Train-to-NZEB
The Building Knowledge Hubs

nZEB ready

nZEB – Nearly Zero Energy Building

Introduction to the nZEB concept and Passive House pillars

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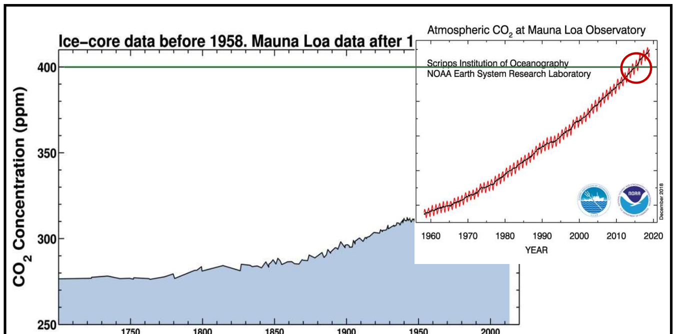
Content

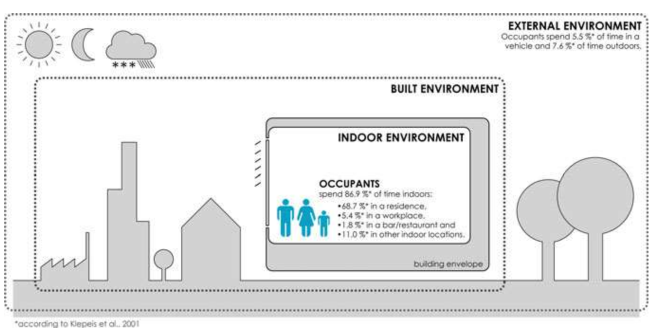
Defining nZEB in the green / sustainable building context



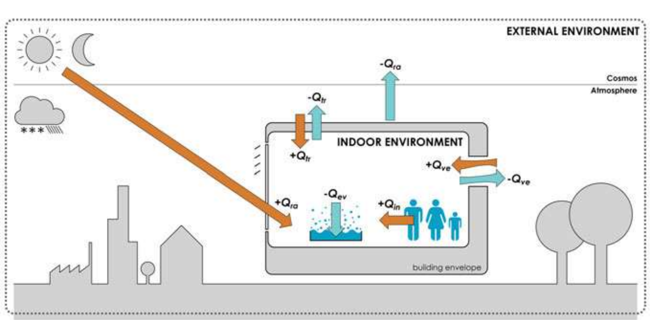
Dr. ing. Horia Petran

Battisti, C. Brown, M. et al. (2021). RESTORY. Managing a COST Action as a Project. COST Action CA16114 RESTORE

Sustainability	→ seeking to limit damage caused to socio-economic and ecological systems
Restorative Sustainability	→ restoring the capability of socio-economic and ecological systems to a healthy state
Regenerative Sustainability	→ regenerating relationships so that socio-economic and ecological systems thrive and continuously evolve
Biophilic Design	→ design that improves health through a connection with nature (biophilia - "our innate relationship with nature")



Sursa: Mitja Košir - *Climate Adaptability of Buildings, Bioclimatic Design in the Light of Climate Change*, © Springer



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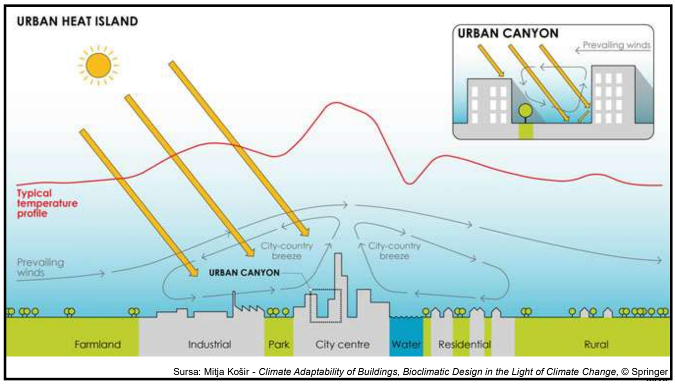

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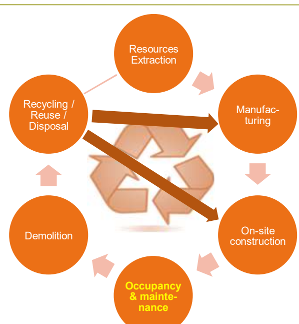
nZEB → sustainable building → green building ?

A **green** or “**sustainable**” **building** responds the present needs without compromising the ability of future generations to meet their own needs

Buildings life cycle



Embodied energy

- Global primary energy use (or carbon emissions) over the full life cycle of a building or a material.
- ‘Cradle-to-Grave’ includes at least
  - Extraction of raw materials
  - Manufacturing capital equipment, heating and lighting of factory
  - Transport
  - On-site assembly
  - Maintenance
  - Disposal
- ‘Cradle-to-Gate’ includes all energy (in primary form) until the product leaves the factory gate.
- ‘Cradle-to-Site’ includes all of the energy consumed until the product has reached the point of use (i.e. building site).

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Table 1 Summary of BREEAM categories and main issues

Management • Commissioning • Construction site impacts • Building User Guide	**Waste** • Construction waste • Recycled aggregates • Recycling facilities
Health and Wellbeing • Daylight • Occupant thermal comfort • Acoustics • Indoor air and water quality • Lighting	**Pollution** • Refrigerant use and leakage • Flood risk • NO_x emissions • Watercourse pollution • External light and noise pollution
Energy • CO_2 emissions • Low or zero carbon technologies • Energy sub metering • Energy efficient building systems	**Land Use and Ecology** • Site selection • Protection of ecological features • Mitigation/enhancement of ecological value
Transport • Public transport network connectivity • Pedestrian and Cyclist facilities • Access to amenities • Travel plans and information	**Materials** • Embodied life cycle impact of materials • Materials re-use • Responsible sourcing • Robustness
Water • Water consumption • Leak detection • Water re-use and recycling	**Innovation** • Exemplary performance levels • Use of BREEAM Accredited Professionals

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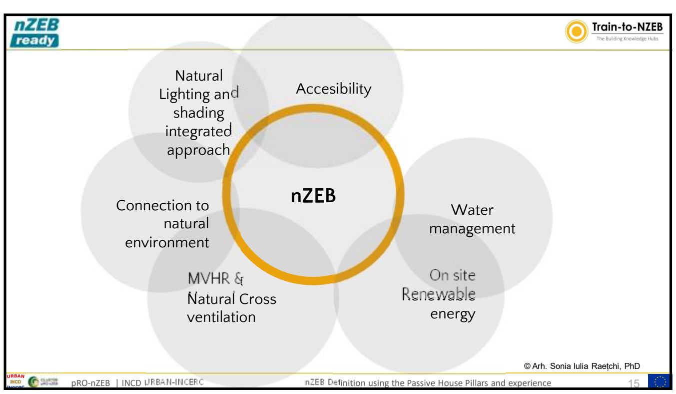
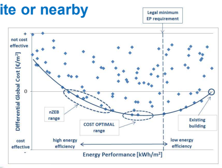


nZEB = nearly Zero Energy Building

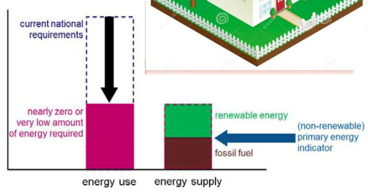
a building that has a very high energy performance, as determined in accordance with Annex I. The **nearly zero** or **very low** amount of **energy required** should be covered to **a very significant extent** by energy **from renewable sources**, **including** energy from renewable sources produced **on-site or nearby**



Primary energy
< x kWh/m²/yr

Renewables Share
> y % PE

CO_2 Emissions
< z kg/m²/yr



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Pillars of the nZEB concept

nZEB = nearly Zero Energy Building

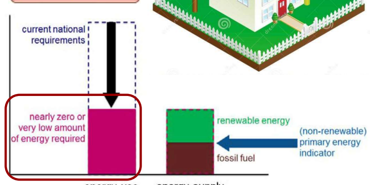
a building that has a very high energy performance, as determined in accordance with Annex I. The **nearly zero** or **very low** amount of **energy required** should be covered to **a very significant extent** by energy **from renewable sources**, **including** energy from renewable sources produced **on-site or nearby**

Primary energy
< x kWh/m²/yr

Renewables Share
> y % PE

CO_2 Emissions
< z kg/m²/yr

… know where to go, but how to do it?



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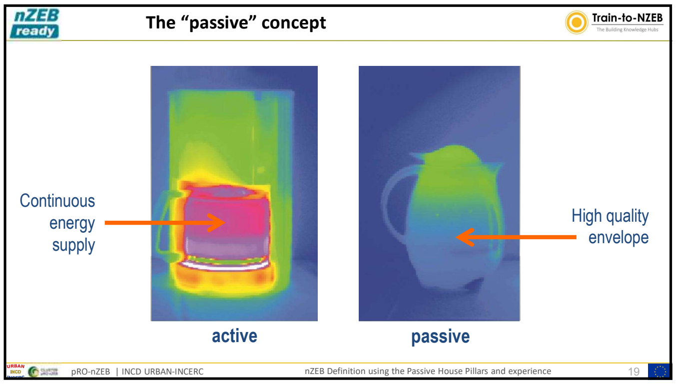
nZEB ready
The "passive" concept
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Continuous energy supply
High quality envelope
active
passive
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nZEB Definition using the Passive House Pillars and experience
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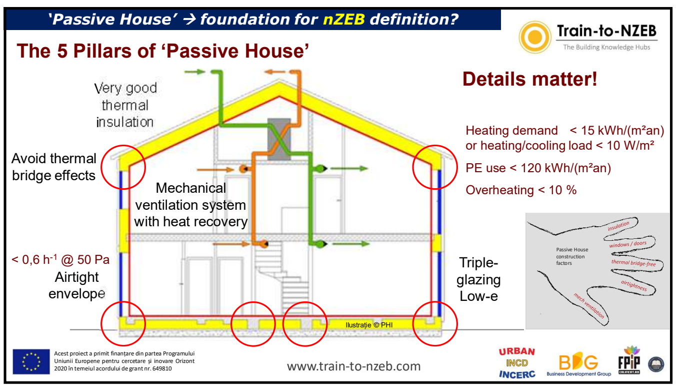
'Passive House' → foundation for nZEB definition?
Train-to-NZEB
The Building Knowledge Hubs
The 5 Pillars of 'Passive House'
Very good thermal insulation
Avoid thermal bridge effects
Mechanical ventilation system with heat recovery
< 0,6 h⁻¹ @ 50 Pa
Airtight envelope
Details matter!
Heating demand < 15 kWh/(m²an)
or heating/cooling load < 10 W/m²
PE use < 120 kWh/(m²an)
Overheating < 10 %
Triple-glazing Low-e
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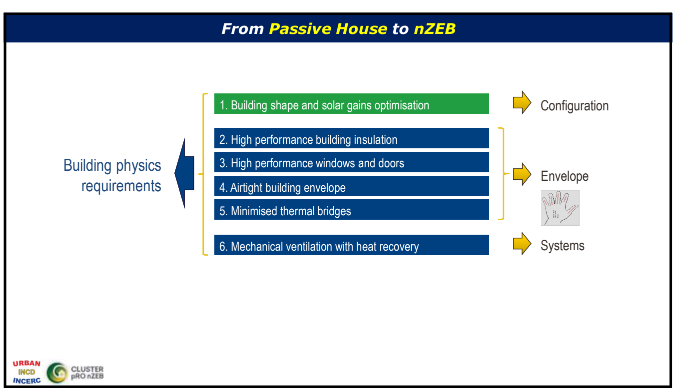
From Passive House to nZEB
Building physics requirements
1. Building shape and solar gains optimisation
2. High performance building insulation
3. High performance windows and doors
4. Airtight building envelope
5. Minimised thermal bridges
6. Mechanical ventilation with heat recovery
Configuration
Envelope
Systems
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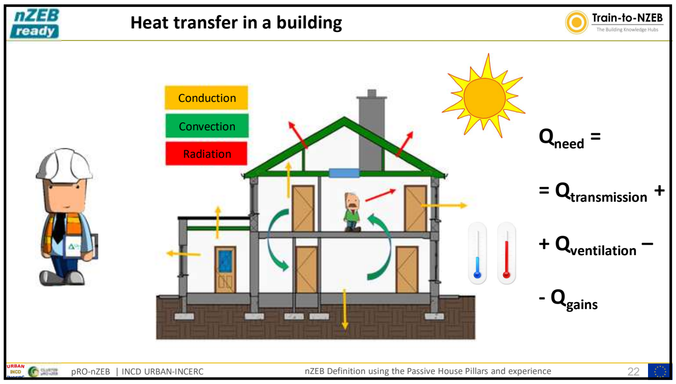
nZEB ready
Heat transfer in a building
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Conduction
Convection
Radiation
Q_need =
= Q_transmission +
+ Q_ventilation –
- Q_gains
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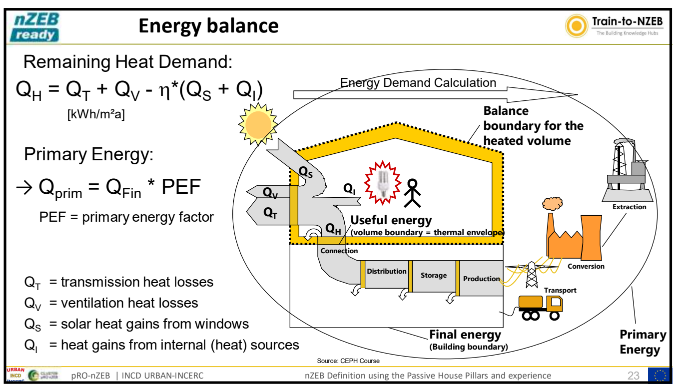
nZEB ready
Energy balance
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Remaining Heat Demand:
Q_H = Q_T + Q_V - η*(Q_S + Q_I)
[kWh/m²a]
Primary Energy:
→ Q_prim = Q_Fin * PEF
PEF = primary energy factor
Q_T = transmission heat losses
Q_V = ventilation heat losses
Q_S = solar heat gains from windows
Q_I = heat gains from internal (heat) sources
Energy Demand Calculation
Balance boundary for the heated volume
Useful energy
(volume boundary = thermal envelope)
Connection
Distribution
Storage
Production
Extraction
Conversion
Transport
Final energy
(Building boundary)
Primary Energy
Source: CEPH Course
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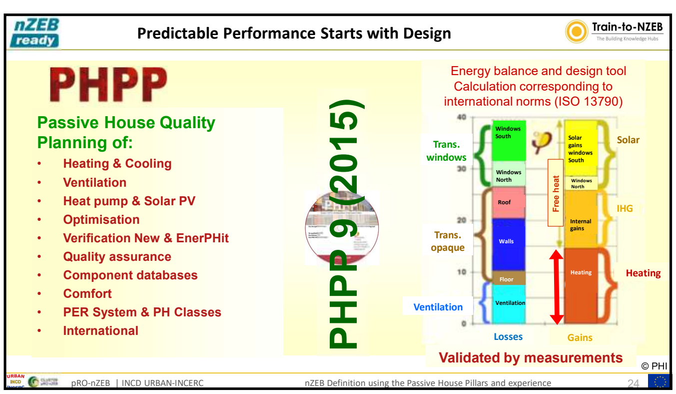
nZEB ready
Predictable Performance Starts with Design
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PHPP
Passive House Quality
Planning of:
Heating & Cooling
Ventilation
Heat pump & Solar PV
Optimisation
Verification New & EnerPHit
Quality assurance
Component databases
Comfort
PER System & PH Classes
International
PHPP 9 (2015)
Energy balance and design tool
Calculation corresponding to
international norms (ISO 13790)
Trans. windows
Trans. opaque
Ventilation
Solar
IHG
Heating
Free heat
Losses
Gains
Validated by measurements
© PHI
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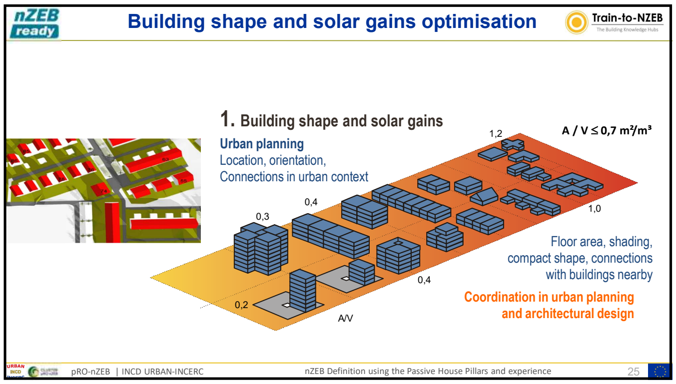
nZEB ready
Building shape and solar gains optimisation
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1. Building shape and solar gains
Urban planning
Location, orientation,
Connections in urban context
A / V ≤ 0,7 m²/m³
1,2
0,4
0,3
1,0
0,4
0,2
A/V
Floor area, shading,
compact shape, connections
with buildings nearby
Coordination in urban planning
and architectural design
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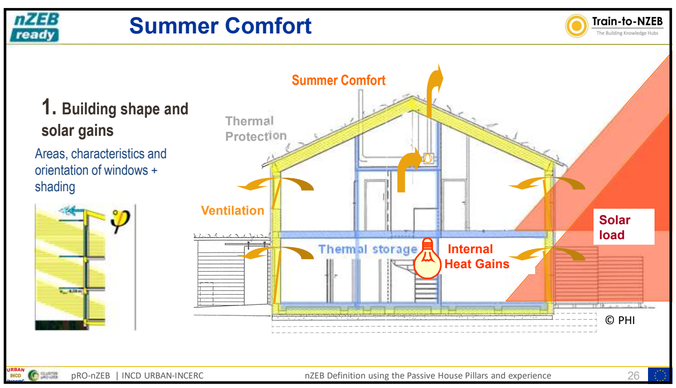
nZEB ready
Summer Comfort
Train-to-NZEB
1. Building shape and
solar gains
Areas, characteristics and
orientation of windows +
shading
Summer Comfort
Thermal
Protection
Ventilation
Thermal storage
Internal
Heat Gains
Solar
load
© PHI
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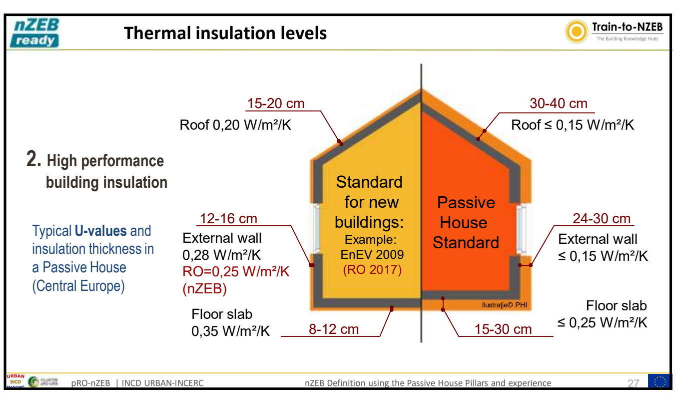
nZEB ready
Thermal insulation levels
Train-to-NZEB
2. High performance
building insulation
Typical U-values and
insulation thickness in
a Passive House
(Central Europe)
15-20 cm
Roof 0,20 W/m²/K
30-40 cm
Roof ≤ 0,15 W/m²/K
Standard
for new
buildings:
Example:
EnEV 2009
(RO 2017)
Passive
House
Standard
12-16 cm
External wall
0,28 W/m²/K
RO=0,25 W/m²/K
(nZEB)
24-30 cm
External wall
≤ 0,15 W/m²/K
Floor slab
0,35 W/m²/K
8-12 cm
15-30 cm
Floor slab
≤ 0,25 W/m²/K
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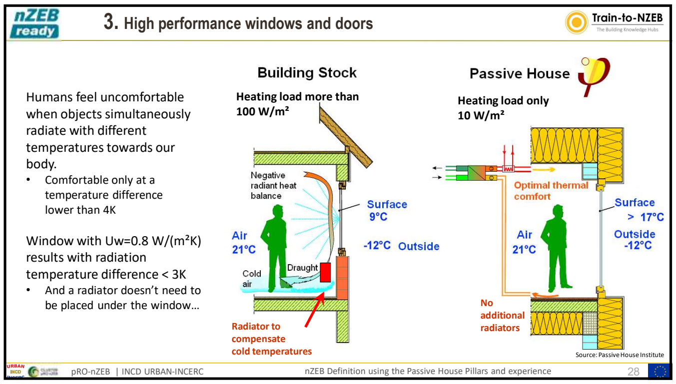
nZEB ready
3. High performance windows and doors
Train-to-NZEB
Building Stock
Passive House
Humans feel uncomfortable when objects simultaneously radiate with different temperatures towards our body.
• Comfortable only at a temperature difference lower than 4K
Window with Uw=0.8 $W/(m^2K)$ results with radiation temperature difference < 3K
• And a radiator doesn't need to be placed under the window…
Heating load more than 100 W/m^2
Negative radiant heat balance
Surface 9°C
Air 21°C
-12°C Outside
Cold air
Draught
Radiator to compensate cold temperatures
Heating load only 10 W/m^2
Optimal thermal comfort
Surface > 17°C
Air 21°C
Outside -12°C
No additional radiators
Source: Passive House Institute
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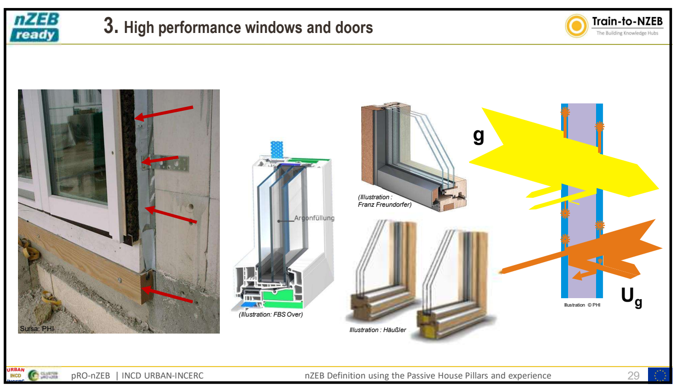
nZEB ready
3. High performance windows and doors
Train-to-NZEB
Sursa: PHI
Argonfüllung
(Illustration: FBS Over)
(Illustration : Franz Freundorfer)
Illustration : Häußler
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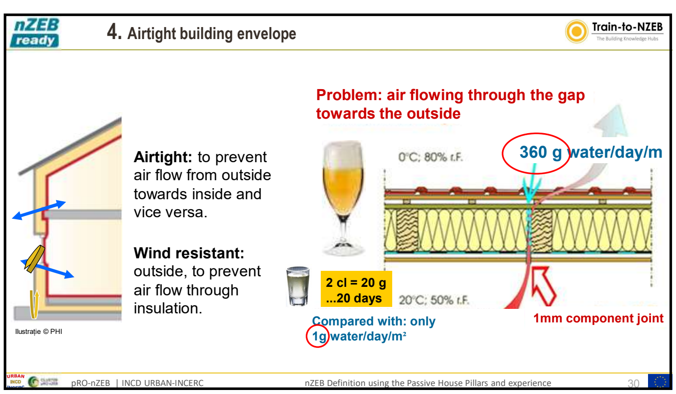
nZEB ready
4. Airtight building envelope
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Airtight: to prevent air flow from outside towards inside and vice versa.
Wind resistant: outside, to prevent air flow through insulation.
Ilustrație © PHI
Problem: air flowing through the gap towards the outside
0°C; 80% r.F.
360 g water/day/m
2 cl = 20 g
...20 days
20°C; 50% r.F.
Compared with: only 1g water/day/m²
1mm component joint
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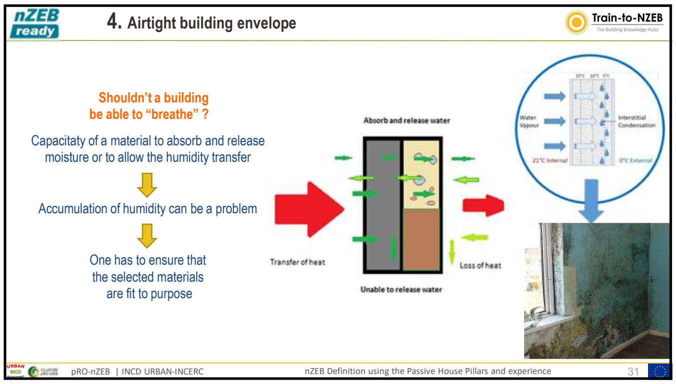
nZEB ready
4. Airtight building envelope
Train-to-NZEB
Shouldn't a building be able to "breathe" ?
Capacitaty of a material to absorb and release moisture or to allow the humidity transfer
Accumulation of humidity can be a problem
One has to ensure that the selected materials are fit to purpose
Absorb and release water
Transfer of heat
Loss of heat
Unable to release water
Water Vapour
Interstitial Condensation
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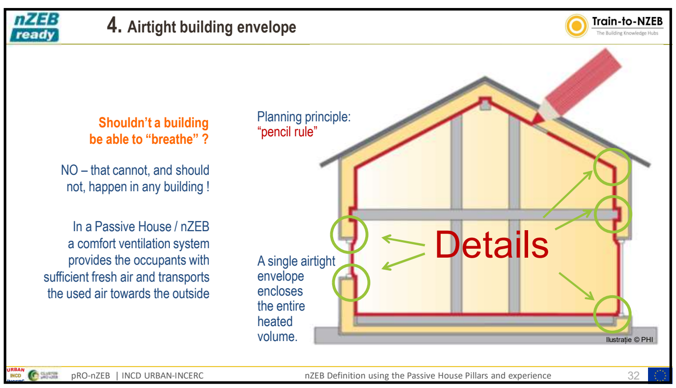
nZEB ready
4. Airtight building envelope
Train-to-NZEB
Shouldn't a building be able to "breathe" ?
NO – that cannot, and should not, happen in any building !
In a Passive House / nZEB a comfort ventilation system provides the occupants with sufficient fresh air and transports the used air towards the outside
Planning principle: "pencil rule"
Details
A single airtight envelope encloses the entire heated volume.
Ilustraţie © PHI
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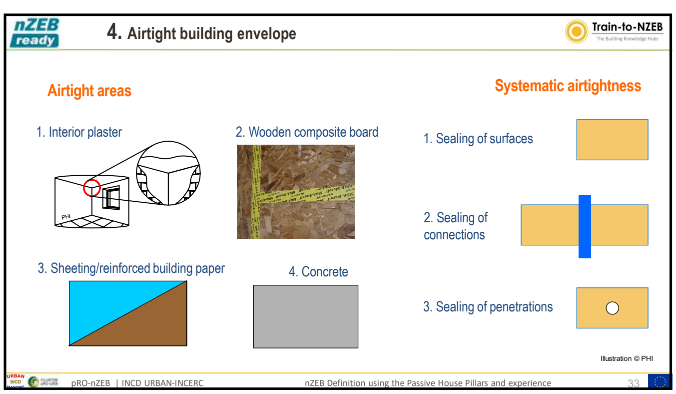
nZEB ready
4. Airtight building envelope
Train-to-NZEB
Airtight areas
1. Interior plaster
2. Wooden composite board
3. Sheeting/reinforced building paper
4. Concrete
Systematic airtightness
1. Sealing of surfaces
2. Sealing of connections
3. Sealing of penetrations
Illustration © PHI
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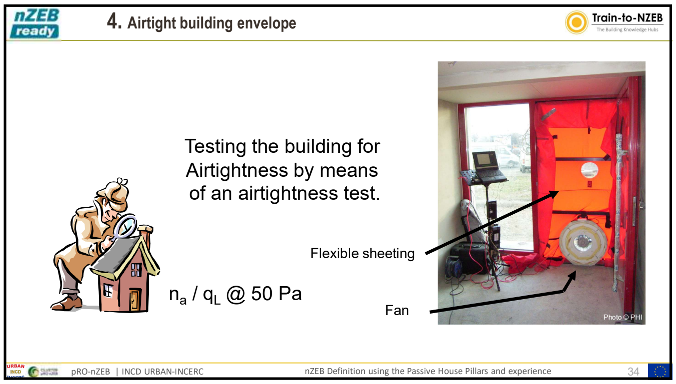
nZEB ready
4. Airtight building envelope
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Testing the building for Airtightness by means of an airtightness test.
Flexible sheeting
n_a / q_L @ 50 Pa
Fan
Photo © PHI
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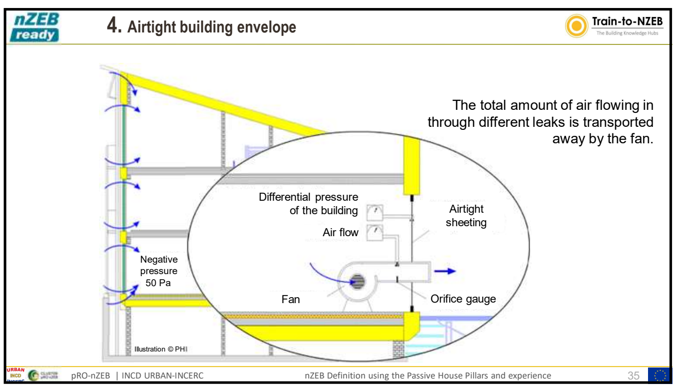
nZEB ready
4. Airtight building envelope
Train-to-NZEB
The total amount of air flowing in through different leaks is transported away by the fan.
Differential pressure of the building
Air flow
Airtight sheeting
Negative pressure 50 Pa
Fan
Orifice gauge
Illustration © PHI
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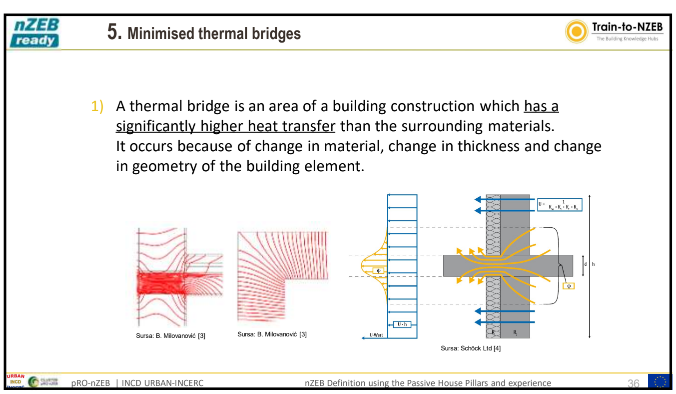
nZEB ready
5. Minimised thermal bridges
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1) A thermal bridge is an area of a building construction which has a significantly higher heat transfer than the surrounding materials.
It occurs because of change in material, change in thickness and change in geometry of the building element.
Sursa: B. Milovanović [3]
Sursa: B. Milovanović [3]
Sursa: Schöck Ltd [4]
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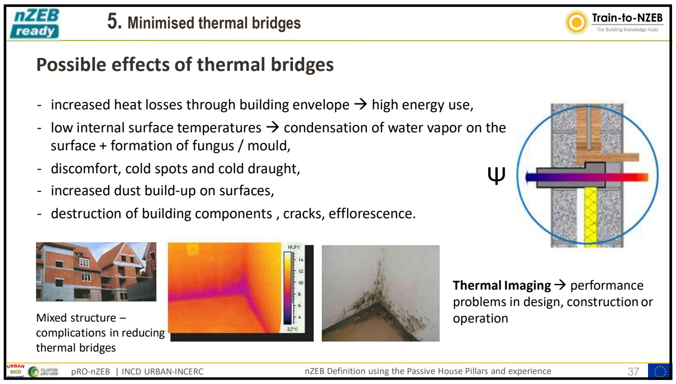
5. Minimised thermal bridges
Train-to-NZEB
Possible effects of thermal bridges
- increased heat losses through building envelope → high energy use,
- low internal surface temperatures → condensation of water vapor on the surface + formation of fungus / mould,
- discomfort, cold spots and cold draught,
- increased dust build-up on surfaces,
- destruction of building components , cracks, efflorescence.
Ψ
Mixed structure – complications in reducing thermal bridges
Thermal Imaging → performance problems in design, construction or operation
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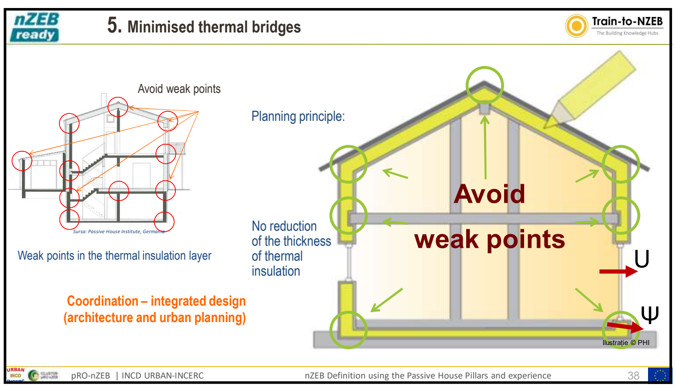
5. Minimised thermal bridges
Train-to-NZEB
Avoid weak points
Weak points in the thermal insulation layer
Planning principle:
No reduction of the thickness of the thermal insulation
Coordination – integrated design (architecture and urban planning)
Avoid
weak points
U
Ψ
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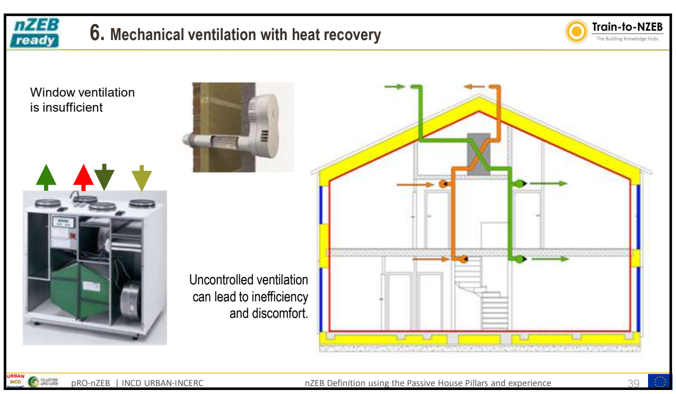
6. Mechanical ventilation with heat recovery
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Window ventilation is insufficient
Uncontrolled ventilation can lead to inefficiency and discomfort.
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6. Mechanical ventilation with heat recovery

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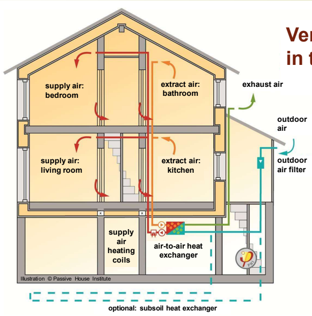


Ventilation principle in the Passive House

- Hygienically clean indoor air
- Air is replaced even during absence
- No odours from the kitchen or WC
- Filtered air for allergy sufferers
- No moisture/mould

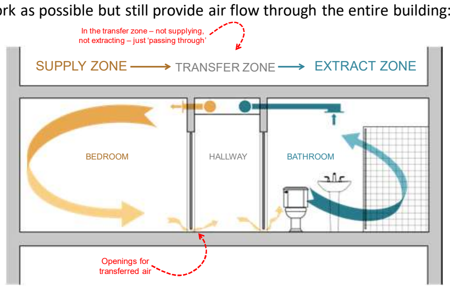
6. Mechanical ventilation with heat recovery

Train-to-NZEB

The distribution of ventilation (fresh air supply and stale air extraction) should use as little ductwork as possible but still provide air flow through the entire building:

Three Ventilation 'Zones'

Cross-ventilation principle



Adapted from original prepared by Passive House Institute

6. Mechanical ventilation with heat recovery

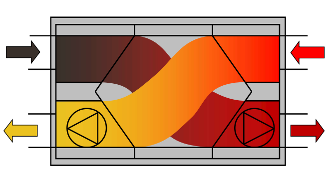
Train-to-NZEB

Air flow temperatures in a typical MVHR winter scenario:

Good quality MVHR's recovery up to 90% of heat from the extract air stream

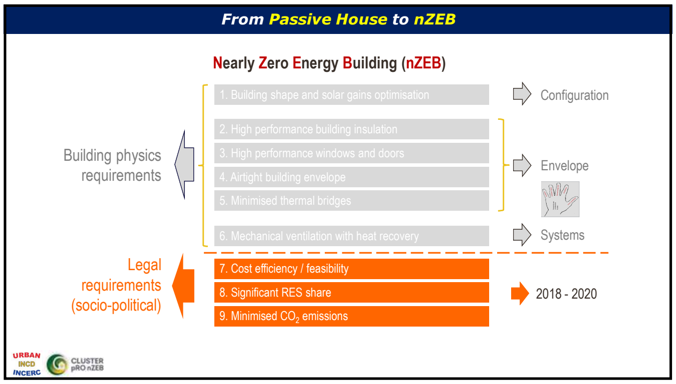
Outdoor air duct: < 0˚C

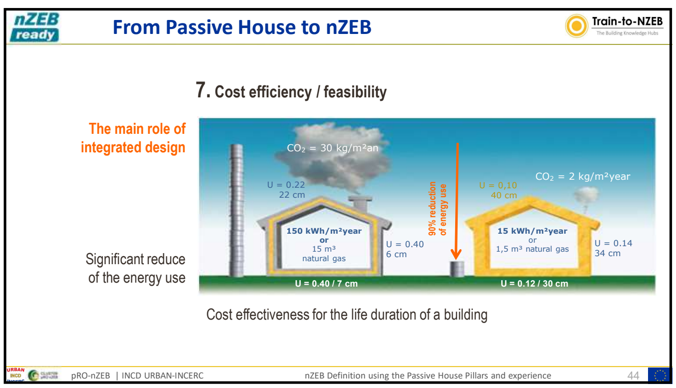
Extract air duct: ~ 20˚C

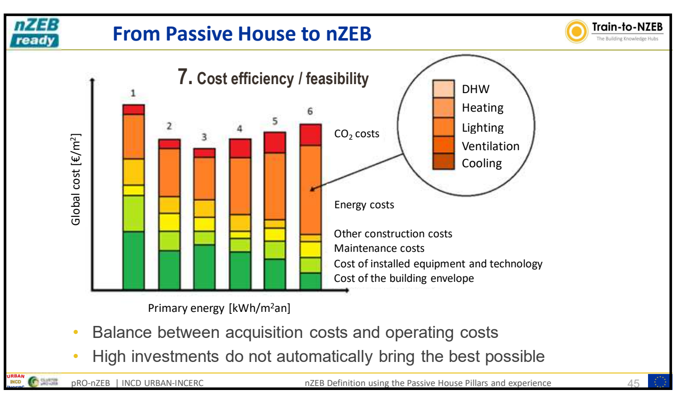


Exhaust air duct: ~ 3-5˚C

Supply air duct : > 17˚C


From Passive House to nZEB
Nearly Zero Energy Building (nZEB)
1. Building shape and solar gains optimisation
2. High performance building insulation
3. High performance windows and doors
4. Airtight building envelope
5. Minimised thermal bridges
6. Mechanical ventilation with heat recovery
7. Cost efficiency / feasibility
8. Significant RES share
9. Minimised CO2 emissions
Building physics requirements
Legal requirements (socio-political)
Configuration
Envelope
Systems
2018 - 2020
URBAN INCD INCERC
CLUSTER pRO nZEB


nZEB ready
From Passive House to nZEB
Train-to-NZEB
7. Cost efficiency / feasibility
The main role of integrated design
Significant reduce of the energy use
CO2 = 30 kg/m²an
U = 0.22
22 cm
150 kWh/m²year
or
15 m³
natural gas
U = 0.40
6 cm
U = 0.40 / 7 cm
99% reduction of energy use
U = 0.10
40 cm
CO2 = 2 kg/m²year
15 kWh/m²year
or
1,5 m³ natural gas
U = 0.14
34 cm
U = 0.12 / 30 cm
Cost effectiveness for the life duration of a building
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
44


nZEB ready
From Passive House to nZEB
Train-to-NZEB
7. Cost efficiency / feasibility
Global cost [€/m²]
1
2
3
4
5
6
CO2 costs
DHW
Heating
Lighting
Ventilation
Cooling
Energy costs
Other construction costs
Maintenance costs
Cost of installed equipment and technology
Cost of the building envelope
Primary energy [kWh/m²an]
Balance between acquisition costs and operating costs
High investments do not automatically bring the best possible
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
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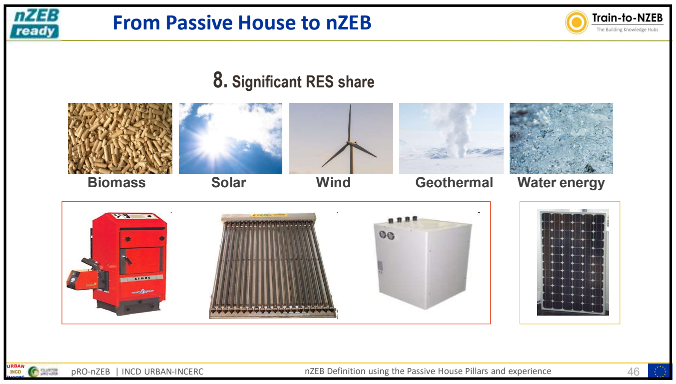
nZEB ready
From Passive House to nZEB
Train-to-NZEB
8. Significant RES share
Biomass
Solar
Wind
Geothermal
Water energy
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
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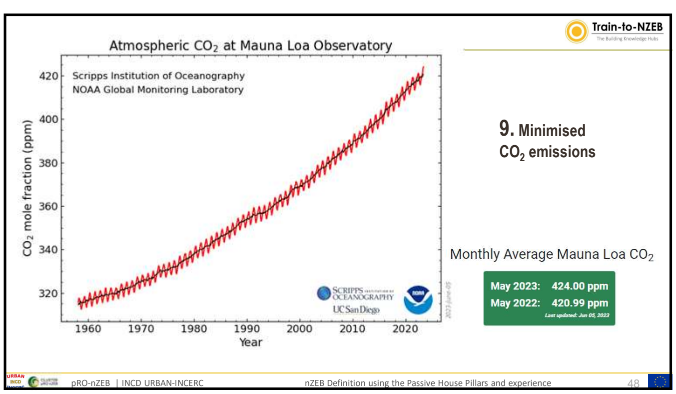
nZEB ready
From Passive House to nZEB
Train-to-NZEB
Integrated design
Coordination –
architecture and technology
8. Significant RES share
Administrative building – Sofia (source Eneffect)
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
47


Atmospheric CO2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
CO2 mole fraction (ppm)
Year
Train-to-NZEB
9. Minimised
CO2 emissions
Monthly Average Mauna Loa CO2
May 2023: 424.00 ppm
May 2022: 420.99 ppm
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
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From Passive House to nZEB

9. Minimised CO_2 emissions

Integrated design

- Solar buildings (the '80s)
- 3-liter fuel building (the '90s)
- Low carbon footprint buildings (UK)
- „Green buildings" – minimum impact on the environment

Romania: nZEB – minimum ~~10%~~ 30% of energy demand is supplied from RES (onsite or nearby)

EU: Transition towards ZEB (Zero Emission Building – in use)

From Passive House to nZEB

Nearly Zero Energy Building (nZEB)

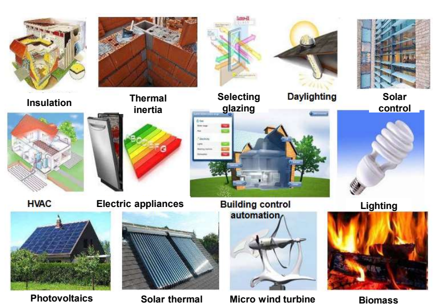
Building physics requirements:

1. Building shape and solar gains optimisation → Configuration
2. High performance building insulation
3. High performance windows and doors
4. Airtight building envelope
5. Minimised thermal bridges → Envelope
6. Mechanical ventilation with heat recovery → Systems

Legal requirements (socio-political):

7. Cost efficiency / feasibility
8. Significant RES share
9. Minimised CO_2 emissions → 2018 - 2020

Technologies for nZEB's

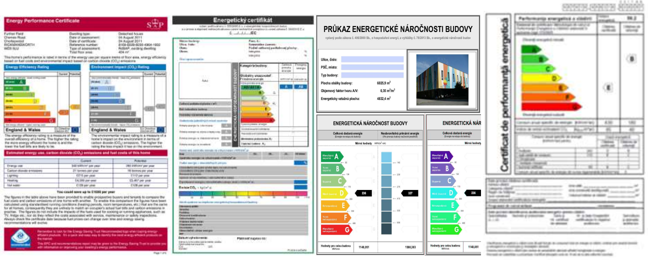


Source: A. Zichi, Politecnico Milano, MCE 2018

Energy performance certificate – display nZEB?

Train-to-NZEB
The Building Knowledge Hubs

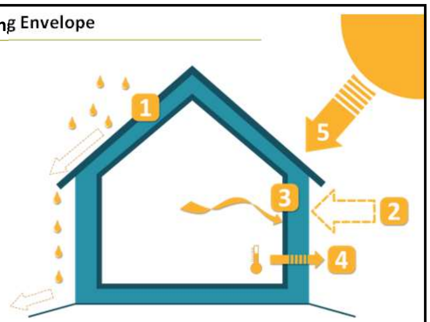
- Primary energy < x kWh/m²/yr
- CO_2 Emissions < z kg/m²/yr
- Renewables Share > y % PE



Criteria for building envelope to reach the nZEB standard

Goals of the Building Envelope

Functions of the thermal envelope:
1: Bulk-water run-off
2. Wind tight protection
3. Insulation & airtightness layer
4. Vapour control layer
5. Prevent overheating

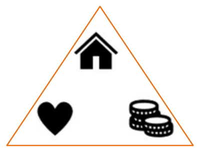


Role of building envelope?

Train-to-NZEB

Ensures **a healthy and pleasant environment** for the **occupants**.

- → Indoor air quality
- → Thermal comfort
- → Sound protection
- → Visual comfort

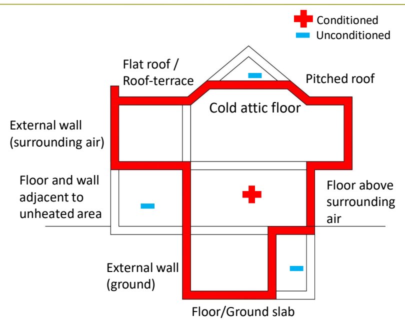


Building envelope

Train-to-NZEB

What is building envelope?

1) **Skin of the building.**
→ Physical barrier between the conditioned interior and exterior of a building.
2) It consists of different building components.
→ opaque elements (floor, wall, roof)
→ transparent elements (window, door)



Thermal envelope

Train-to-NZEB

Requirements for thermal envelope

1) Quality of construction: good workmanship → damage free
2) Fire safety
3) Thermal bridges minimized
4) Airtightness ensured
5) Moisture-safe: Control of water vapour diffusion (diffusion-impermeable and diffusion-permeable solutions) & Bulk-water run-off

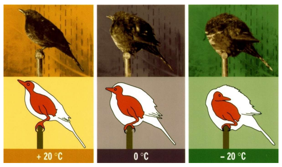
WIDE RANGE OF THERMAL INSULATION MATERIALS AND SYTEMS AVAILABLE ON THE MARKET!

The proper selection and application depends from case to case (exterior or interior insulation, fire safety requirements, water presence etc.)!

Building envelope

Train-to-NZEB

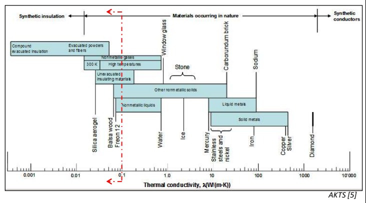
Learning from nature – good insulation decreases heat loss



At low emperatures blackbirds increase their "feather envelope " and withdraw deep into this "insulation".

CEPH Project [4]

What makes material a good thermal insulator?



AKTS [5]

Thermal insulation materials: **λ ≤ 0.10 [W/(mK)]**

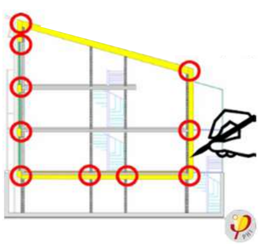
(According to the definiton in DIN 4108)

Thermal envelope

Train-to-NZEB

Golden rule: „The Pencil Rule"

CONTINUITY – unbroken thermal envelope

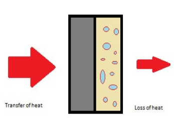


In principle it should be possible to draw the insulation layer and the air tight membrane without „raising" the pencil.

CEPH Project

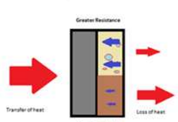
Thermal Properties of Materials

Thermal Conductivity Lambda (λ) W/mK



Is the indication of its ability to conduct heat.

Thermal Resistance R-Value (R) m²K/W



A measure of a material's ability to resist heat transfer.

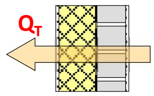
$R = d/\lambda$, $U = 1/R$

Where **d** is the thickness of the material and **λ** is the thermal conductivity

Thermal envelope

Train-to-NZEB

Quantification of heat loss through thermal envelope →**TRANSMISSION LOSSES**



SEEDpass project [9]

$$Q_T = A * U * b_T * G_t$$

A = Area of thermal envelope
U = U-value
b_T = Temperature-correction factor
G_t = Heating degree hours

$$H_T = \Sigma b_j A_j U_j + \Sigma b_j \Psi_j l_j + \Sigma b_j X_j$$

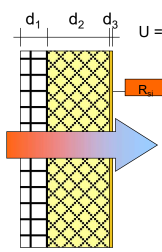
Areas of thermal envelope | Linear thermal bridges | Point thermal bridges

- Opaque Elements → **Walls, Roof, Slab**
- Transparent Elements → **Windows**

Thermal envelope

Train-to-NZEB

U-value of homogenous building components (calculation according to EN ISO 6946)



$$U = \frac{1}{R_T} = \frac{1}{R_{si} + d_1/\lambda_1 + d_2/\lambda_2 + d_3/\lambda_3 + R_{se}}$$

R_{si} – concrete – insulation – plaster – R_{se}

(Thermal conductivity λ according to DIN 4108-4, EN 12524 or technical approval certificate)

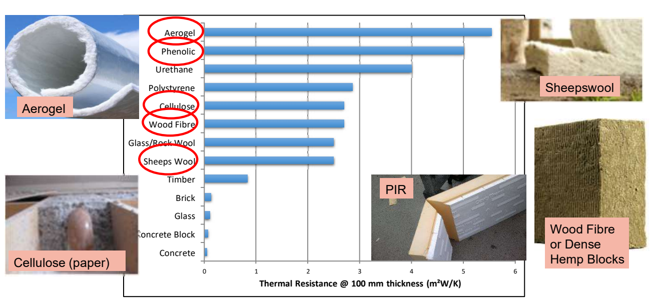
Heat transfer resistance [m²K/W] EN ISO 6946

	Direction of heat flow		
	upward ≤ 30°	horizontal	downward
R_{si}	0.10	0.13	0.17
R_{se}	0.04	0.04	0.04
PHPP: ground contact building elements			R_{se} = 0
PHPP: strongly ventilated air layers			R_{se} = R_{si}

Source: © PHI

Good insulating properties

Train-to-NZEB



Thermal insulation

Different insulation materials are possible

Natural | Artificial

Source: CPHT Course

Thermal insulation

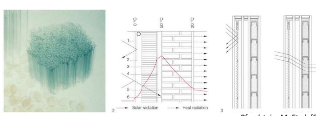
High-tech thermal insulation materials

Berkeley Lab [7]

Aerogel („frozen smoke"): $\lambda < 0.024$ [W/(mK)]

Phase Change Materials, PCM: thermal energy storage

Vacuum Insulated Panel, VIP: $\lambda = 0.00576$ [W/(mK)]



Pfundstein, M. Et al. [8]

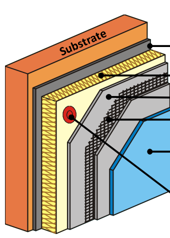
Transparent thermal insulation, TWD: use of solar energy for heating in conjunction with an opaque external wall

External thermal insulation – External walls

ETICS systems (External Thermal Insulation Composite System)

One of most commonly used systems for thermal enhacement of walls.

Thermal insulation material	Advantages	Disadvantages
Stone wool	•Vapour permeable •Good reaction to fire •Good sound insulation	•15-30% more expensive •More demanding for installation •Risk of damping
EPS-polystyrene	•Lower material price •Easier for installation •Greater choice of finishing layers	•Less vapour permeable •Weaker sound insulation •Weaker reaction to fire



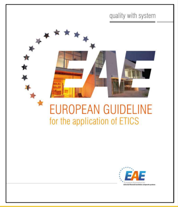
IMPORTANT:
1. Adhesive
2. Reinforcement
3. Finishing layer have to be from the same producer

External thermal insulation – External walls

Train-to-NZEB

ETICS systems (External Thermal Insulation Composite System)

- The **quality and durability of ETICS** depends on the **careful choice of system components**.
- This composition is done by system holders. They take care that **components perfectly fit together**.
- Each system placed on and sold to the market by the system holder is intensely **tested** regarding its **essential characteristics**. Regarding to the CPR, all suppliers (system suppliers and/or dealers) are obliged to supply complete ETICS.
- ETICS require a European Technical Approval (ETA).



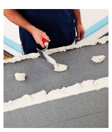
External thermal insulation – External walls

Train-to-NZEB

Phases of ETICS installation

1. **Pre-treatment of the substrate + preparation works**

2. **Bonding**



3. **Anchoring**

4. **Reinforcement**

5. **Finishing coat with primer and paint coating**

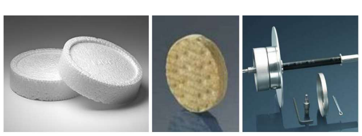
Each phase has its own specifics and it should be conducted respecting the professional guidelines!

HUPFAS [32]

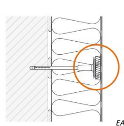
External thermal insulation – External walls

Train-to-NZEB

Anchor head countersunk into the insulation material



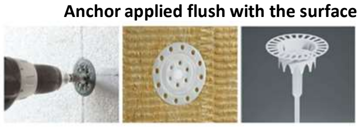
HUPFAS [32]

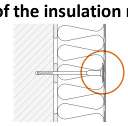


EAE [29]

MINIMIZED POINT THERMAL BRIDGES!

Anchor applied flush with the surface of the insulation material

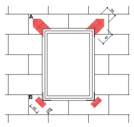




External thermal insulation – External walls

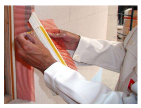
Train-to-NZEB

Diagonal reinforcements

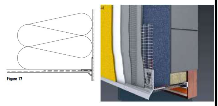


HUPFAS [32]

Formation of edges, outer and inner corners



Formation of drip edges



EAE [29] Asb.sk [35]

Dilatations

Meister Farben [36]

External thermal insulation – External walls

Train-to-NZEB

Selection of finishing coat/plaster

PRICE →

PLASTER:	Mineral	Silicate	Acrylic	Silicone
Water repellent	o	+	++	++
Vapour permeable	++	+	-	+
Dirt resistant	o	+	++	++
Elastic	-	o	++	+
Colour range	o	+	++	+

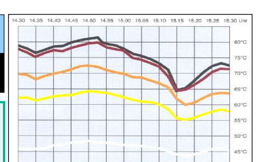
LEGEND: ++ very good + good o conditional good - poor

External thermal insulation – External walls

Train-to-NZEB

Colour of finishing coat/plaster

33°C	40°C	47°C
47°C	54°C	64°C



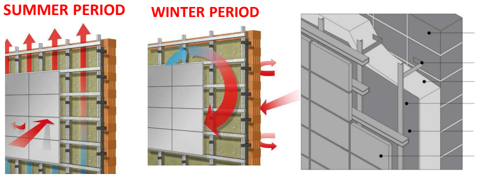
Dark colours are not recommended!!!
- Acrylic and silicone plasters: HBW,VOSS ≥ 25%
- Silicate plasters: HBW,VOSS ≥ 30%
- Mineral plasters:
  Thin plasters (1,5 do 4,0 mm): HBW,VOSS ≥ 50%

External thermal insulation – External walls

Ventilated facades

Building envelope system with layer of air ventilating between thermal insulation and external cladding.

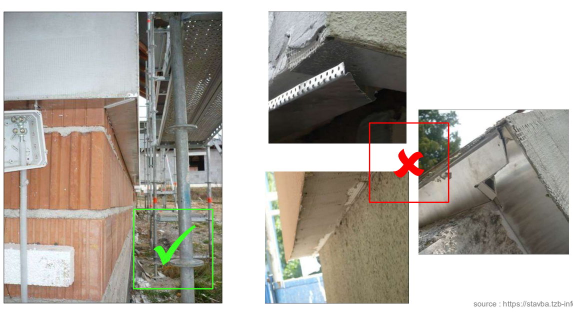
SUMMER PERIOD **WINTER PERIOD**



- Passive cooling of building

- Heat retention
- Drying out

ETICS – base bar

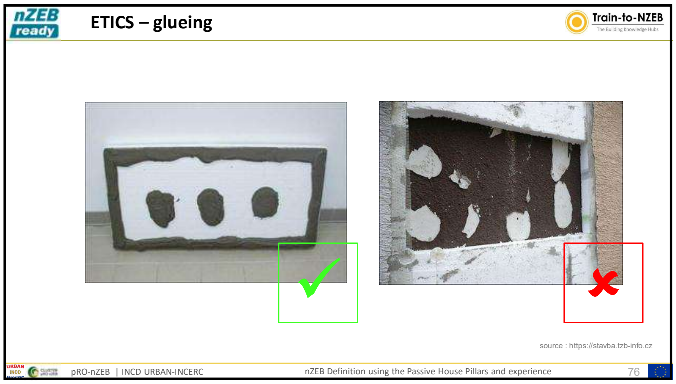


source : https://stavba.tzb-info.cz

External thermal insulation – External walls

Poor-practice examples ...

Škomrlj, D.


nZEB ready
ETICS – glueing
Train-to-NZEB
source : https://stavba.tzb-info.cz
pRO-nZEB | INCD URBAN-INCERC
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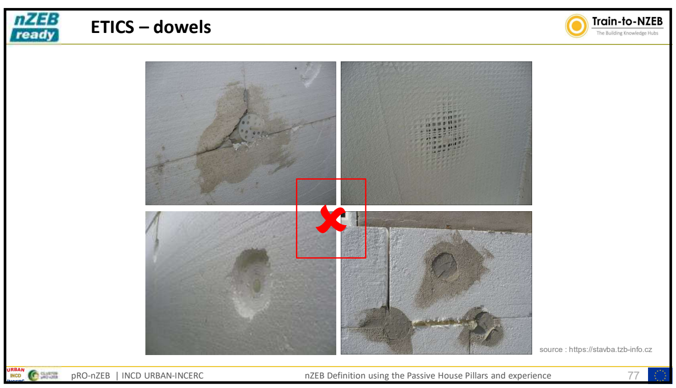
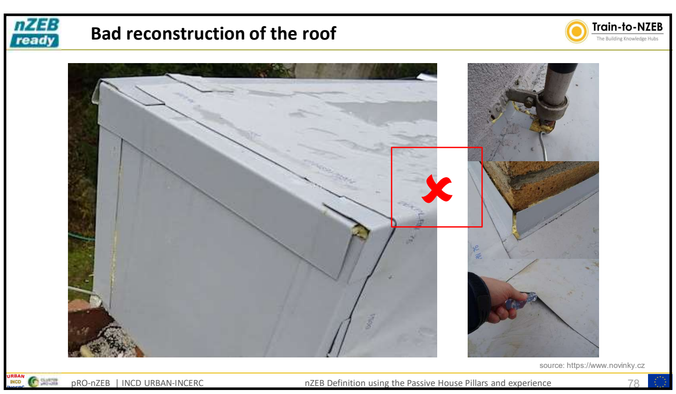

nZEB ready
ETICS – dowels
Train-to-NZEB
source : https://stavba.tzb-info.cz
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
77


nZEB ready
Bad reconstruction of the roof
Train-to-NZEB
source: https://www.novinky.cz
pRO-nZEB | INCD URBAN-INCERC
nZEB Definition using the Passive House Pillars and experience
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Thermal envelope

Train-to-NZEB

For good thermal behavior low λ is not sufficient

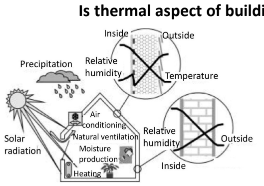
Material	Specific heat capacity c [J/(kg*K)]	Density [kg/m³]	c [J/(m³*K)]
Aluminium	880	2800	2.5×10^6
Steel	450	7800	3.5×10^6
Concrete	1000	2500	2.5×10^6
Brick (full)	900	1800	1.6×10^6
EPS	1200	30	3.6×10^4
Water	4182	1000	4.2×10^6
Ice at -10°C	900	2000	1.8×10^6

High density and high specific heat capacity of materials → offers great possibility for **heat storage** → **reduction of energy consumption in buildings**

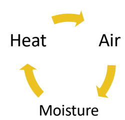
Thermal envelope

Train-to-NZEB

Is thermal aspect of building envelope sufficient?



Holm, A. et al. [12]



HYGROTHERMAL PERFORMANCE OF BUILDING ENVELOPE!

KEY GOAL: ensure **OPTIMAL** hygrothermal performance

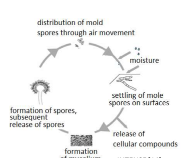
- Prevent or reduce moisture entry into construction and ensure sufficient drying capacity → **moisture-safe and damage-free design**.
- Ensure **designed thermal performance** (U-value) of building components and **thermal comfort** in buildings.
- **Healthy indoor environment**.

Thermal envelope

Train-to-NZEB

What if building envelope solution is not moisture safe?

dspInspections [13]



INTENSE [14]

1) Mould growth is directly linked with indoor air humidity and surface temperature. The lower the surface temperature of the wall, the moister the surface of the building component.
2) Mould spores are natural allergens. After repeated contact they can trigger allergies in susceptible people

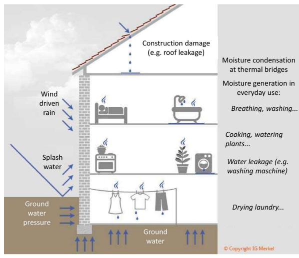
Thermal envelope

Train-to-NZEB

How to avoid mould growth?

1) **Increase wall temperature**
2) **Promote low-moisture conditions**
3) **Prevent moisture sources**
4) **Reduce building moisture**
5) **Ensure airtightness of building envelope**
6) **Proper ventilation control!**
7) **Miscellaneous**

INTENSE [14]



Merkel [16]

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Benefits of Vapour Control

Train-to-NZEB

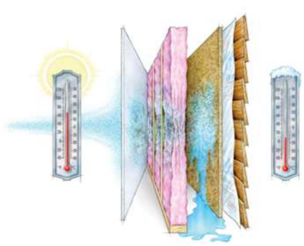

Image: Green Building Advisor

- Prevent vapour-laden air escaping into the exterior envelope
- Create vapour-open exterior face to allow envelope to 'breathe' to the outside
- Reduce risk of condensation and mould in the envelope
- Protect structural integrity
- Reduce risk of adverse health effects from mould

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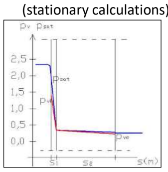
Assessment of hygrothermal performance

Train-to-NZEB

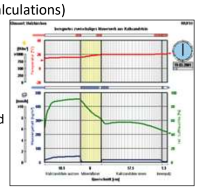
How to assess overall hygrothermal performance of building components?

1. Traditional methods – Glaser method (stationary calculations)



Widely used method in everyday engineering practice!

2. Dynamic methods – HAM (Heat, Air and Moisture) models (transient calculations)



WUFI [25]

Especially it is important to assess hygrothermal performance of:

- New materials and systems being developed
- Building envelopes going through deep energy renovation
  - change of existing dynamic hygrothermal equilibrium
- Designing new high-performing building envelopes

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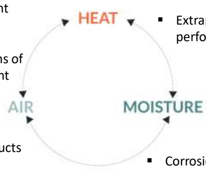
Assessment of hygrothermal performance

Possibilites of hygrothermal simulations

- Transfer to different climatic zones
- Different conditions of indoor environment
- Development and optimization of construction products
- Mold growth assessment
- Extrapolation (long-term performance)
- Corrosion risk assessment
- Freeze/twah risks assessment



Different HAM tools

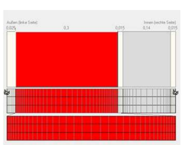
WUFI
MATCH
MOIST
1-D HAM
DELPHIN
HygIRC 1-D
TCCD2
LATENITE
...

EVERY TOOL HAS ITS OWN LIMITATIONS!
USER HAS TO BE AWARE OF THOSE LIMITATIONS!

Assessment of hygrothermal performance

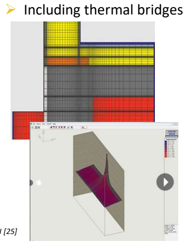
Possibilites of hygrothermal simulations

1-D simulations



2-D simulations

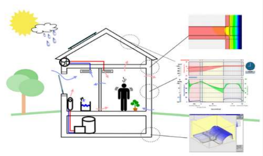
- Including thermal bridges



WUFI [25]

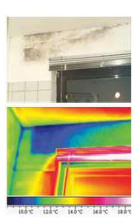
3-D simulations

- Whole building simulation
- Including thermal bridges
- Energy consumption calculations



Consequences of thermal bridges

1) increased heat losses through building envelope during winter,
2) condensation of water vapor on the surface
3) formation of fungus / mold
4) destruction of building components due to corrosion
5) increased dust buildup on the wet surfaces
6) cracks caused by different thermal expansion of materials
7) destruction of building components due to freezing
8) segregation of plaster and wallpaper
9) increase in thermal conductivity of insulating materials
10) efflorescence on material surfaces (stone, concrete...)



Source: B. Milovanović [3]

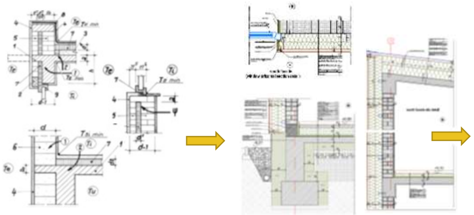
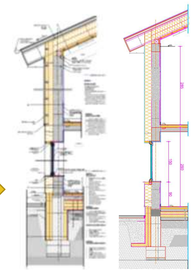
- Grater degree of heat insulation of the building means greater condensation risk around the area of the thermal bridge.

nZEB ready

Structure details adaptation – good practice → nZEB

Train-to-NZEB

Details for improved constructive solutions
Analysis of current practice in constructions and definition of best practices → fit for use in nZEB / PH

1997 2010 2020

nZEB ready

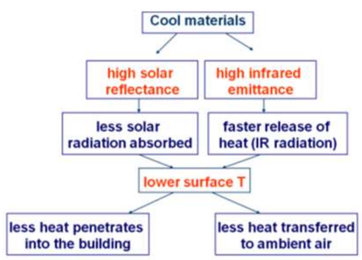
Cold materials / surfaces (ex. cold roofs)

Train-to-NZEB

- **Construction materials**
  - high solar absorptance
  - facilitate high solar gains
- **Cold materials**
  - high solar reflection
  - reduce solar gains
  - high emissivity
  - the building radiate accumulated heat towards external environment

⬇

– Efficient on roofs (horizontal and pitched surfaces)



nZEB ready

Green roofs

Train-to-NZEB

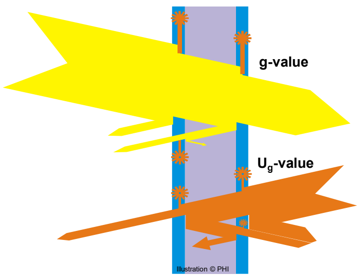
- Influencing building aesthetics
- Improving air quality in urban areas
- Alleviate urban heat island
- Improving building insulation
- Improving building solar control

California Academy of Science
http://rpbw.r.ui-pro.com/

Green roof performances are strongly influenced by materials used, building characteristics, building use and climatic conditions.

Windows

Glazing: U_g- and g-Values



- The total energy trans-mission (**g-value or SHGC**) of glazing describes the sum of the energy transmitted from direct solar radiation and from secondary heat emission from the outside towards the inside.
- The **U_g-value** is an indicator of the transmission heat losses of a glazing.

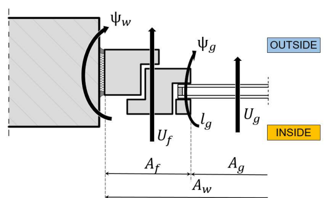
An optimal energy balance for windows is a **basic requirement** for nZEBs

Source: CPHD

Thermal performance of a window - the losses

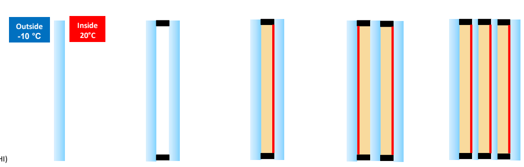
Window thermal transmittance

$$U_W = \frac{A_g U_g + A_f U_f + l_g \Psi_g}{A_g + A_f}$$



6-7 4-5

Inner surface temperature



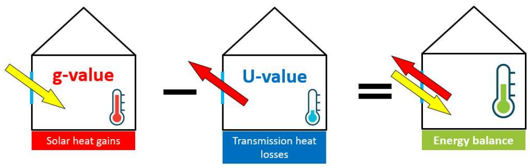
Source:
SEEDPass project, W. Hasper (PHI)

Glazing	Single pane	Double pane with air	Insulating glass units with low-e coating (pos 3) and Argon	Tripple insulating glass units with low-e coating (pos 2 & 5) and Argon	Quadrouple insulating glass units with low-e coating (pos 3, 5 & 7) and Argon
Glass U-value U_g [W/m²K]	5.8	2.7	1.1 – 1.3	0.53 – 0.75	0.36 – 0.44
Inner surface temperature (At -10 °C ambient & 20°C room)	-2.6 °C	9.5 °C	14.9 – 15.7 °C	17.1 – 17.9 °C	18.3 – 18.6 °C
Total transmittance g-value	0.87	0.78	0.62 – 0.71	0.49 – 0.60	0.43 – 0.57

3. High performance windows and doors

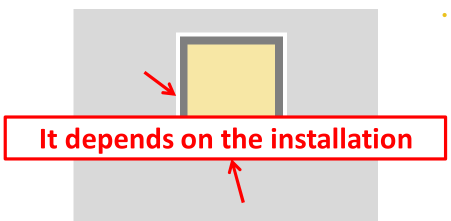
Balancing heat losses and heat gains through windows

The U- and g-values are the most dominant factors affecting the annual energy performance.



An optimal energy balance for windows is therefore a basic requirement for nZEBs

Window is a part of building's thermal envelope



- The installation must address several key issues, it shall be :
  - structurally sound,
  - watertight,
  - airtight,
  - vapor smart and
  - increase the installed thermal performance of the window.

Wall – complies to the design and/or regulatory requirements
Window – complies to the design and/or regulatory requirements
What about a Wall with the window ????

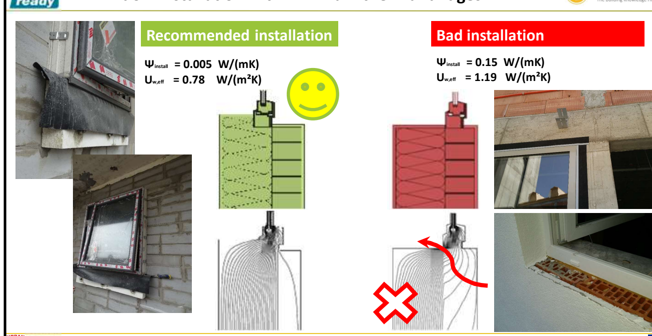
Window installation with minimum thermal bridges

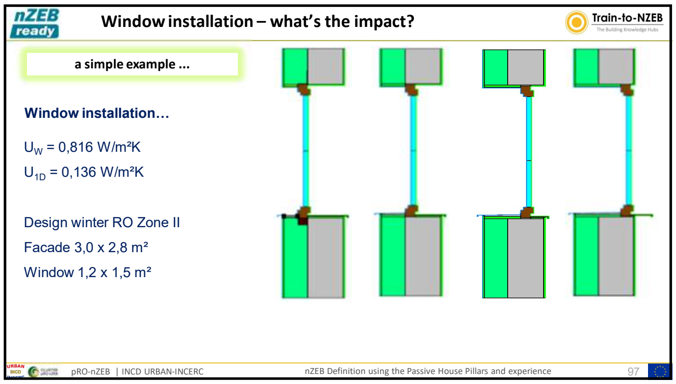
Recommended installation

$\Psi_{install}$ = 0.005 W/(mK)
$U_{w,eff}$ = 0.78 W/(m²K)

Bad installation

$\Psi_{install}$ = 0.15 W/(mK)
$U_{w,eff}$ = 1.19 W/(m²K)




Window installation – what's the impact?
Train-to-NZEB
a simple example ...
Window installation…
U_W = 0,816 W/m²K
U_{1D} = 0,136 W/m²K
Design winter RO Zone II
Facade 3,0 x 2,8 m²
Window 1,2 x 1,5 m²
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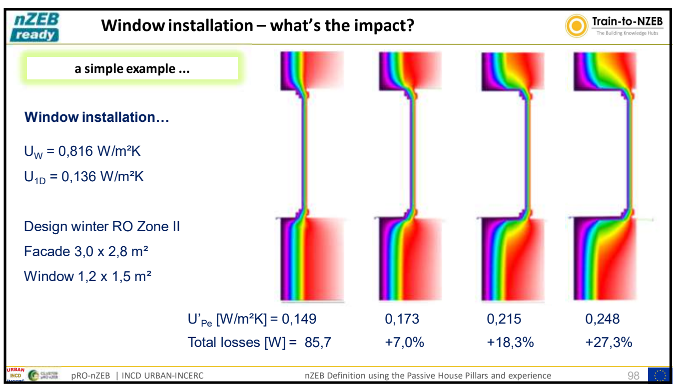
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Train-to-NZEB
a simple example ...
Window installation…
U_W = 0,816 W/m²K
U_{1D} = 0,136 W/m²K
Design winter RO Zone II
Facade 3,0 x 2,8 m²
Window 1,2 x 1,5 m²
U'_{Pe} [W/m²K] = 0,149 0,173 0,215 0,248
Total losses [W] = 85,7 +7,0% +18,3% +27,3%
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Airtight window installation
Train-to-NZEB
• Different technologies available
Source: SEEDPass project, S. Pallantzas
Source: B. Milovanovic
Source: SEEDPass project, S. Pallantzas
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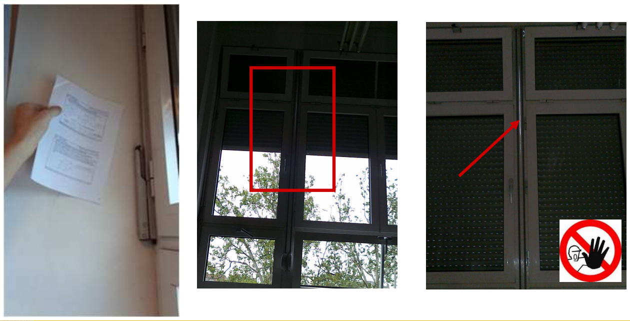
Poor window installation examples



Poor window installation examples

Build Tight – Ventilate Right!

It is essential to provide high indoor air quality as part of any dep retrofit project.

Where good levels of airtightness are being delivered (3.0 air changes per hour @ 50 Pascal or less), it is important to provide some kind of mechanical ventilation (ideally with heat recovery)

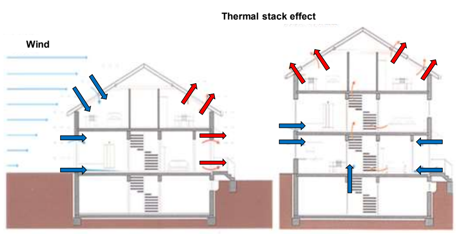
Benefits of Airtightness

- Eliminate drafts
- Improve comfort
- Reduce heat losses
- Reduce heating bills
- Improved sound proofing
- Increase efficiency of ventilation system

Airtightness

Pressure difference

Infiltration and exfiltration via leakages in the building fabric

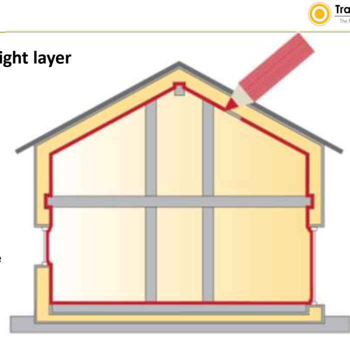


Source: ebök Tübingen

Airtightness

<u>Design</u> a UNIQUE airtight layer

An uninterrupted airtight layer encloses the thermal envelope



Source: Passive House Institute

Airtightness

Why build airtight?

Avoids structural damage (condensate within the fabric build-up)

Enhances living comfort: no droughts or cold air accumulation (ground floor)

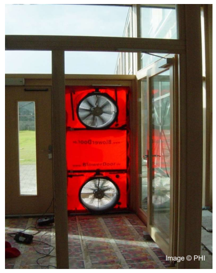
Avoids pollutants (e.g. Radon) entering the room air

Air quality: directed air circulation becomes possible, precondition for controllable demand-oriented ventilation

Energy conservation through reduced ex- and infiltration (ventilation losses)

Enhances noise protection

BLOWER DOOR
Differential pressure method according to EN ISO 9972
Max n_{50} = 0,6/h

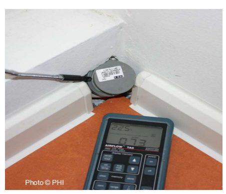


Source: CPHD

3. Airtightness

Tracing Leakages

At 50 Pa underpressure, inspection of entire building (tracing is easiest at underpressure) leakage search per room

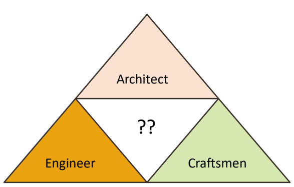


Inspection of typical weak spots:
Doors, windows, corners/joints, outlets, penetrations of airtight layer (pipes, cables) joints between different materials or build-ups

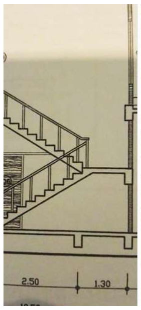
Source: CPHD

Quality control

QUALITY CONTROL – Why and who?



How it should not be done …




Quality control

QUALITY CONTROL

1) Every material and construction product has its own, specific properties.
2) Materials and products incorporated into building envelope must be compatible.
3) Every material and product should be used only for purpose prescribed by producer.
4) Not respecting abovementioned rules can result with construction damage


HUPFAS [32]

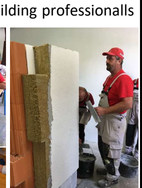

Energie-experten.org [50]


Quality control

Integrated planning

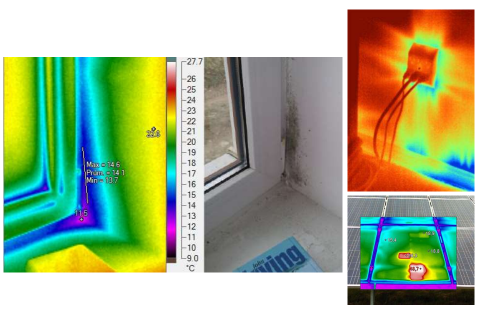
Cross-crafting

- ✓ knowledgeable,
- ✓ skilled and
- ✓ responsible building professionalls


Thermography – infrared inspection

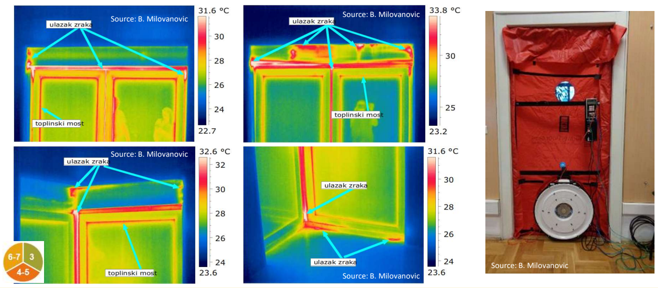
Thermography



Thermography

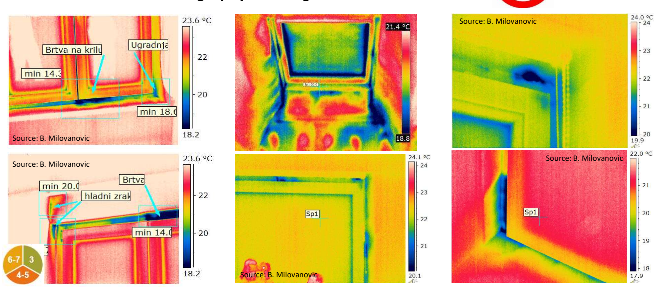
Quality control

Infrared thermography – during blower door test

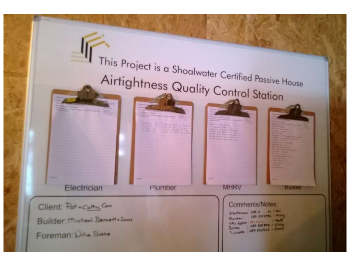


Quality control

Infrared thermography – during blower door test



Communicate Importance of Airtightness



Innovative approach by Irish contractor where all penetrations by different trades are recorded on clipboards to be sealed by project airtightness champion

St. Bricin's Park: We Did It! EnerPHit Standard Reached

Initiatives and actions to enhance market readiness for nZEB implementation

nZEB & DER challenges

Main barriers:

- Comparably high investment costs → high payback periods
- Mobilising the correct **level of investments**,
- **Optimal integration of the technologies** suitable for nZEB / DER
- Quality compliance and skills gaps
- Lack of **business models** – reliable and economically viable for companies

New business models – to shape future construction market in EU:

- Different stakeholder perspectives
- Clustering / partnerships – reasonable to create win-win situations

- ☺ Planner
- ☺ Real estate/ urban developer
- ☺ Construction companies
- ☺ General contractor
- ☺ Facility manager
- ☺ Building operators
- ☺ Public administration
- ☺ Financing institutions
- ☺ EE&RES suppliers

Cost efficiency / feasibility – global cost

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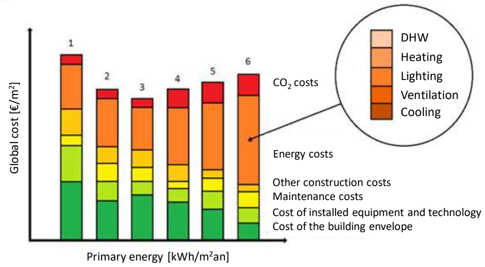


- Balance between acquisition costs and operating costs
- High investments do not automatically bring the best possible

Qualification of the building workforce

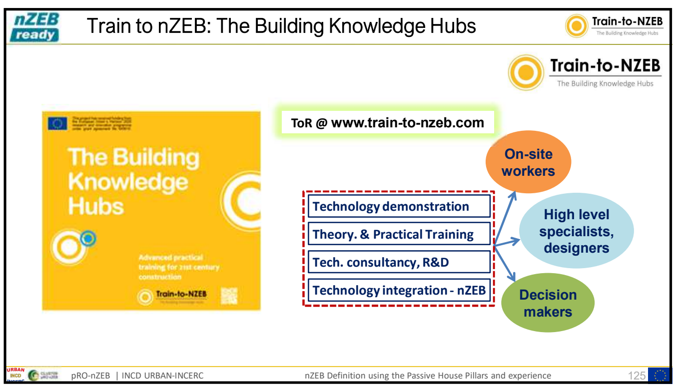
Train-to-NZEB

QUALICHeCK - Boundary conditions for:
a better compliance (reliable EPC/documentation)
a higher quality of energy related building works

→ Tender specification – building:
- Set performance levels (→ nZEB),
- Provide performance verification,
- Specify quality / qualification requirements.

✓ Specifications (annexes to contract) to set up specific requirements for design / construction to:
- Promote nZEB performances *and*
- Guarantee the achievement of nZEB levels.


Train-to-NZEB
The Building Knowledge Hubs
pRO-nZEB | INC


nZEB ready
Train to nZEB: The Building Knowledge Hubs
Train-to-NZEB
The Building Knowledge Hubs
The Building Knowledge Hubs
ToR @ www.train-to-nzeb.com
Technology demonstration
Theory. & Practical Training
Tech. consultancy, R&D
Technology integration - nZEB
On-site workers
High level specialists, designers
Decision makers
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nZEB ready
The Building Knowledge Hub Romania
Train-to-NZEB
Practical training facility
Courses for nZEB / Passive House Tradespersons and Designers/consultants
→ Secure transition to nZEB
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Certified Passive House Professionals → nZEB

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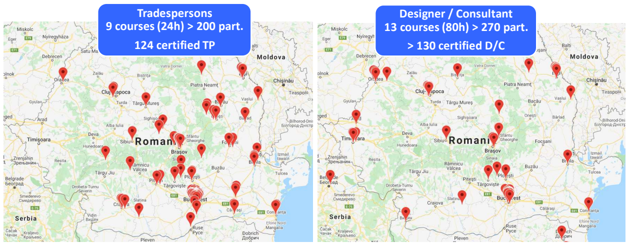
The Building Knowledge Hubs



nZEB ready

- nzebready
- nzeb-ready
- nzebreadyeu
- www.nzebready.eu

Horizon 2020: Stimulating demand for sustainable energy skills in the construction sector

ENHANCING MARKET READINESS FOR NZEB IMPLEMENTATION

September 2021 – August 2024

"**Why** nZEB?"
"**Who** can provide nZEB?"
"**How** to reach nZEB"

Prepare **ready to use frameworks** to answer the needs related to lack of awareness, lack of skilled professionals and lack of support instruments, implementing the **nZEB ready labelled procedures** in **5 pilot countries (BG, HR, PL, PT, RO)**

nZEB Awarenes

Train-to-NZEB

nZEB Training

- Strategic Professionals: Continuous Learning Training and Certification Program for Mutual Recognition
- Specialisation courses, general 12-16h, microcredits

- *Needs identification* of key target groups to become nZEB ready
- *Awareness campaigns* (new generations, beneficiaries' engagement, testimonials, nZEB brokerage events)

Target Category		Learning Program
White Collars	1. Designers (Architects and Engineers)	*Thermal bridges calculation*
		Mechanical ventilation system with heat recovery
	2. Energy Auditors and Assesors	*Building air tightness evaluation*
		Solar shading systems
		Bioclimatic design
		Renewable energy sources
	Execution Engineers	*Civil eng. Skills for nZEB Execution*
		MEP Skills for nZEB Execution
Public Authorities		*nZEB Concept in practice*
Key specialists for nZEB Certification		*Blower-door tester*
		Thermal bridges evaluator - infrared evaluator
Blue Collars		*General skills related to nZEB construction*
		General skills related to nZEB MEP

Train-to-NZEB

nZEB Roadshow

Bulgaria | Croatia | Romania | Greece | Italy

nzebroadshow

nzebroadshow

www.nzebroadshow.eu

Horizon 2020:
Stimulating demand for sustainable energy skills in the construction sector

Train-to-NZEB

nZEB Roadshow

National-scale marketing and communication campaigns (caravans demonstrating technologies and advantages of nZEB) in 5 European countries focused around nZEB weeks organized in 3 to 5 selected cities / country

June 2020 – November 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 892378

The nZEB Weeks Romania – a personal experience

nZEB Roadshow

- Conferences
- Workshops
- Training sessions – nZEB principles
- Mock-ups
- Demonstrations nZEB
- Consultations on design
- Debates
- nZEB Site visits
- Games
- Networking
- Learning

pRO-nZEB | INCD URBAN-INCERC nZEB Definition using the Passive House Pillars and experience 133

nZEB ready — nZEB Roadshow — Train-to-NZEB

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nZEB WEEK Timișoara: 10 – 13 May 2023

Train-to-NZEB

pRO-nZEB | INCD URBAN-INCERC nZEB Definition using the Passive House Pillars and experience 135

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Train-to-NZEB

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Train-to-NZEB

nZEB WEEK Timișoara: 10 – 13 May 2023

Train-to-NZEB

If there is smoke

then it's heat loss

nZEB WEEK Timișoara: 10 – 13 May 2023

nZEB WEEK Bucharest: 22 – 25 November 2023

Thank you !

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