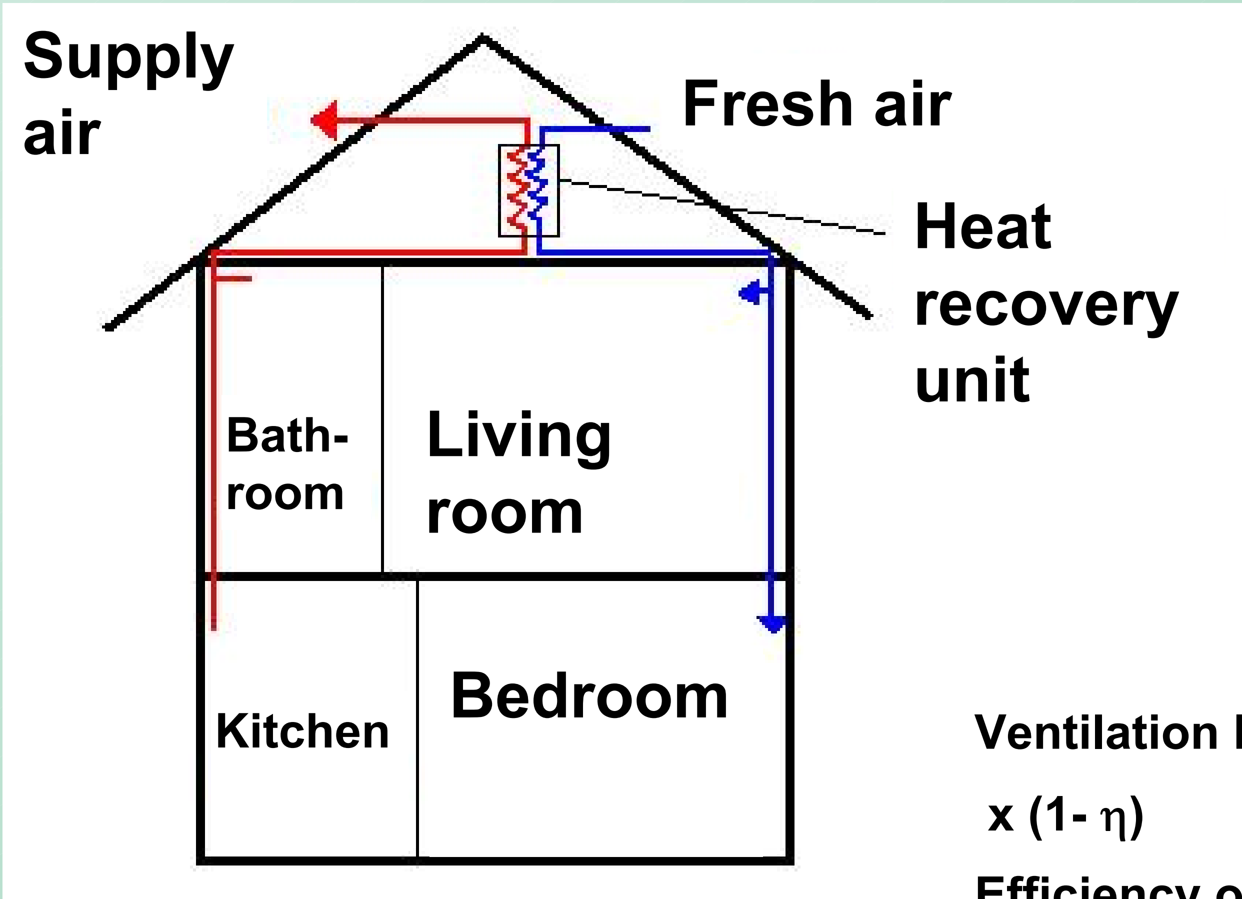
Preheating of ventilation air, heat recovery



Ventilation heat loss:

x (1- η)

Efficiency of heat recovery

η = 60 .. 90%

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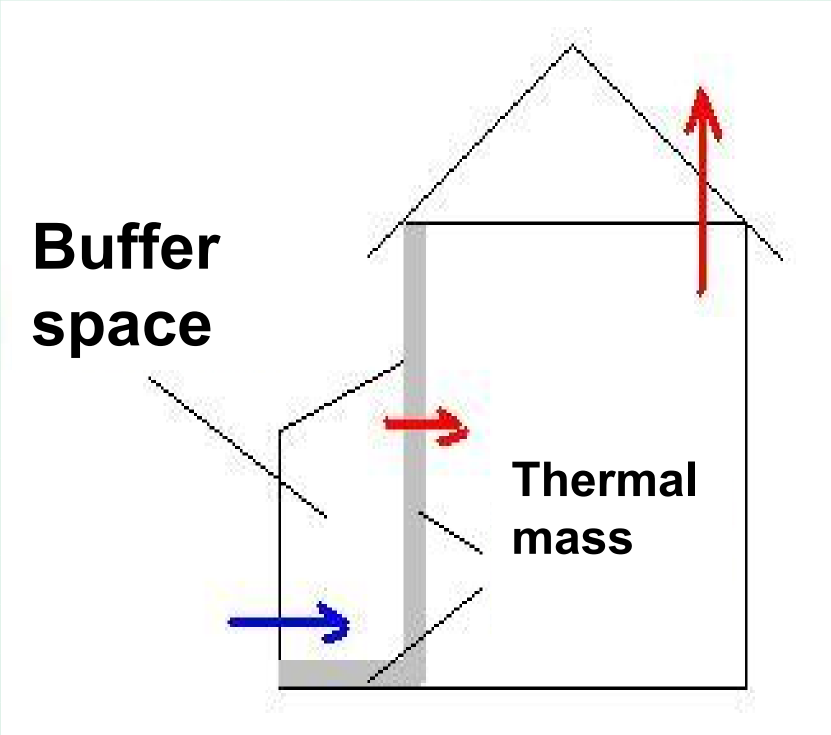
Preheating in a sunspace



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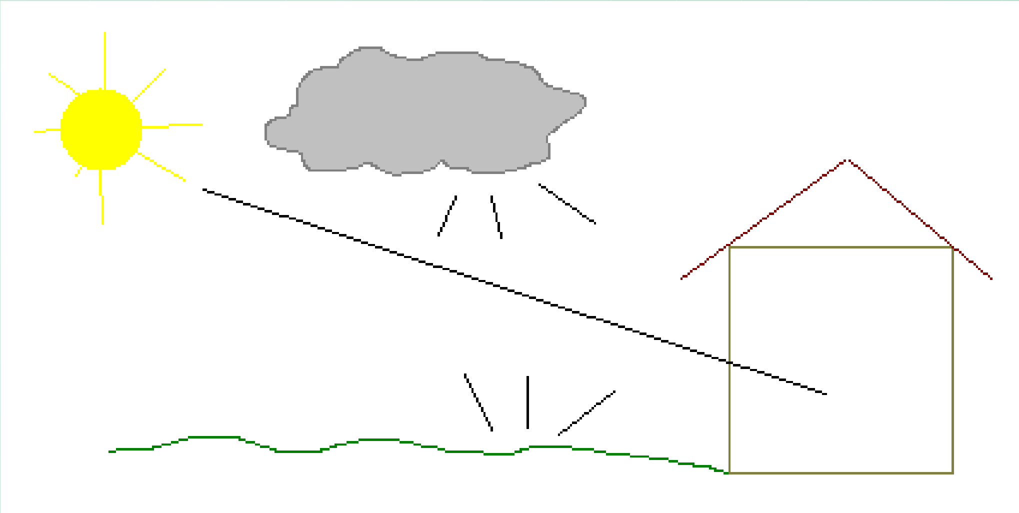
SOLAR GAINS

Solar radiation

- 3 parties : direct, diffuse, reflected



- Radiation global horizontal
- Radiation on different vertical orientations

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Solar gains

Utilised solar gains depend on:

- Climate
- Geographical position of the site
- Orientation of glazing
- Shading objects (neighbouring buildings, trees)
- Shading coefficient of shading devices
- g-value of the glazing
- Thermal mass of the building

DESIGN VALUES OF SOLAR RADIATION DEPEND ON THE LOCATION AND ARE GIVEN BY THE STANDARDS

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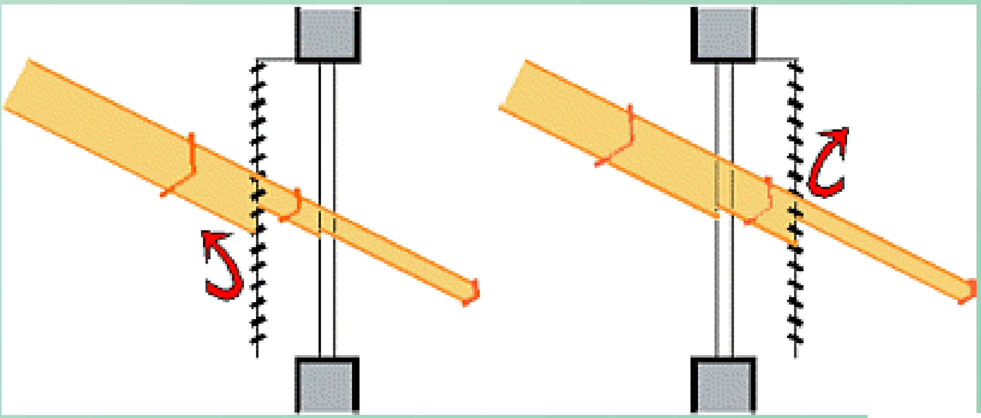
Shadowing devices and movable insulation

- Shadowing devices and movable insulation are of importance both in winter and summer from the points of view of reducing transmission heat losses and controlling solar penetration.
- If the shadowing device is outside, in front of the glazing, the total solar energy transmittance can be as low as 0,1-0,4. For the same device, if it is behind of the glazing, the shading coefficient is higher: 0,4-0,7.



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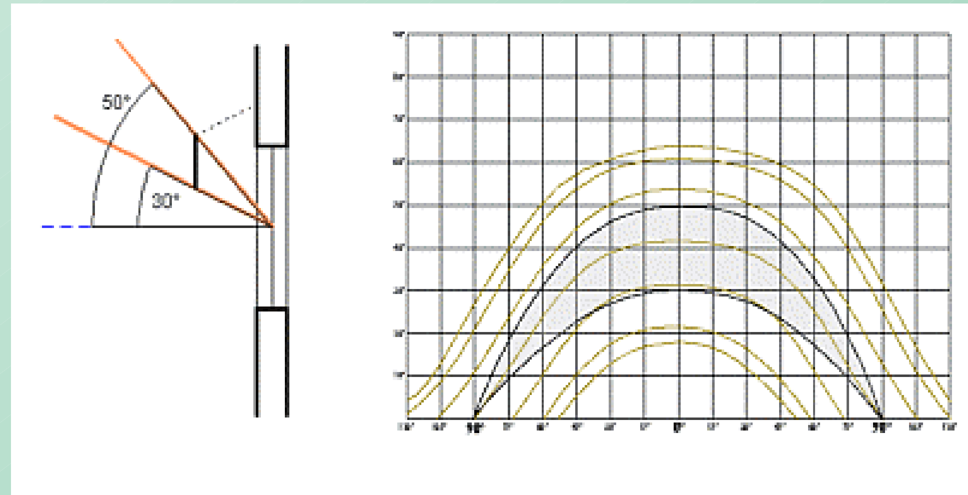
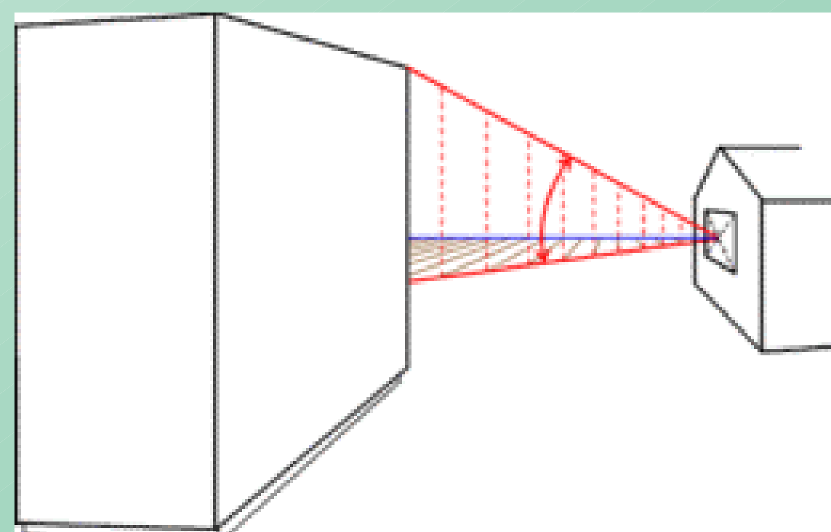
Sun path diagram and shadow mask calculator

Sun path diagram and shadow mask calculator are tools to determine the shading effect of the neighbouring objects and shading devices





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INTERNAL GAINS

Internal gains

- Occupants : about 100 W / person (in function of physical activity)
- Artificial lighting
- Office equipments (computers, photocopy machines)
- Cooking
- A part is lost (e.g. hot water)

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Energy consumption reduction by solar and internal gains

- The real reduction is only a part of the internal and solar gains. Expressed with efficiency: η
- η depends:
  - The proportion of the gains (γ : gains Φ_g / losses Φ_L)
  - The thermal mass and the time constant of the building
  - Heavy building can utilise more gains than light ones

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THERMAL MASS

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Thermal mass

- The change of the stored heat is proportionate to the change of the temperature, the mass (m) and the specific heat (C):

  $\Delta q = m*C*\Delta T$

  - concrete : C=0.26 Wh/kg/K, 2400 kg/m3
  - wood : C= 0.36 Wh/kg/K, 630 kg/m3
  - polistyrene : C= 0.34 Wh/kg/K, 25 kg/m3
  - glass : C= 0.5 Wh/kg/K, 2500 kg/m3

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External and internal insulation, time constant

- Time constant depends on the level of thermal transmittance (H=A*U) and heat capacity $\tau = C / H$
  - If external insulation: lower H → higher τ
  - If heavy structures: higher C → higher τ
  - If internal insulation: lower thermal mass → lower τ
- Maximum 10 cm of the inner part of exposed structures can store heat (for 24 hours). Mass and resistance of this layer is a key issue.
- Intermittent (programmed) heating can result in energy saving because of thermal mass

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HEATING LOAD CALCULATION FOR A PERIOD

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Heat losses during a period

- Heat loss coefficient: losses in case of 1K temperature difference:
- $H = H_T + H_V$
- $H_T = \{\Sigma\ (U\ .\ A) + \Sigma\ (\psi\ .\ L\ )$

  - $\Sigma\ (\psi\ .\ L)$: thermal bridges)
  - $\Sigma\ (U\ .\ A)$: walls, roof, ground, windows and doors

- $H_V = ACH\ .V\ .\rho\ .C$
- $\Phi = H\ .(\vartheta_i - \vartheta_e)$

  - ϑ_i: Prescribed indoor air temperature for example $\vartheta_i = 20°C$
  - ϑ_e variable during the heating season

Yearly losses = Σ monthly losses = Σ hourly losses

$\Sigma\ H\ (20 - \vartheta_e) = H\ .\ \Sigma\ (20 - \vartheta_e)$

$\Sigma\ (20 - \vartheta_e)$: Degree - hours based on 20°C

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Degree - hours

- Simplification of climatic model
- $\Sigma\,(18 - \vartheta_e)$ = degree hours based on $\vartheta_i = 18°C$
- Heating not needed if T_e >= balanced point temperature, depends on climate e.g. 12 °C (internal heat gains)
- Examples for yearly degree hours:
  - Warshaw: 93 000 degree hours
  - Budapest: 72 000 degree hours
  - Paris : 58 000 degree hours
  - Nice : 32 000 degree hours
  - Athens: 34 000 degree hours
  - Copenhagen: 70 000 degree hours

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Heating period

- $\theta_{ext} \leq \theta_{int} - \eta_1 \, . \, Q_g / (H \, . \, 24)$
- θ_{ext} : daily average outdoor temperature
- θ_{int} : daily average indoor temperature
- $\eta_1 = a / (a+1)$ (η for $\gamma = 1$)
- Q_g : daily average gains
- H = total heat losses in W/K
- In case of monthly calculations: $a = 1 + \tau / 15$
- Time constant $\tau = C / H$

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Conclusions

- **EPBD, Energy certification, energy label**
- **Links with simulation**
- **Normative references:**
  - EN 832: Thermal performance of buildings – Calculation of energy use for heating – Residential buildings
  - prEN 410: Glass in building – Determination of luminous and solar characterisics of glazing
  - EN ISO 7345: Thermal insulation – Physical quantities and definitions (ISO 7345:1987)
  - prEN ISO 10077-1 Windows, doors and shutters – Thermal transmittance – Part 1: Simplified calculation method
  - EN ISO 13786: Thermal Performance of Building components –Dynamic thermal characteristics – Calculation method
  - EN ISO 13789: Thermal Performance of Buildings – Transmission heat loss coefficient – Calculation method

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