Module 14

Measuring Performance

Energy Efficiency for Construction

Date of Event

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To equip the learner with the basic knowledge and skills required to understand the importance of acceptable U-values and achieving compliance using the Energy Assessment Procedures (EAP)

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➢ Outline the importance of low **U-values buildings**

➢ List the **minimum U-values** required by current National Building Regulations

➢ Understand the principles of **heat loss calculations** for walls, floors and roofs

➢ Understand the role and importance of **Energy Assessment Procedures** EAPs

➢ Outline the **EAPs inputs** for fabric calculation

➢ **Case study** demonstrating scenarios in energy consumption and CO_2 emissions

Energy Efficiency for Construction:
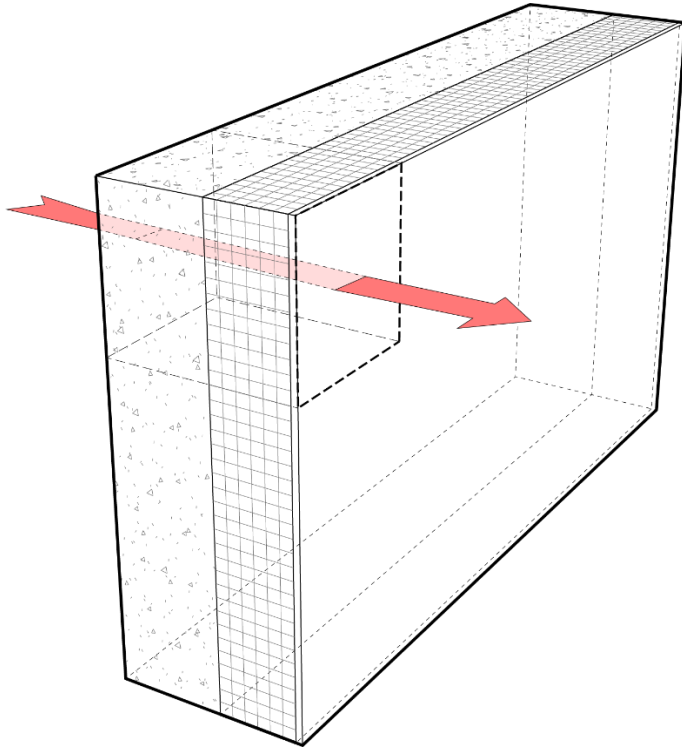Measuring Performance

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Topic 1 – Understanding U-Values

Topic 2 – Energy Assessment Procedures

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1. Understanding U-Values

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Thermal Transmittance (U-value)

What is a U-Value?

Thermal transmittance, also known as Uvalue, is the rate of transfer of heat through a single material or a composite.

$$W/(m^2 \cdot K)$$

How much heat energy moves

.....

.... Continuously ....

.... through one square metre of surface area ....

.... given a 1 degree temperature difference between faces.

Tip! The better-insulated a structure is, the lower the U-value will be.

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Thermal Resistance (R-value)

What is an R-Value?

(m^2K/W)

The ability of a material to resist heat transfer. This is known as the R-value.

The more a material is able to impede heat transfer, the greater its thermal resistance.

The resistances for each of the materials within an element are calculated and added together to determine the total resistance (R_T) of the building element

Tip! With R-Values, the higher the number, the better!

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Thermal Resistance (R-value)
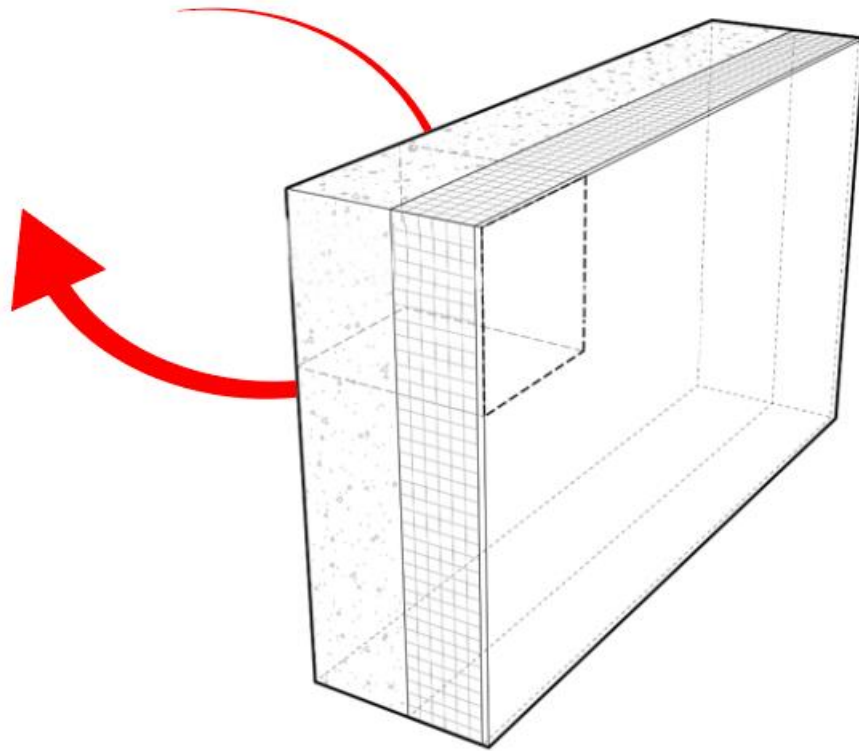
What is an R-Value?

$$(m^2K/W)$$

The R-value of a material is impacted by two factors;

Material conductivity W/mK

and

Material thickness (m)

Tip! Thickness (m) / Conductivity (W/mK) = R-Value (m²K/W)

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Thermal Conductivity

Thermal Conductivity is:

- The rate at which heat passes through a specified material

- It is expressed as W/mK

- The lower the conductivity, the better job a material will do at insulating

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Image Source: Left: IconsPng.com silver spoon Right: Kingspan

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Wood is More Forgiving than Concrete

Thermal Conductivity of Building materials

Thermal conductivity (λ) W/mK
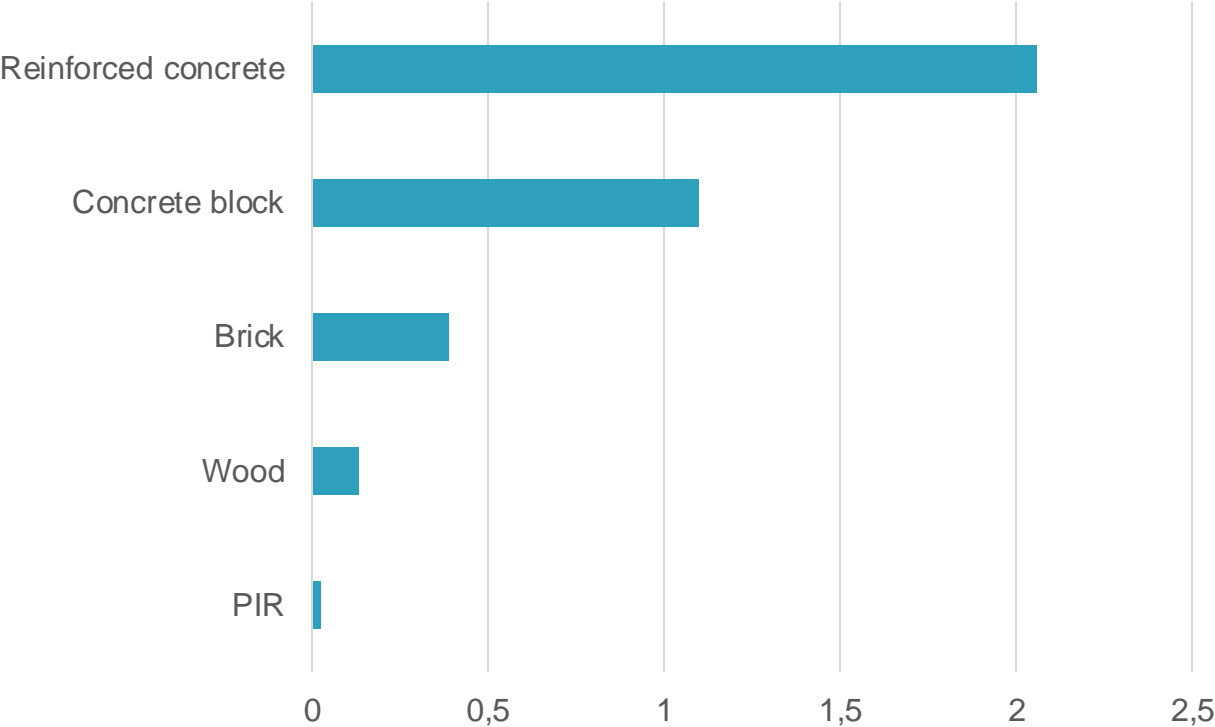
Material	Value
Aluminium:	237 W/mK
Reinforced concrete:	2.06 W/mK
Concrete block:	1.1 W/mK
Brick:	0.39 W/mK
Wood:	0.13 W/mK
PIR:	0.023 W/mK

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Image Source: MosArt

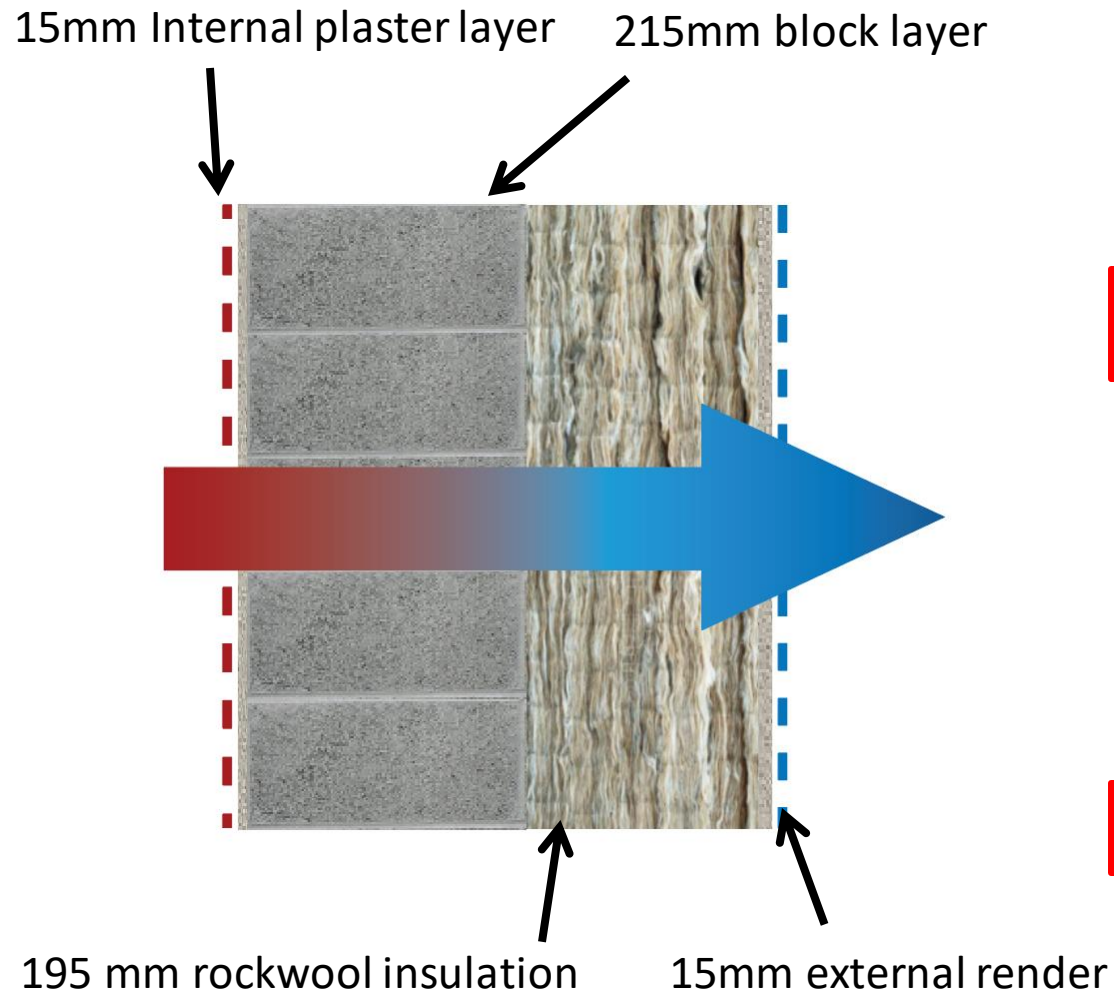Insert Organiser Logo Here
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Thermal Conductivity of Materials

Table A1 Thermal conductivity of some common building materials

Material	Density (kg/m³)	Thermal Conductivity (W/mK)
General Building Materials		
Clay brickwork (outer leaf)	1,700	0.77
Clay brickwork (inner leaf)	1,700	0.56
Concrete block (heavyweight)	2,000	1.33
Concrete block (medium weight)	1,400	0.57
Concrete block (autoclaved aerated)	700	0.20
Concrete block (autoclaved aerated)	500	0.15
Concrete block (hollow)	1800	0.835
Cast concrete, high density	2,400	2.00
Cast concrete, medium density	1,800	1.15
Aerated concrete slab	500	0.16
Concrete screed	1,200	0.41
Reinforced concrete (1 % steel)	2,300	2.30
Reinforced concrete (2 % steel)	2,400	2.50
Wall ties, stainless steel	7,900	17.00
Wall ties, galvanised steel	7,800	50.00
Mortar (protected)	1,750	0.88
Mortar (exposed)	1,750	0.94
External rendering (cement sand)	1,800	1.00
Plaster (gypsum lightweight)	600	0.18
Plaster (gypsum)	1,200	0.43
Plasterboard	900	0.25
Natural slate	2,500	2.20
Concrete tiles	2,100	1.50
Clay tiles	2,000	1.00
Fibre cement slates	1,800	0.45
Ceramic/Porcelain tiles	2,300	1.30
Plastic tiles	1,000	0.20
Asphalt	2,100	0.70
Felt bitumen layers	1,100	0.23
Timber, softwood	500	0.13
Timber, hardwood	700	0.18
Wood wool slab	500	0.10
Wood-based panels (plywood, chipboard, etc.)	500	0.13

Note:
The values in this table are indicative only. Certified values, should be used in preference, if available.

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Source: Department of Housing, Planning and Local Government Ireland

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Different thermal insulation materials

Material	Thickness
Mineral wool	5 cm
EPS	5,2 cm
Sheep wool	5,3 cm
Cellulose	5,3 cm
Cork	5,8 cm
Coke	6,7 cm
Clay	9,2 cm
Wood fibers	10,8 cm
Chipboard	14,3 cm
Perlite	14,3 cm
Timber	16,2 cm
Hollow brick	54,2 cm
Concrete block	59,2 cm
Full brick	69,2 cm
Reinforced concrete	248 cm

Sample Insulation Data Sheets
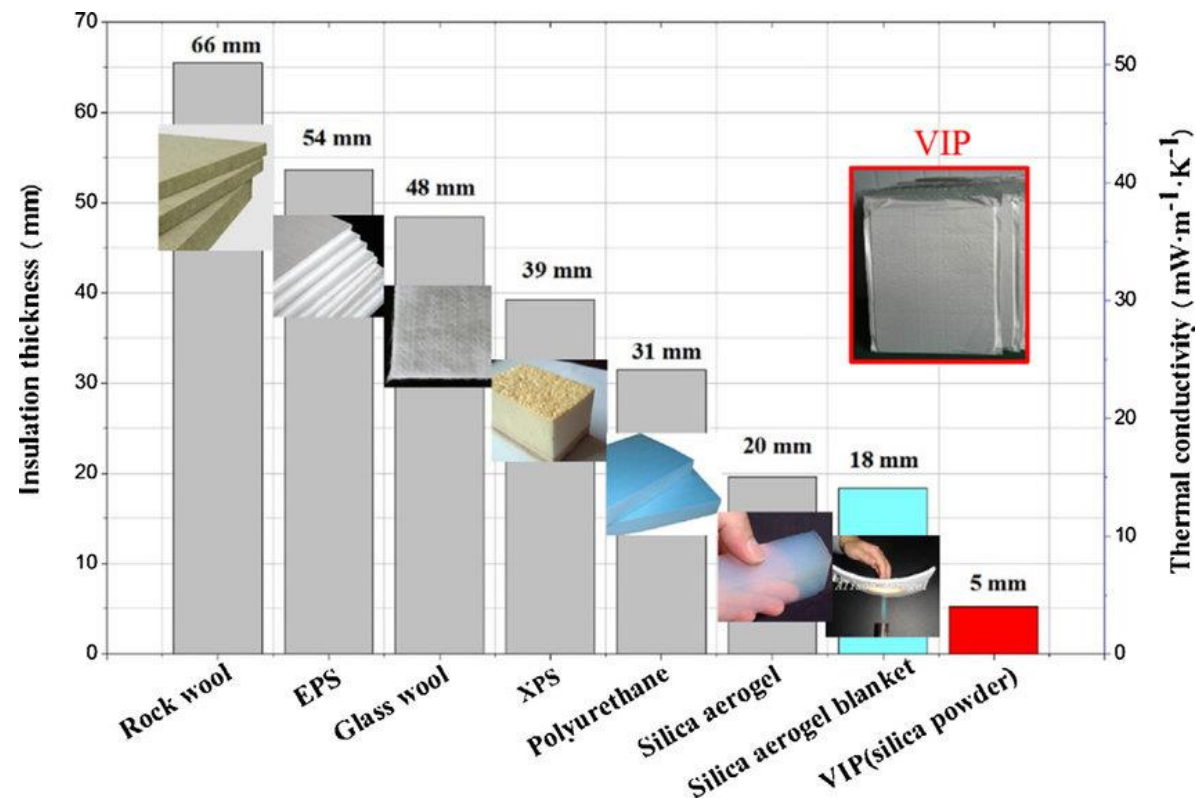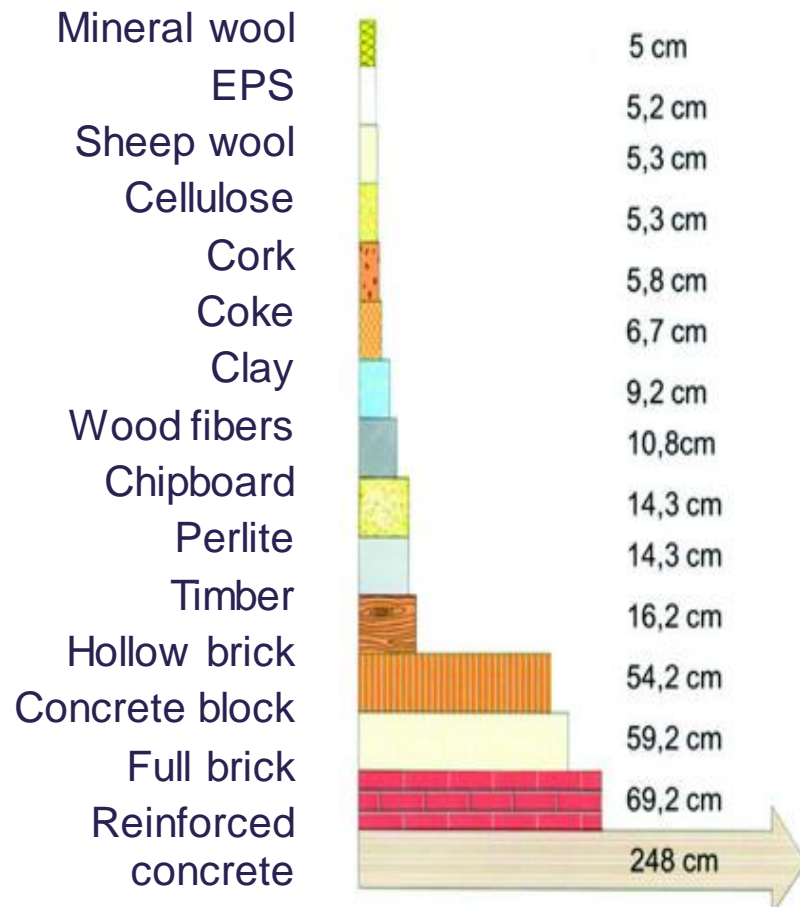
Kingspan Cavity Wall Insulation Board

Product Details	
Thermal conductivity (insulant thickness)	0.021 W/m.K (25–44 mm) 0.020 W/m.K (≥ 45 mm)
Facings	Composite foil
Core	Premium performance rigid thermoset modified resin insulant manufactured with a blowing agent that has zero Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP).
Board size	1.2 x 0.45 m

Xtratherm Cavity Wall Insulation Board

Property & Units	
Water Vapour Resistivity	>100 (MNs/gm)
Thermal Conductivity	0.021 (W/mK)
Service Temperature	-20 to +100 (°C)

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Image Source: Top: Kingspan / Bottom: Xtratherm

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Constant Values (defaults) for Surface Resistances

Upward Heat Flow +0.10

Downward Heat Flow +0.17

Horizontal Heat Flow +0.13

+0.04

+0.04

+0.04

Below ground exterior surface

Note: Ceilings over 60 degrees are considered 'horizontal' heat flow (like walls)
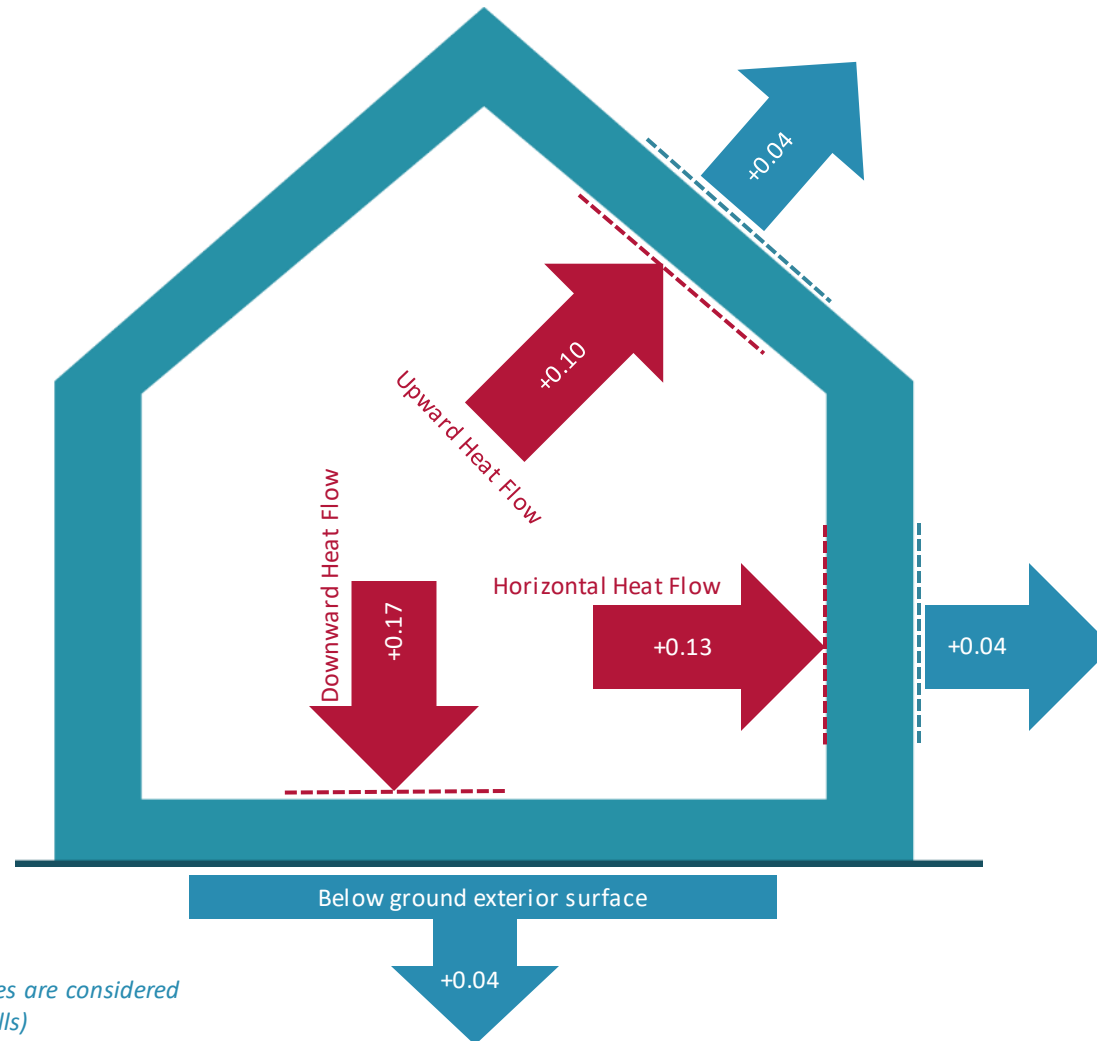
- Internal Surface resistance (R_{si})

- External surface resistance (R_{se})

- Units for Surface Resistance: **m²K/W**

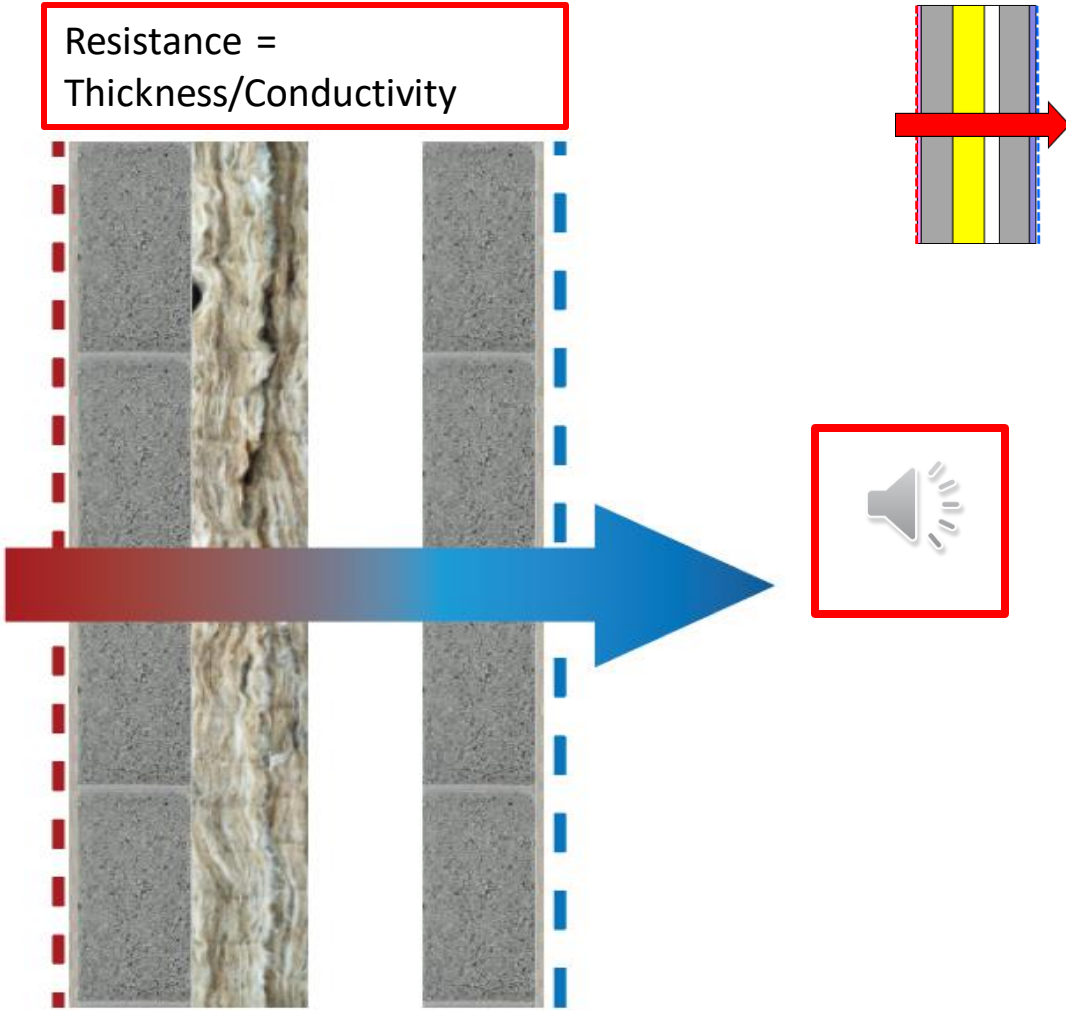Energy Efficiency for Construction: Measuring Performance

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How to Calculate a U-Value - Homogeneous Heat Flow

15mm Internal plaster layer   215mm block layer

195 mm rockwool insulation   15mm external render

Step 1: Calculate the thermal resistance of all the layers

Thermal resistance = thickness of material ÷ thermal conductivity

Step 2: Add up thermal resistance of all layers **including surface resistance of internal and external layers**

Step 3: Overall U-value is the inverse of the total resistance

1 ÷ thermal resistance = U-value

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How to Calculate a U-Values through Walls
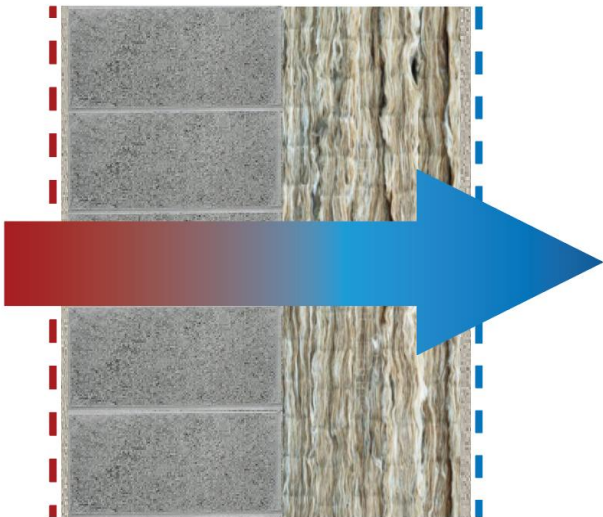
Block Wall with Rockwool Insulation
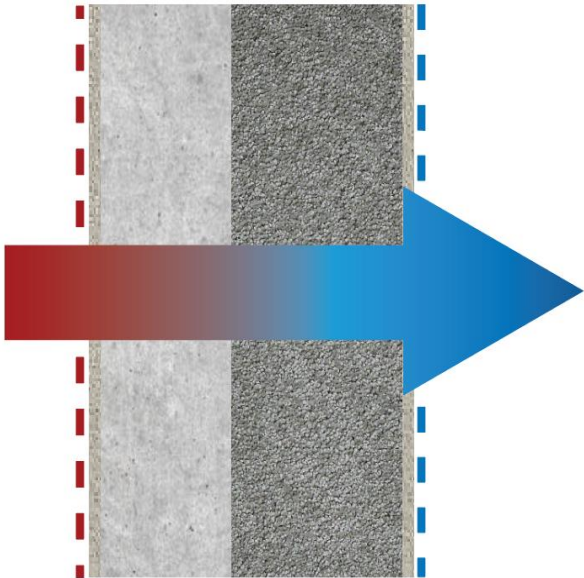
Mass Concrete with Polystyrene Insulation
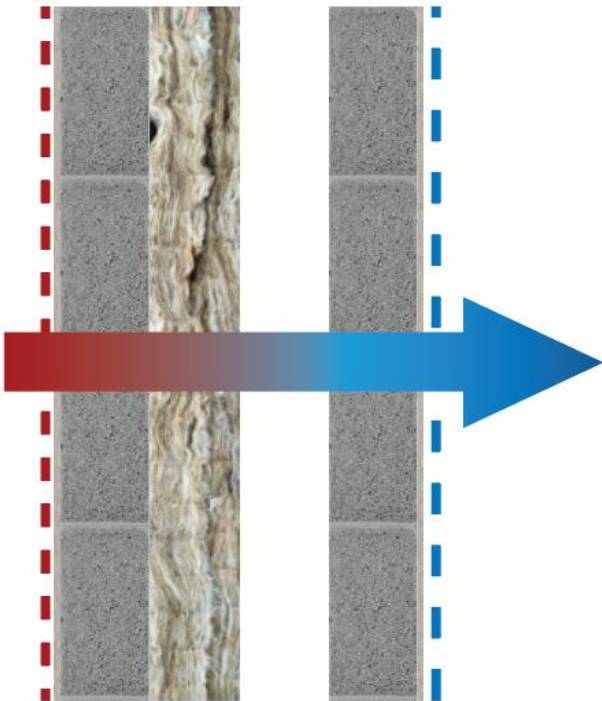
Block Cavity Wall with Rockwool Insulation

Brick Cavity Wall with Rockwool Insulation

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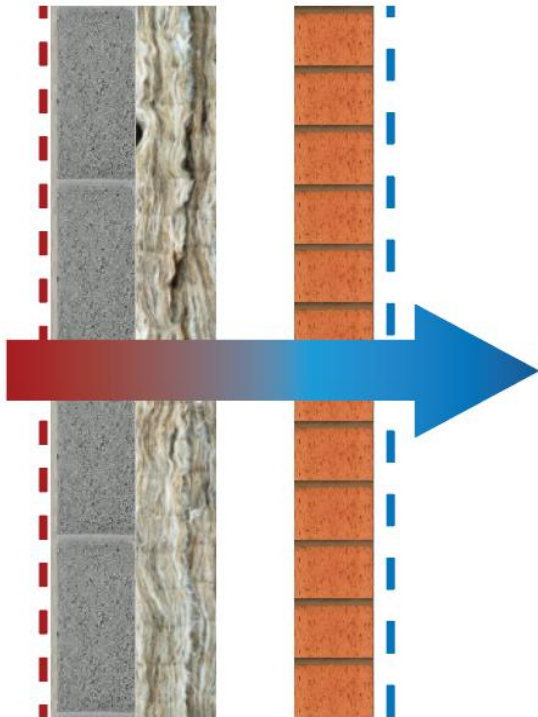
How to Calculate a U-Value – Block Wall with Rockwool Insulation

15mm Internal plaster layer

215mm block layer
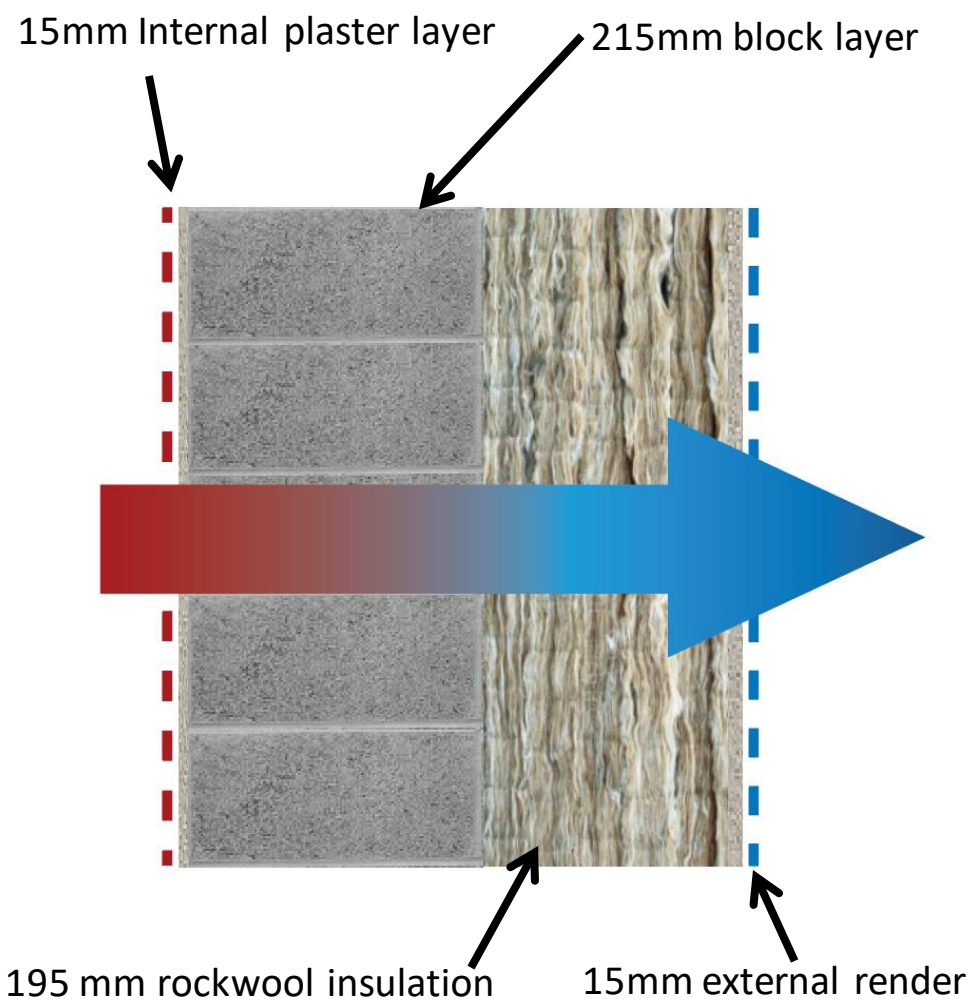
Just-about complies with NZEB!

Element	Thickness (m)	Conductivity (W/mK)	Resistance (m²K/W)
Internal surface resistance (default)	---	---	0.13
Internal plaster	0.015 ÷	1.6	= 0.009
Blockwork	0.215 ÷	1.1	= 0.195
Rockwool insulation	0.195 ÷	0.038	= 5.132
External plaster	0.015 ÷	1.6	= 0.009
External surface resistance (default)	---	---	0.04
Total Resistance			5.555 m²K/W
Overall U-value	**=1/R**		**0.180 W/m²K**

195 mm rockwool insulation

15mm external render

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How to Calculate a U-Value – Mass Concrete with Polystyrene Insulation

15mm Internal plaster layer (1.6 W/mK)

160mm mass concrete (2.06 W/mK)
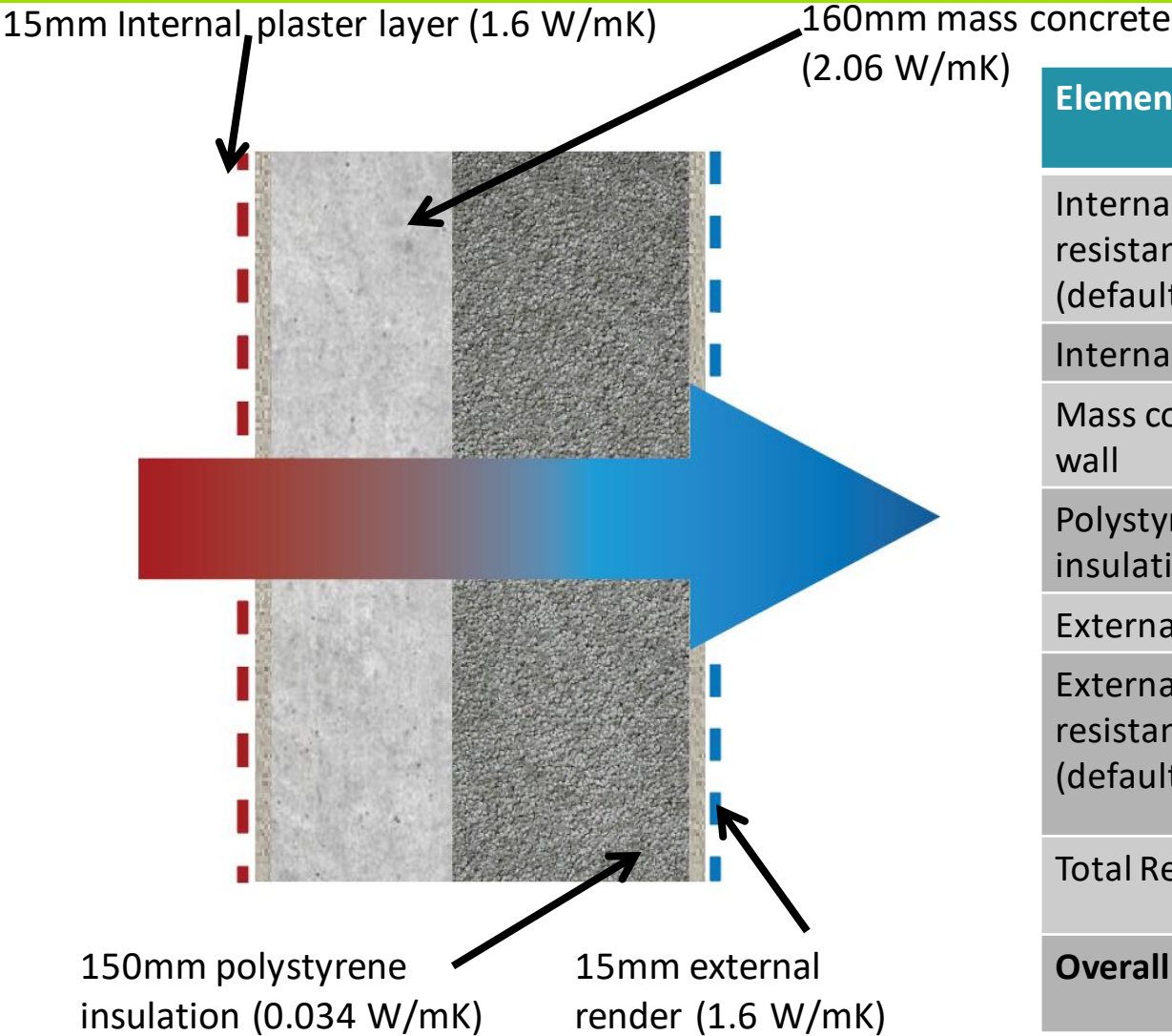
Fails to comply with NZEB!

150mm polystyrene insulation (0.034 W/mK)

15mm external render (1.6 W/mK)

Element	Thickness (m)	Conductivity (W/mK)	Resistance (m²K/W)
Internal surface resistance (default)	---	---	
Internal plaster			
Mass concrete wall			
Polystyrene insulation			
External plaster			
External surface resistance (default)	---	---	
Total Resistance	---	---	
Overall U-value			
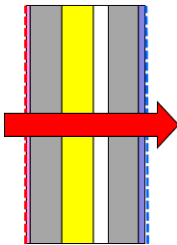
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How to Calculate a U-Value – Block Cavity Wall with Rockwool Insulation

Element	Thickness (m)	Conductivity (w/mK)	Resistance (m²K/W)
Internal Surface Resistance	---	---	0.130
Internal Plaster	0.013	0.18	0.072
Concrete Block	0.100	1.33	0.075
Insulation	0.100	0.021	4.760
Cavity	0.050	---	0.440
Concrete Block	0.10	1.33	0.075
External Render	0.019	1.00	0.019
External Surface Resistance	---	---	0.040
Total Resistance	---	---	5.611

U-Value of Construction = 1/5.611 = **0.18W/m²K**

Resistance = Thickness/Conductivity

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How to Calculate a U-Value – Brick Cavity Wall with Rockwool Insulation

Element	Thickness (m)	Conductivity (w/mK)	Resistance (m²K/W)
External Surface Resistance	---	---	
Clay Brick	0.10		
Cavity	0.05	---	0.44
Insulation	0.12	0.021	
Concrete Block	0.1		
Plaster (gypsum)	0.013		
Internal Surface Resistance	---	---	
Total Resistance	---	---	
U-Value of Construction =			

Image Source: MosArt

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Note: These dimensions are internal

10m

5m

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$$U_{FLOOR} = \lambda_g / (0.457B' + d_t)$$

λg = Thermal conductivity of unfrozen ground (W/mK). The ISO standard 13370: Table 1 states that this has a set value of 2W/mK unless otherwise known.

B' =Characteristic dimension of the floor (m), for insulated floors:

$$B' = \frac{2A}{p}$$

A = Area of floor (M^2)

P = heat loss perimeter (m)

d_t = Equivalent thickness (m) d_t = w+ λ_g (R_{si} + R_f + R_{se})

W = Wall thickness (m)

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λ_g = Thermal conductivity of unfrozen ground = 2W/mK

R_{si} = Internal surface resistance for floors = 0.17m^{2}K/W

R_{se} = External surface resistance for floors = 0.04m^{2}K/W

Rf = Floor fabric resistance (m^{2}K/W)

NOTE: The floor is evenly insulated with 180mm of insulation with a conductivity (λ) of 0.027W/mK

Downward Heat Flow
+0.17

Below ground exterior surface

0.04

Note: These dimensions are internal

10m

5m

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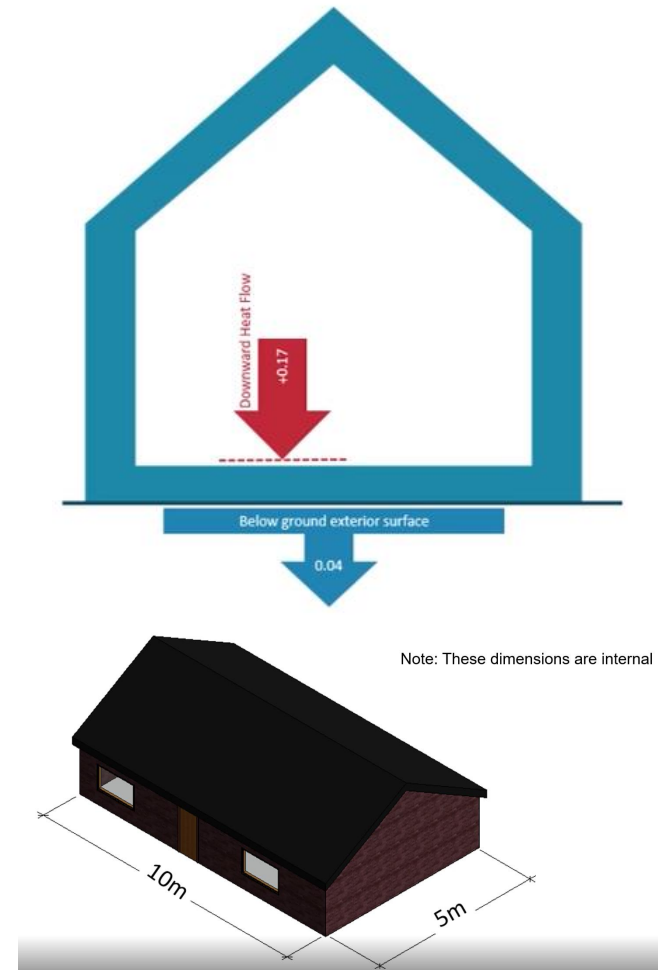
Calculate Floor U-Values – Dimension of Floor

$$B' = \frac{2A}{p}$$

P = Length of the exposed perimeter = 10m + 10m + 5m +5m = 30m

A = Area of floor = 10m x 5m = 50m^2

Note: These dimensions are internal

$$B' = \frac{2A}{p} \qquad B' = \frac{2(50)}{30} \qquad B' = 3.33$$

10m

5m

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$$d_t = w + \lambda_g (R_{si} + R_f + R_{se})$$

Note: These dimensions are internal

w = Wall thickness = 0.36m

λ_g = Thermal conductivity of unfrozen ground = 2W/mK

R_{si} = Internal surface resistance for floors = 0.17m2K/W

R_{se} = External surface resistance for floors = 0.04m2K/W

10m

5m

R_f = **Insulation resistance** $R_f = d/\lambda$ $R_f = 0.18/0.027$ $R_f = 6.67$ (m²K/W)

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$$d_t = w + \lambda_g (R_{si} + R_f + R_{se})$$

dt = 0.36 + 2(0.17 + 6.67 + 0.04)

dt = 0.36 + 2(6.88)

dt = 0.36 + 13.76

dt = 14.12

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Calculate Floor U-Values

$$U_{Floor} = λ / (0.457B' + d_t)$$

λg = Thermal conductivity of unfrozen ground = 2W/mK

B' = Characteristic dimension of the floor = 3.33

dt = Equivalent thickness = 14.12m

U Floor = 2 / (0.457 x 3.33 + 14.12)

U Floor = 2 / 15.64

U Floor = 0.13W/m²K

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Average Elemental U-Values - IRELAND

When the calculations have been completed for all elements of the external envelope.
Consider the acceptable elemental U-Values as stated in the TGD Part L documents.

NEW BUILD DWELLINGS: TYPICAL U VALUES IN IRELAND
[W/(m2K)]

Pitched Roof 0.16W/(m2K)

Flat Roof 0.18W/(m2K)

Wall 0.18W/(m2K)

Ground Floor 0.18W/(m2K)
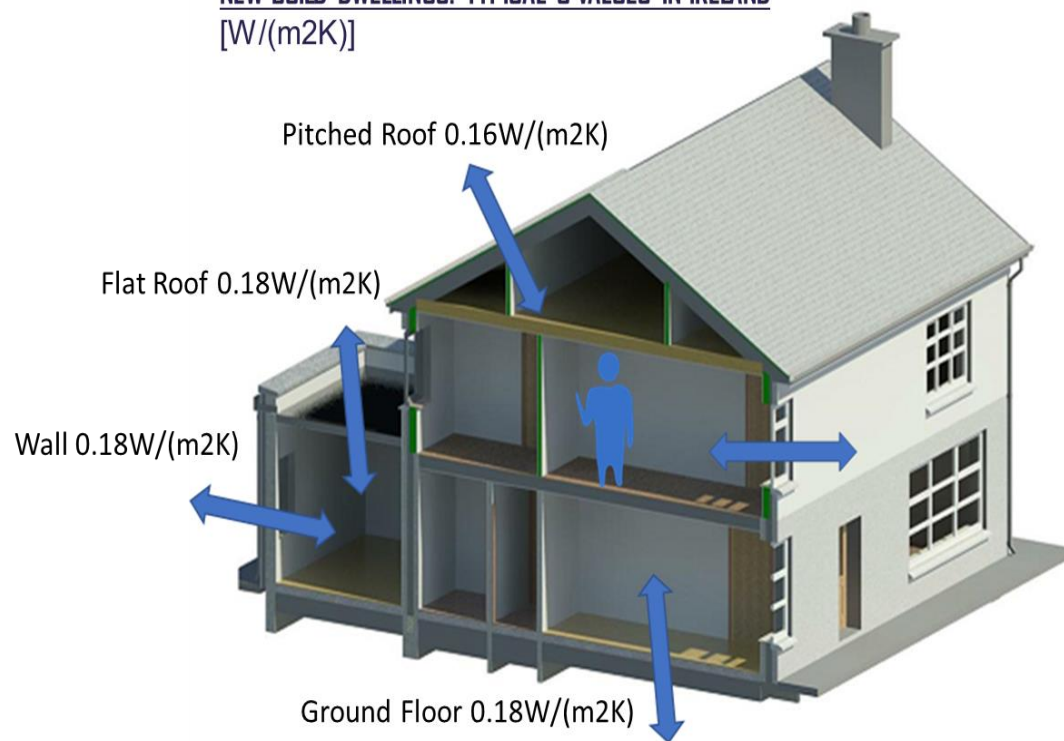
DEEP RETROFIT DWELLINGS: TYPICAL U VALUES IN IRELAND
[W/(m2K)]

Pitched Roof (insulation at pitch) 0.16W/(m2K)

Pitched Roof (insulation at ceiling) 0.25W/(m2K)

Flat Roof 0.25W/(m2K)

Other Wall 0.35W/(m2K)

Ground Floor 0.45W/(m2K)
Ground Floor (underfloor heating) 0.25W/(m2K)

Cavity Wall 0.55W/(m2K)
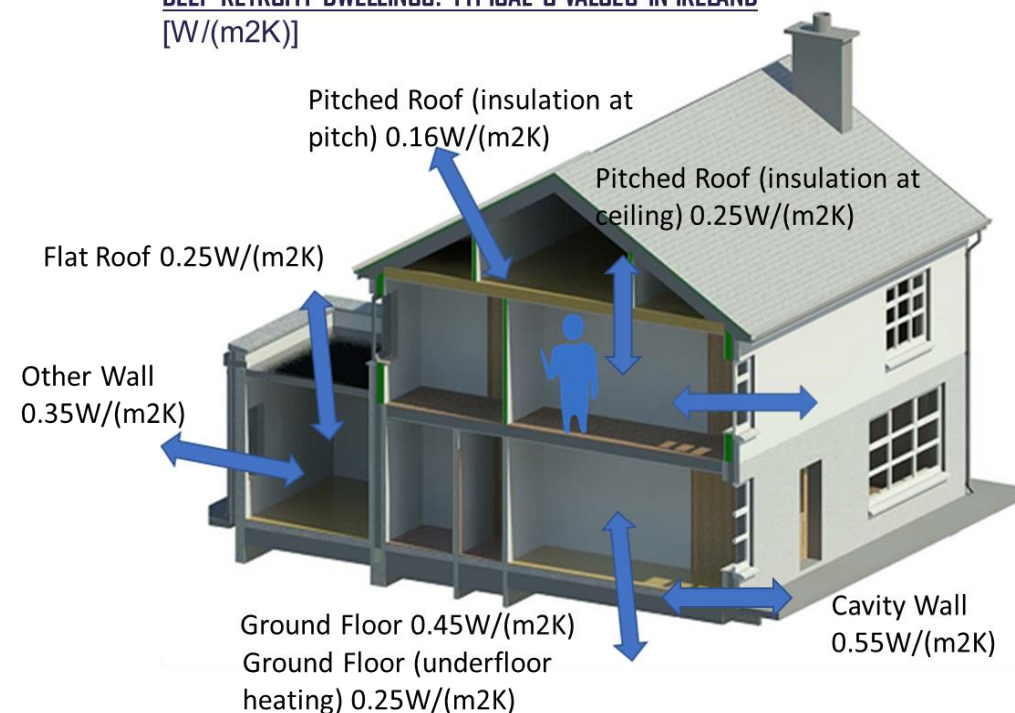
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2. Energy Assessment Procedures

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National Energy Assessment Procedures

ENERGY PERFORMANCE CERTIFICATES ACROSS THE EU

In this section we will look at the National Energy Assessment Procedures, NEAPs

A MAPPING OF NATIONAL APPROACHES

Energy Efficiency for Construction: Measuring Performance

Image Source: BPIE.eu

National Energy Assessment Procedures

National Energy Assessment Procedures, NEAPs is the methodology for calculating primary energy consumption and CO_2 emissions for buildings (residential and non-residential).

Building energy consumption is measured in $kWh/m^2/yr$, while CO_2 emissions are calculated as kg $CO_2/m^2/yr$.

Assessment for compliance with regulations is based on meeting a reference Maximum Permitted Energy Performance Coefficient (MPEPC) and a Maximum Permitted Carbon Performance Coefficient (MPCPC).

These can be derived using the National Energy Assessment Procedures.

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Energy Performance Certificates - EPCs

Each Member State have established their own Energy Performance Certificates (EPCs) to register and provide information on the energy performance of buildings. Article 20 (2) EPBD

EPCs provide the following information:

- Information on the structure and typology of the building
- Energy performance of the building
- Carbon emissions for the building
- Cost-effective solutions
- Inspection and/or advisory energy reports

The EPCs cover residential and non-residential buildings

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Measuring Performance

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Energy Assessment Procedures - IRELAND

NEAP is the **Non-Domestic Energy Assessment Procedure**, and is the methodology for demonstrating compliance with specific aspects of TGD Part L – Other than Dwellings of the Building Regulations.

DEAP is the **Dwelling Energy Assessment Procedure**, which is the methodology for demonstrating compliance with specific aspects of TGD Part L for Dwellings of the Building Regulations.

NEAP and DEAP generate energy performance certificates, known as the **Building Energy Rating (BER)** and an advisory report for new and existing dwellings.

NEAP and DEAP calculates the energy consumption and CO_2 emissions associated with a standardised use of the building.

NEAP calculates monthly energy use and CO_2 emissions based on building geometry, construction, use, and HVAC and lighting equipment.

DEAP is calculated based on the amount of energy the home requires for:
- space and hot water heating
- ventilation
- lighting

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Domestic Energy Assessment Procedure

The DEAP calculation is not based on the number of occupants in a dwelling or the levels and durations of heating or hot water demand. It is independent of how the individual occupants actually use energy in the dwelling (space and DHW, ventilation and lighting).

For example:
1. **the number of occupants is assumed based on floor area**
2. **the dwelling's heating patterns and temperatures are assumed to be the same across all dwellings**
3. **individual ownership and efficiency of particular domestic electrical appliances are not assessed**

The calculation uses the Dwelling Energy Assessment Procedure (DEAP). This is Ireland's official method for calculating a dwelling's BER. The DEAP calculation framework is based on IS EN 13790

The DEAP software has been developed by SEAI, who are also responsible for auditing DEAP assessors.
The use of DEAP is strictly outlined in the DEAP manual.

DEAP is the only tool that can be used to prove NZEB compliance

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Compliance with National EAPs AND NZEB

Explaining BER
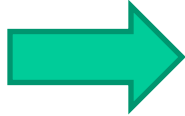
When the building is certified by the BER assessor, it **generates the Building Energy Rating (BER) and advisory report** for new and existing domestic buildings.

The software calculates the energy consumption, expressed as, kWh/m^2.yr and CO_2 emissions, kg CO_2/m^2.yr.

DEAP is compliant with all the **EU Energy Performance of Buildings Directives (EPBDs)**
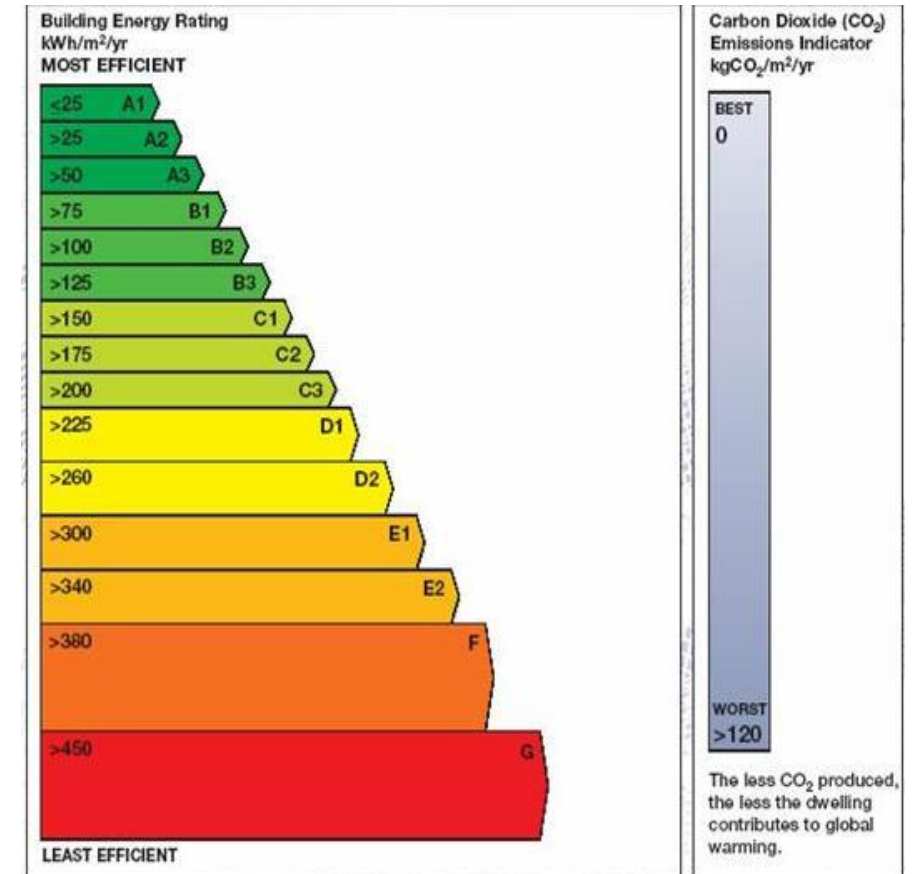
Building Energy Rating (BER) certificate

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Compliance with National EAP & NZEB

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The energy certificate is a document that measures the energy characteristics of a shop, office or home.

In Spain, it is regulated by Royal Decree 235/2013, in which the basic procedure for its application is developed. In this document an energy rating is obtained which is classified according to an energy label.

Thus we have homes or shops A, B, C, D, E, F or G.

Energy label indicates the energy rating of a building within a seven-letter scale from most to least efficient, with A being the most favorable rating and G the least.

Next to each letter is the energy consumption expressed in kWh/year and the emissions in kgCO2/m2 year.

Building Energy Rating (BER) certificate

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What affects a BER?

Age of construction

It is essential to provide data on the year of construction of the dwelling (and any extensions) - particularly for existing dwellings. To prevent the use of assumed values (default values) which are generally based on the standards in place at the time of construction.

Floor area

The floor area for the BER is based on internal dimensions and is calculated in accordance with the DEAP methodology. These are conservative estimates of the energy performance of certain areas of your home.

Thermal insulation

This is the wall, attic and floor insulation of the building. On average, a home loses between 20-30% of its heat through the walls. Up to a further 30% can be lost through a poorly insulated attic, so this leads to higher energy use.

Windows and doors

You can lose about 10% of your homes heat through your windows and doors depending on the glazing and frame types. Non-default thermal performance values must be supported by certificates stating U-value & solar transmittance values for the installed windows/doors.

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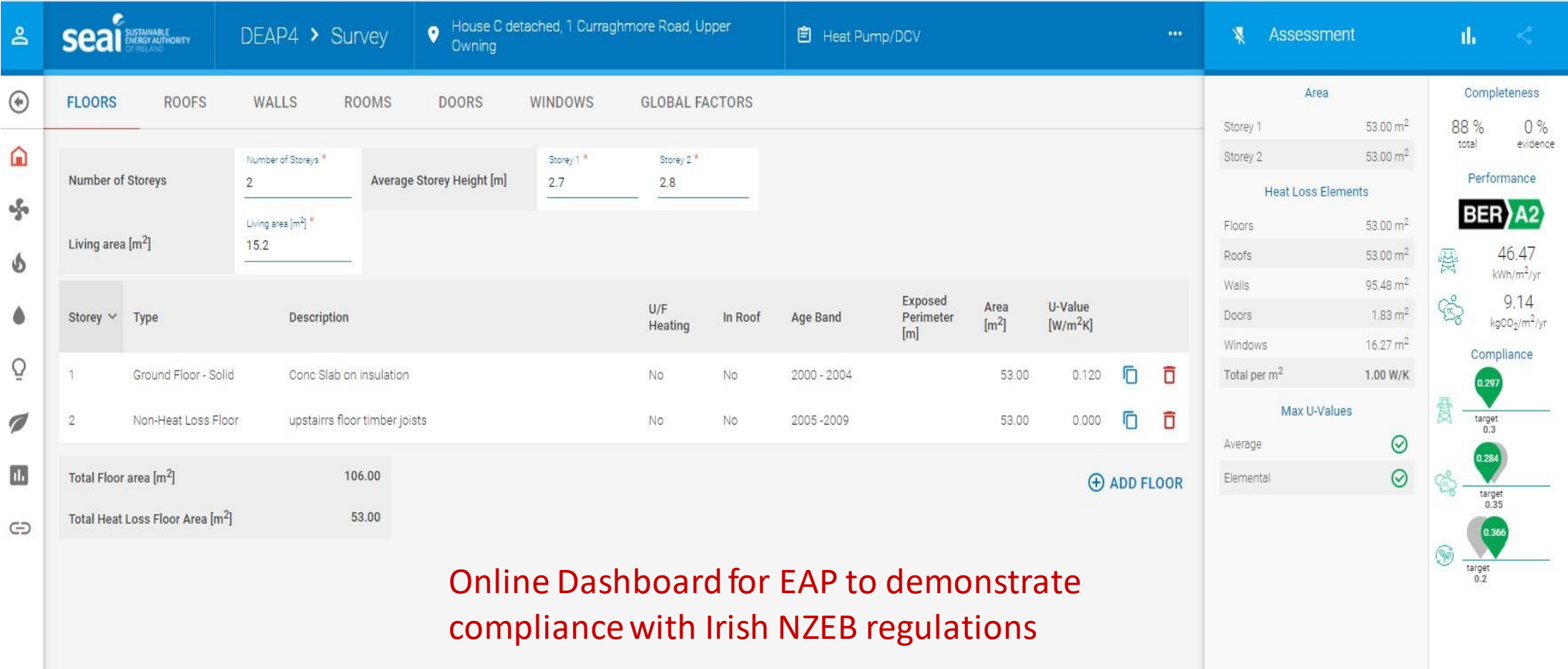For illustrative purposes only delete this shape from final presentation

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What affects a BER?

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Heating systems and controls

Older gas or oil boilers with no controls are less energy efficient than newer solutions such as a heat pump.

Light fittings

The type and quantity of fixed lamps within a dwelling are recorded, the more energy efficient light bulbs used, the lower the calculated energy usage

Renewables

Renewables installed in your home will have a positive impact on your BER rating. Renewables include, for example, photovoltaics (PV), heat pumps, solar water heating, biomass, wind energy, solar space heating.

Defaults values

In accordance with the DEAP methodology, default values may be used when assessing existing dwellings.
This may result in your home receiving a lower BER rating than expected.

In the **absence of supporting data**, default efficiencies in DEAP manual must be used.
1. Where there is insufficient documentation available to the BER assessor, insulation levels may be determined based on the age of construction and construction type.
2. For electrical and heating systems, take photographs (e.g. boiler, heat pump, etc.) to support data inputs in the BER. Photographs of nameplates with make and model number can also be taken to support non-default efficiencies. Heating system manuals or installation certificates can also be copied and used as supporting data.

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Compliance with National EAP & NZEB - IRELAND

Let's look at an example in Ireland

Complying with Energy Assessment Procedures

IRELAND

illustrates energy
balance of a dwelling
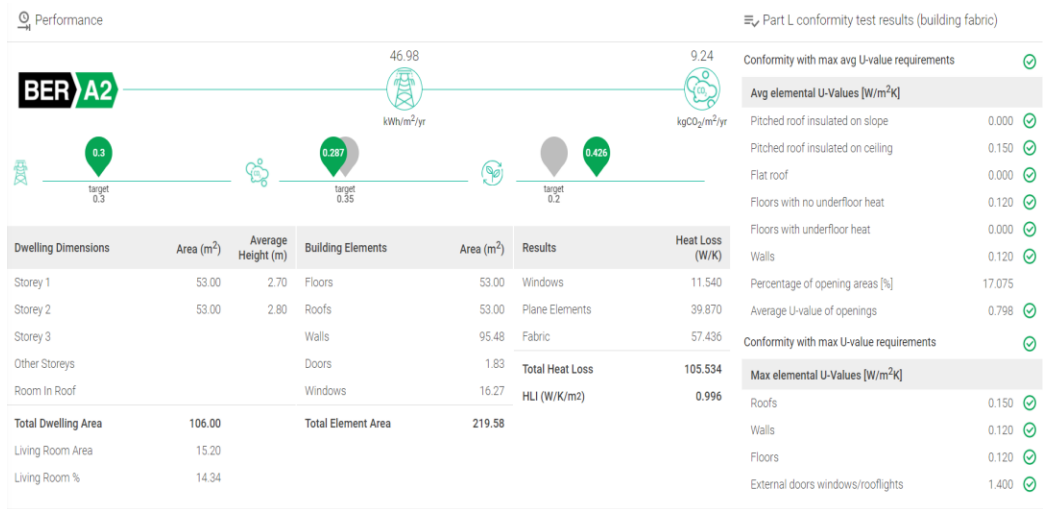
The (DEAP) online portal: left shows that a dwelling is compliant with the relevant Part L TGDs for the year of construction below

Review the Sustainable Energy Authority of Ireland Video: https://youtu.be/l-ubz0X7u3E (5 mins)

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Compliance with National EAP & NZEB - IRELAND

Complying with Energy Assessment Procedures

Online Dashboard for EAP to demonstrate compliance with Irish NZEB regulations

Energy Efficiency for Construction:
Measuring Performance

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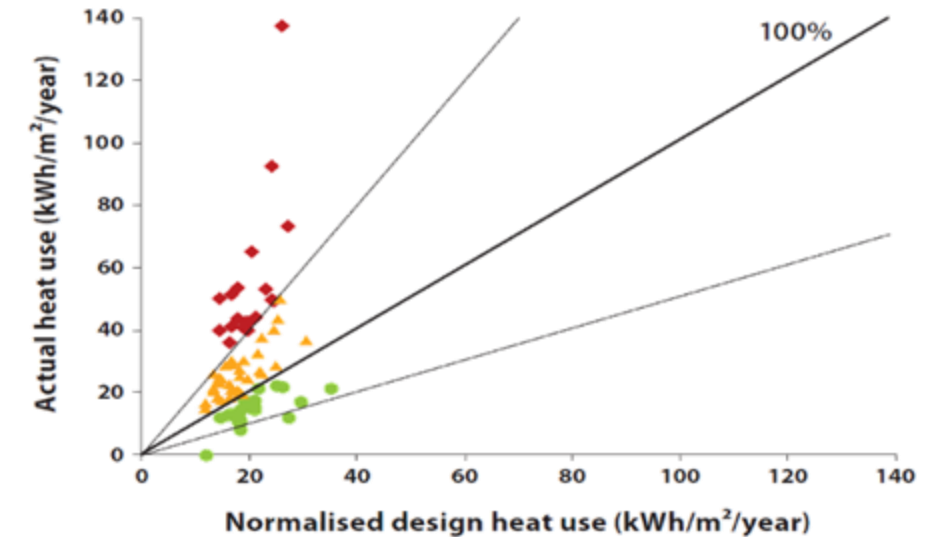For illustrative purposes only delete this shape from final presentation

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Quality Control and Checks

It is important to check the following in the NEAP

Envelope
1. U-values,
2. Insulations,
3. Thermal Bridging,
4. Air-tightness,
5. Wind-tightness,

Services
1. Controlled ventilation,
2. heating & cooling,
3. Renewables
4. Lighting
5. smart controls and sensors

Performance Gap - the difference between predicted and actual performance.

There is significant evidence to suggest that buildings do not perform as well when they are completed as was anticipated when they were being designed. The difference between anticipated and actual operation is known as the **performance gap**.

Recent studies suggest that in-use energy consumption can 5 to 10 times higher than compliance calculations carried out during the design stage TM 61 provides insights into operational building performance
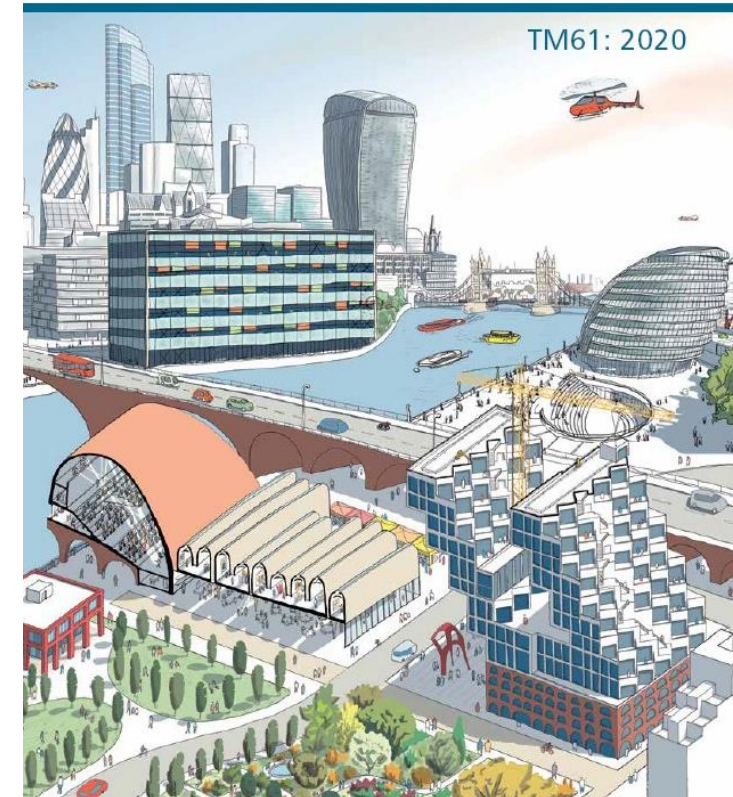
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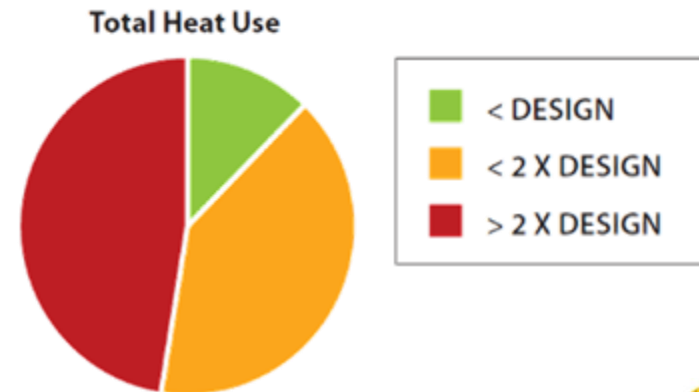For illustrative purposes only delete this shape from final presentation

Mind the Gap – Why?

These are some of the Reasons why many buildings on completion do not perform as predicted in the design.

- Design assumptions do not properly reflect the in-use performance of buildings.
- Discrepancies between design specification and the as-built specification and quality of works of installation.
- Poor feedback from site about what is, and what is not buildable.
- Site practices that may have been acceptable 20 years ago, no longer meet the required standards.

Source: Ghent University

Total Heat Use

🟩	< DESIGN
🟧	< 2 X DESIGN
🟥	> 2 X DESIGN

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Activity

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Thank You

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