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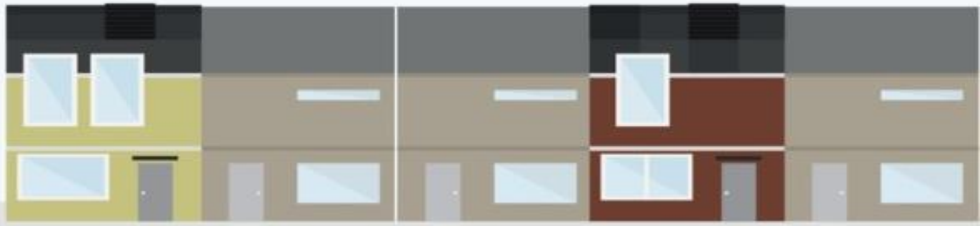

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ENVELOPE'S THERMAL PERFORMANCE – THERMAL BRIDGES

3 rd Module

Manuela Almeida | Luis Bragança
Sandra Silva | Ricardo Mateus | Ricardo Barbosa

University of Minho
Portugal

MODULE OVERVIEW

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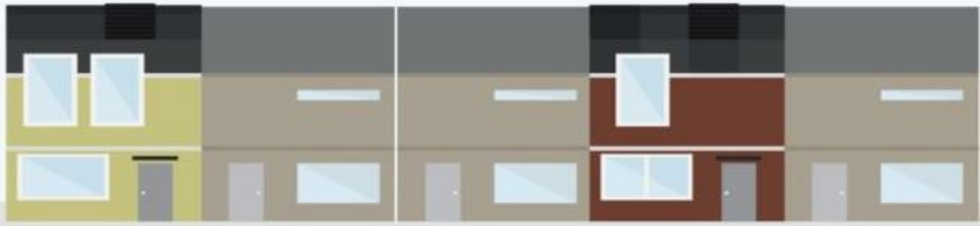

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1. TOPIC INTRODUCTION

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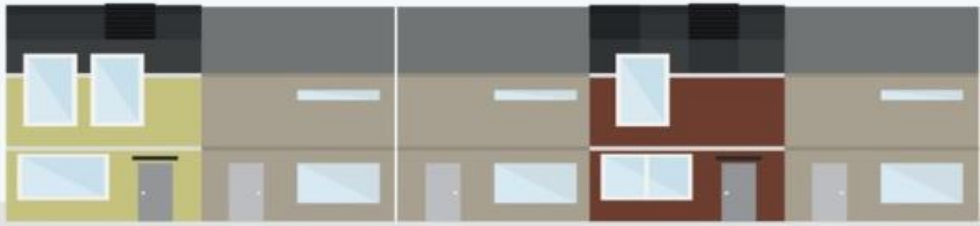
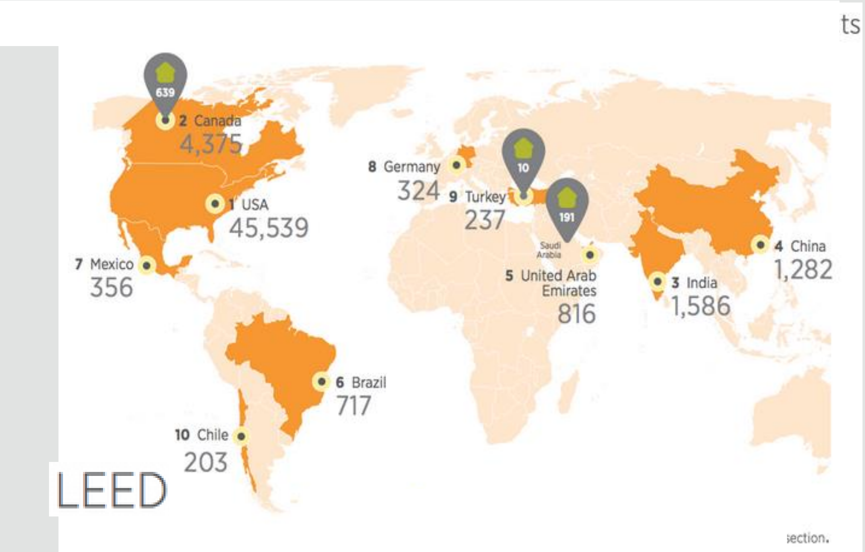
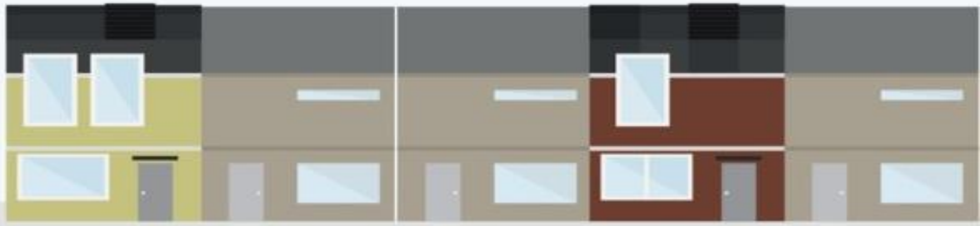


Context



Overview of countries where Envionmental Assessment Methodologies BREEAM and LEED are active in improving overall building performance by setting out strict criteria covering many aspects including materials, insulation and energy performance.

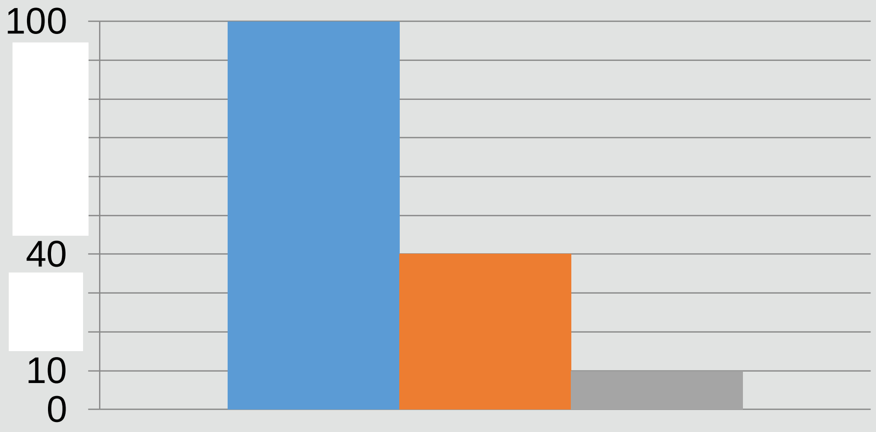
1. TOPIC INTRODUCTION

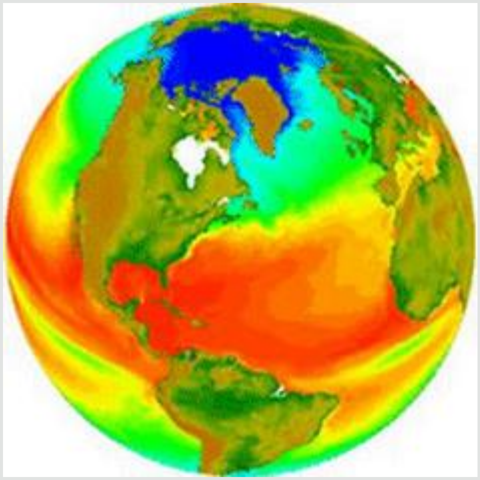


Context

Climate Change Impact

The construction and operation of buildings and cities accounts for around 50 % of the UK's CO_2 emissions and is thus a significant contributor to climate change.

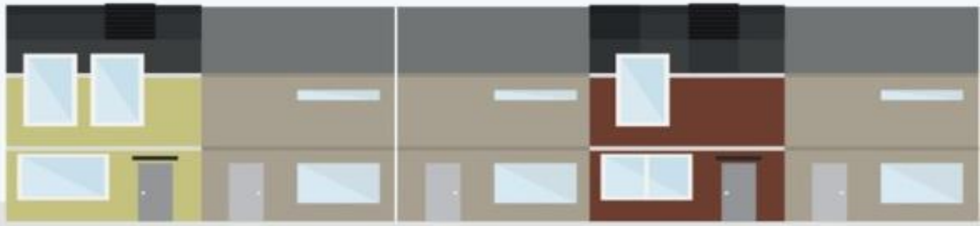




Breakdown of CO_2 emissions and the building industry

A reduction in carbon emissions of at least 40 – 50 % can be achieved simply by building and refurbishing our buildings to much higher insulation and airtightness standards. This could lead to at least an 80 % reduction in our space heating demand.

1. TOPIC INTRODUCTION



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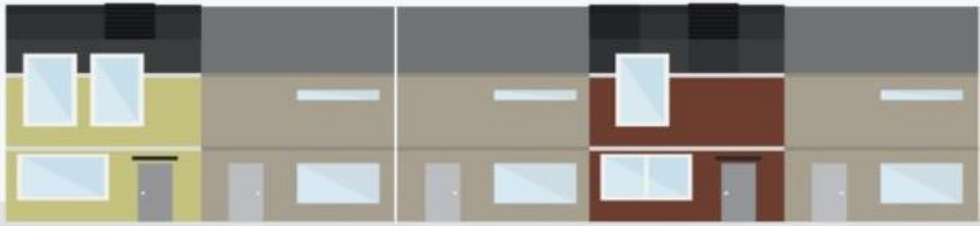
Context

Drivers for improving buildings (from Building Regulations):

- 1966 Health in focus – minimisation of damp and mould
- 1975 Energy conservation – tackling the fuel crisis
- 1991 Cost effectiveness & fuel poverty
- 2002 Reducing greenhouse gas emissions (GHGs)
- **2015 All of the above**

Improved fabric performance can lead to improved:

- Health
- Maintenance resource
- Productivity
- Energy consumption
- Occupant satisfaction
- Carbon footprint



Key Definitions

What is Building?

Birds make nests

Rabbits dig holes

People build buildings

2. BUILDING ENVELOPE

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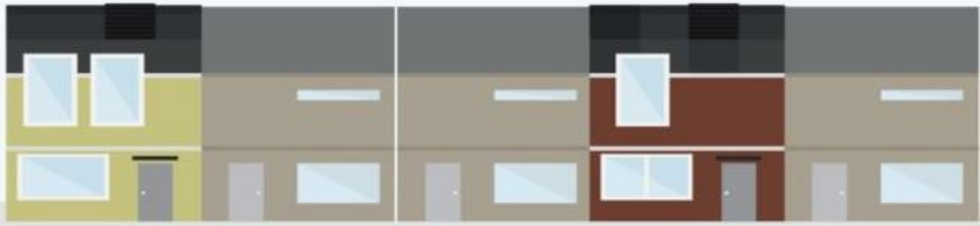

Key Definitions

- **Building Envelope/Enclosure:** The part of the building that makes a thermal barrier between interior of the building and exterior
- **Air Sealing:** preventing the passage of air through building envelope
- **Heating Load:** The amount of energy need to be added to maintain a comfortable temperature
- **Cooling Load:** The amount of energy need to be removed to maintain a comfortable temperature
- **Thermal Performance:** The overall performance of the building in what pertains to cooling and heating. The better the building envelope the better thermal performance is.

2. BUILDING ENVELOPE

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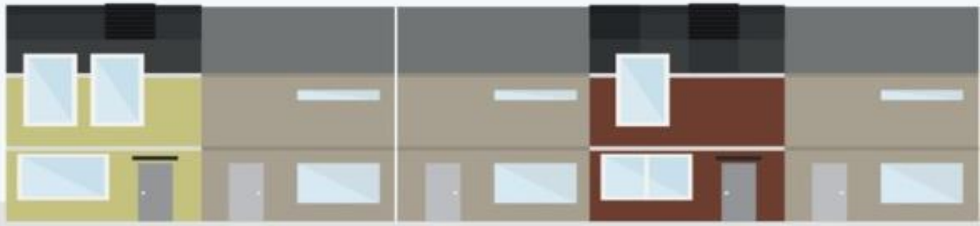


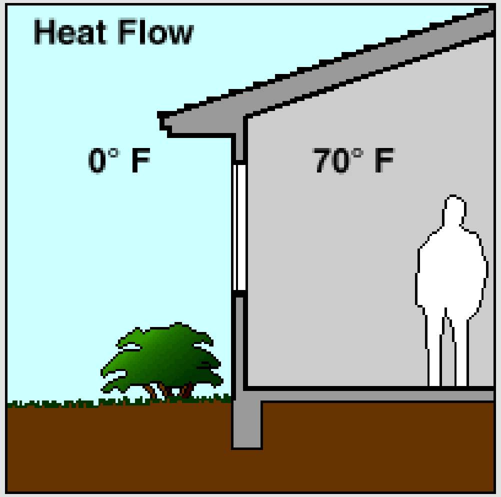
Key definitions

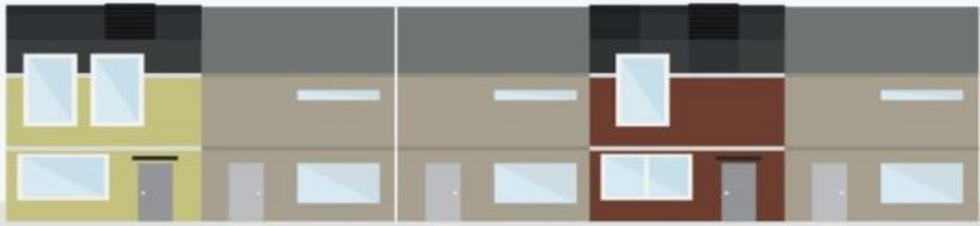
- **Zero Energy Building (ZEB):** An energy fully self-sufficient building. Energy produced ≥ energy consumer over the year.
- **Low-Emissivity (Low-e):** microscopically thin, virtually invisible, metal or metallic oxide layers applied to windows to reduce U-factor.
- **Solar heat gain coefficient (SHGC)**: fraction of radiation passing through a glazing (directly transmitted, absorbed and subsequently released inward).
- **Vacuum glazing:** an insulating glazing made of two glass layers with vacuum in between to act as an insulator and eliminate heat transfer

Key definitions

Heat Transfer Factors – U-Factor

- Is the rate of steady-state heat flow,
- The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating properties.
- Thermal performance and U-factors are also affected by the quality of construction.

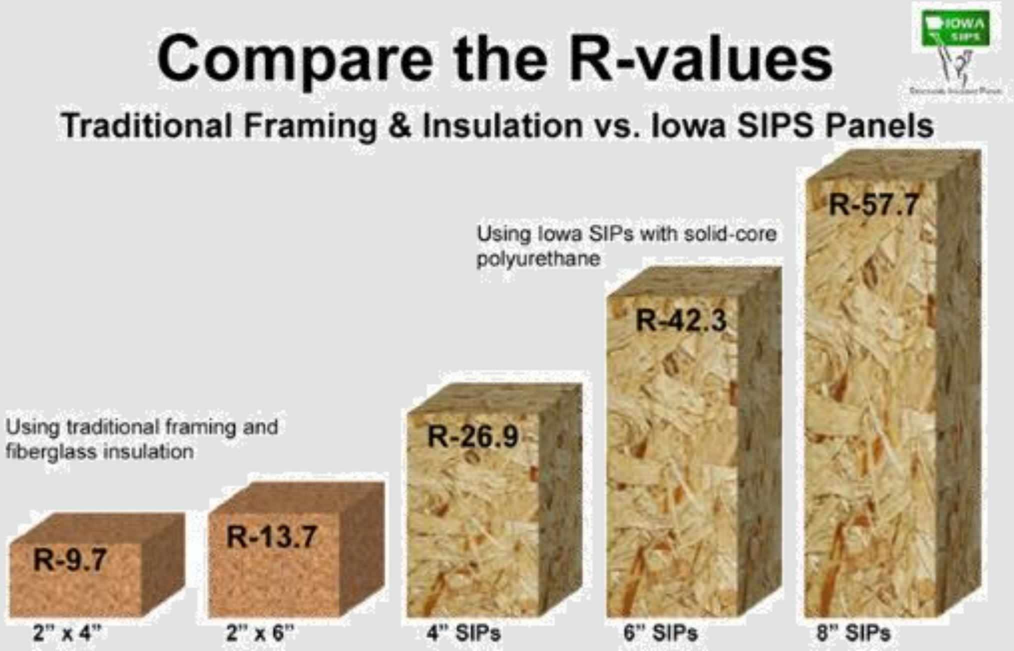


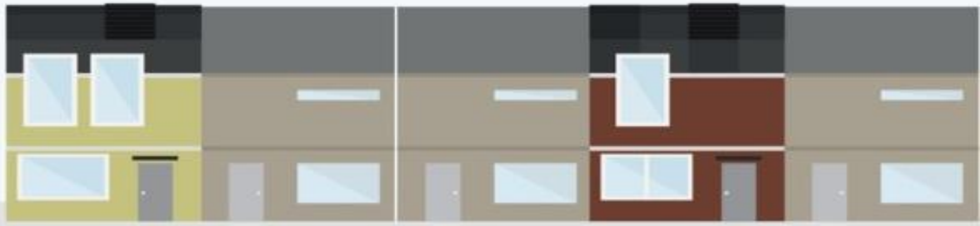


Key definitions

Heat Transfer Factors – R-Value

- Thermal resistance measure
- A larger R-value has greater thermal resistance, or more insulating potential, than a smaller R-value.

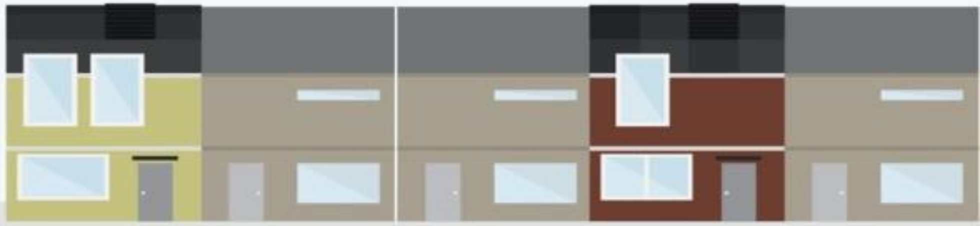




Key definitions

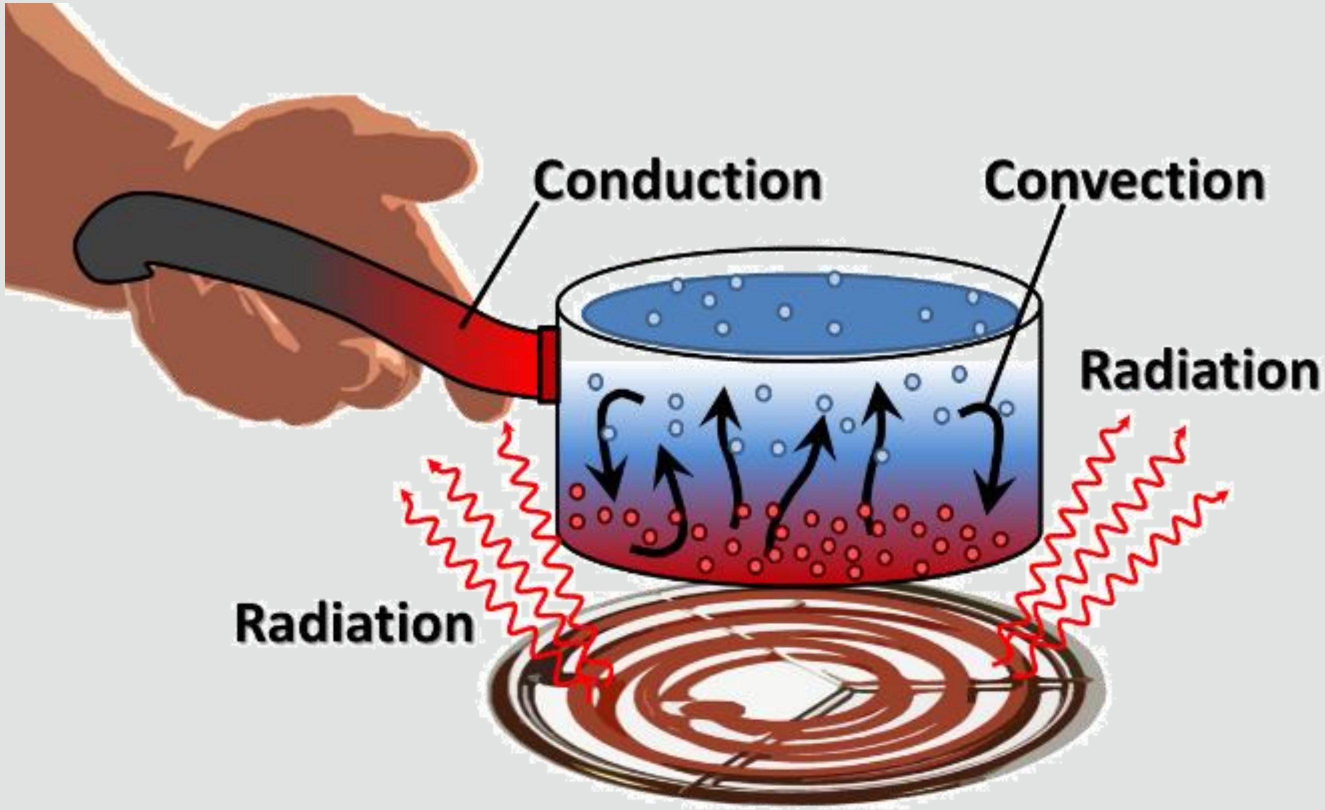
Heat Transfer Factors – U-Factor vs R-Value

- *U-factor* expresses the insulation value
- *R-value* is used for insulation in most other parts of the building envelope (walls, floors, roofs).
- Different assumptions and test criteria are used in calculating U-Factor and R-Value.
- U-factor takes account of the overall construction assembly
  R-value is a material property, like density, specific heat, and conductance.
- To compare R-value and U-factor, divide 1 by the U-factor number



Key definitions

Modes of Heat Transfer



2. BUILDING ENVELOPE

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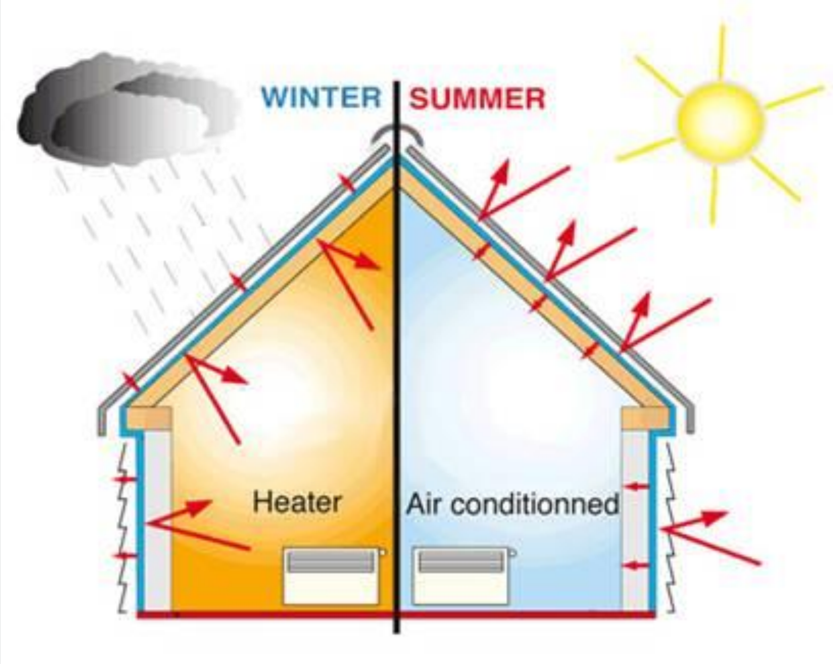
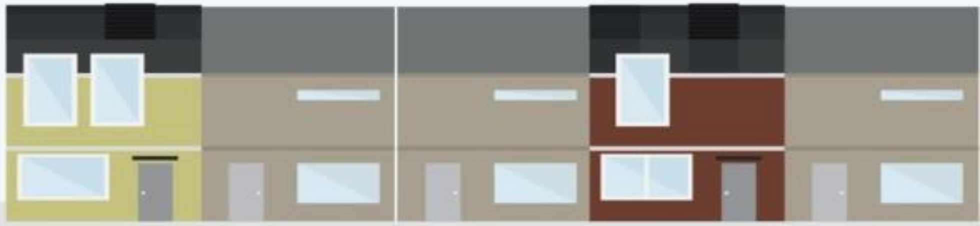
Key definitions

Modes of Heat Transfer – Controlling Conduction

- Increasing R-Value ➔ Decreasing U-Value

1. Use low conductivity building material
2. Proper utilization of thermal insulation
3. Avoid thermal bridges



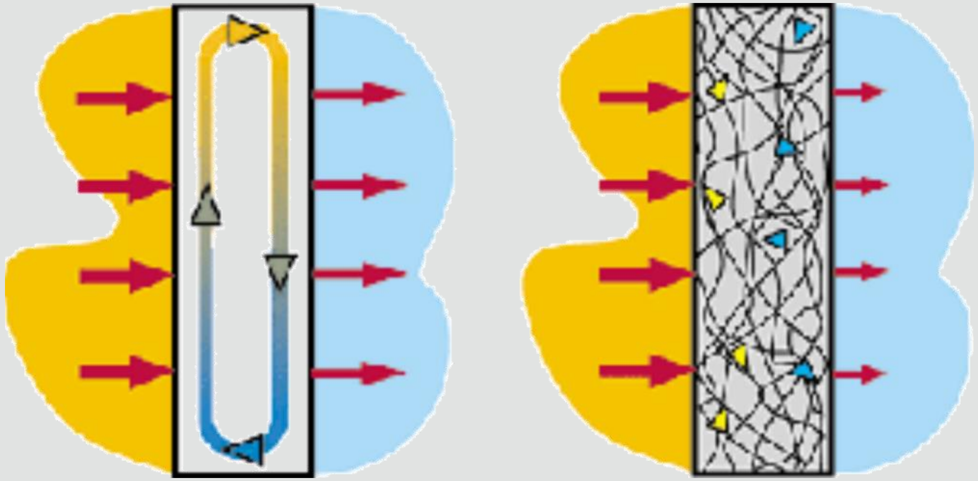


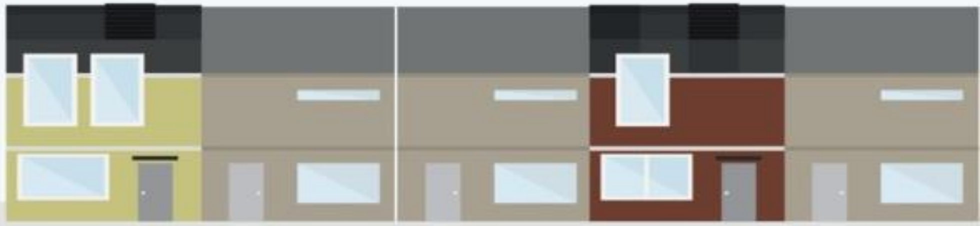
Key definitions

Modes of Heat Transfer – Controlling Convection

- Reducing air flow and limit air motion ➔ reduce bulk convective heat transfer

1. Reduce air gap size between elements
2. Add inserts to block
3. Install air barrier material

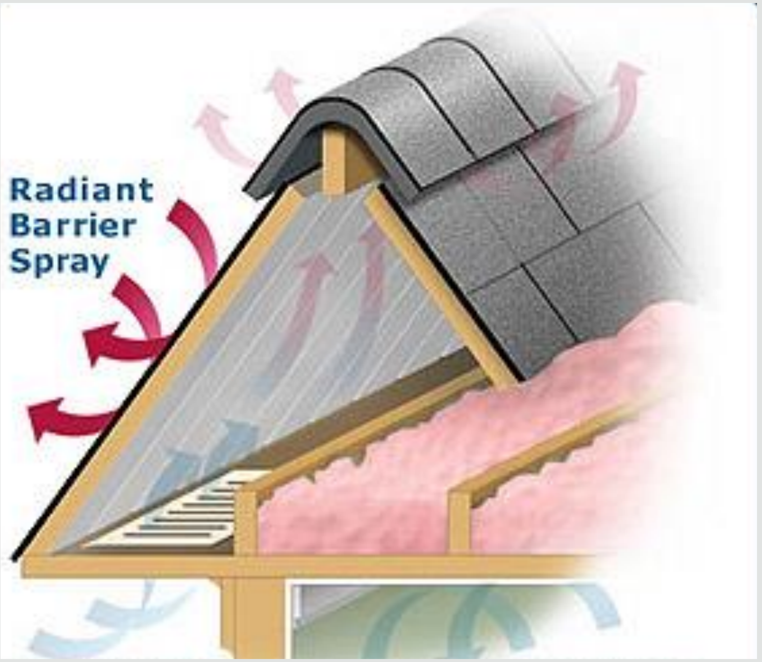


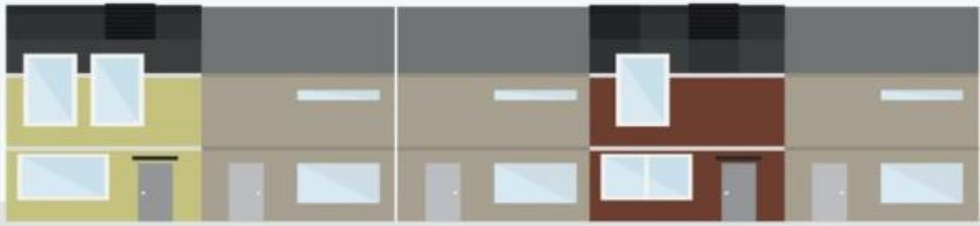


Key definitions

Modes of Heat Transfer – Controlling Radiation

- Reducing exposure to solar radiation ➔ minimizing transmission of radiation
  1. Smart building location
  2. Select proper glazing system
  3. Use radiant heat barriers

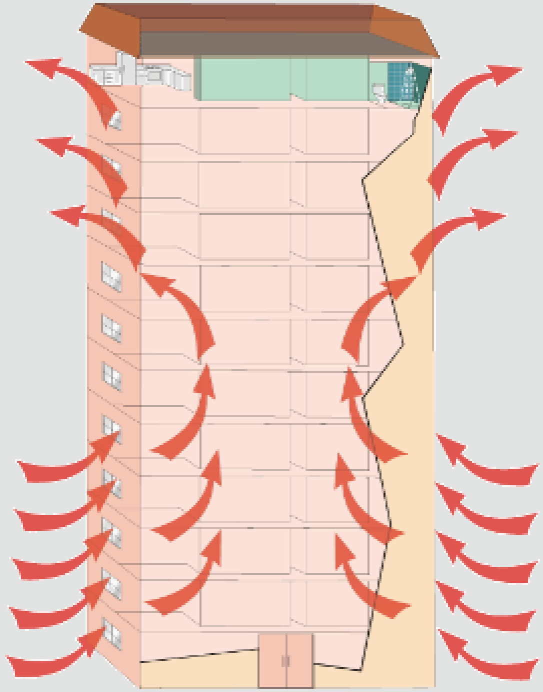


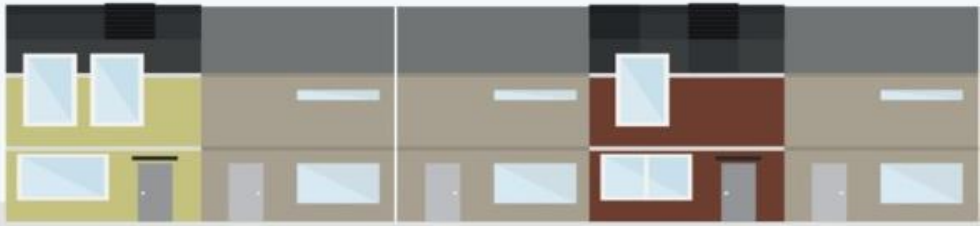


Key definitions

Stack Effect

- Stack effect is the pressure driven flow produced by convection (the tendency of warm air to rise).





Question:

How Building Energy is Lost?

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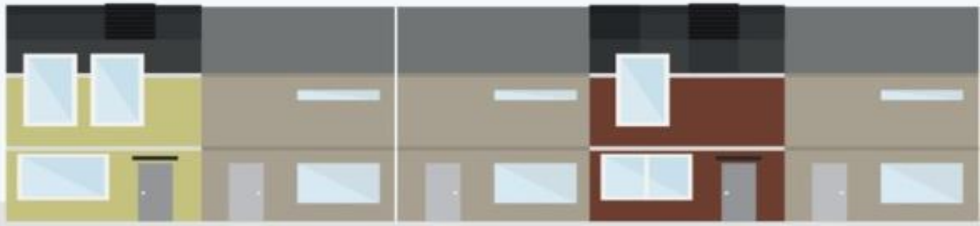

Most Common Energy Hogs (1/3)

- Non-insulated piping in basement
- Leaks (steam, water)
- Inefficient or oversized boiler/burner
- Poor or no heating control equipment
- Poor heating Distribution: balancing problems
- Incandescent lighting
- Obsolete refrigerators
- DC motor elevators

Most Common Energy Hogs (2/3)

- Common area lighting on 24h/day
- Occupant behavior and poor use of equipment
  - Controls are not set properly ➔ overheating
  - Window opening during winter time
  - Apartment lights on 24h/day
  - Lack of maintenance on equipment

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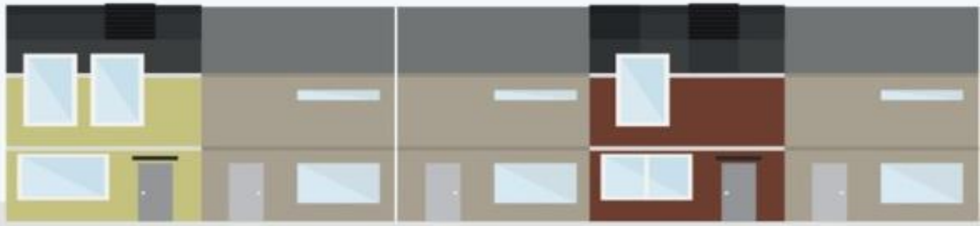
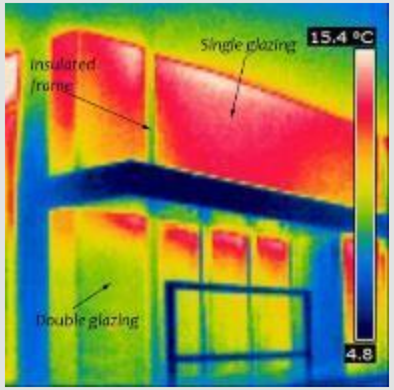
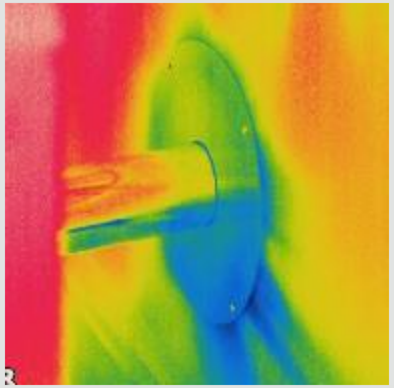
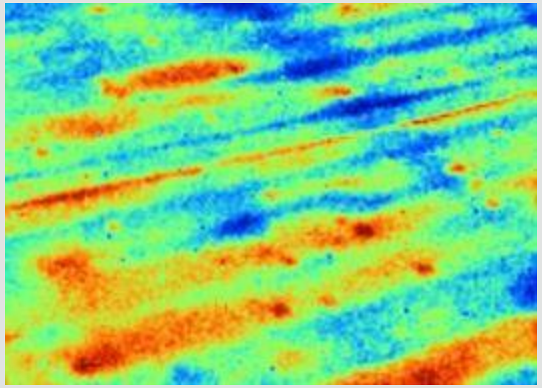


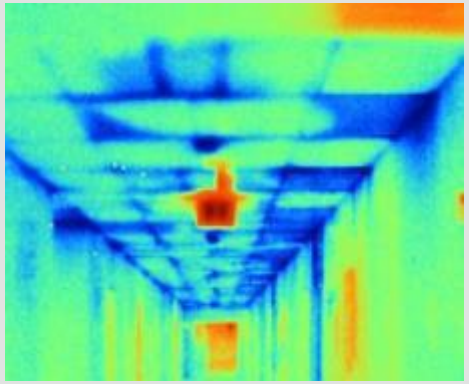
Most Common Energy Hogs (3/3)

- Improper building envelope
  - Non-insulated roof
  - Single-pane windows
  - Poor air-sealing tightness









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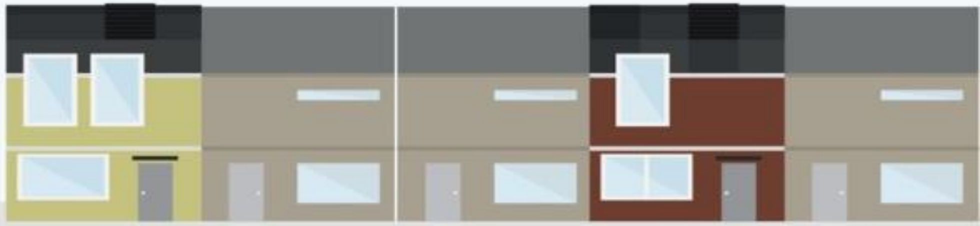
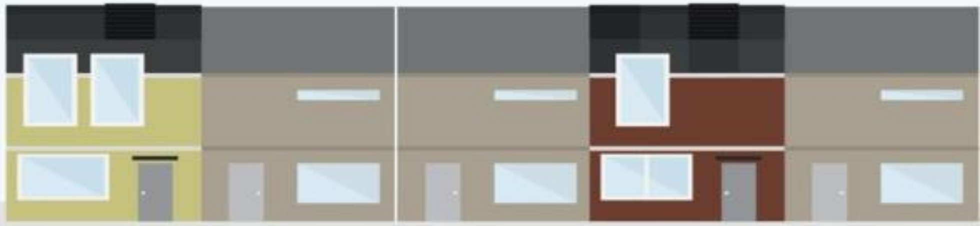


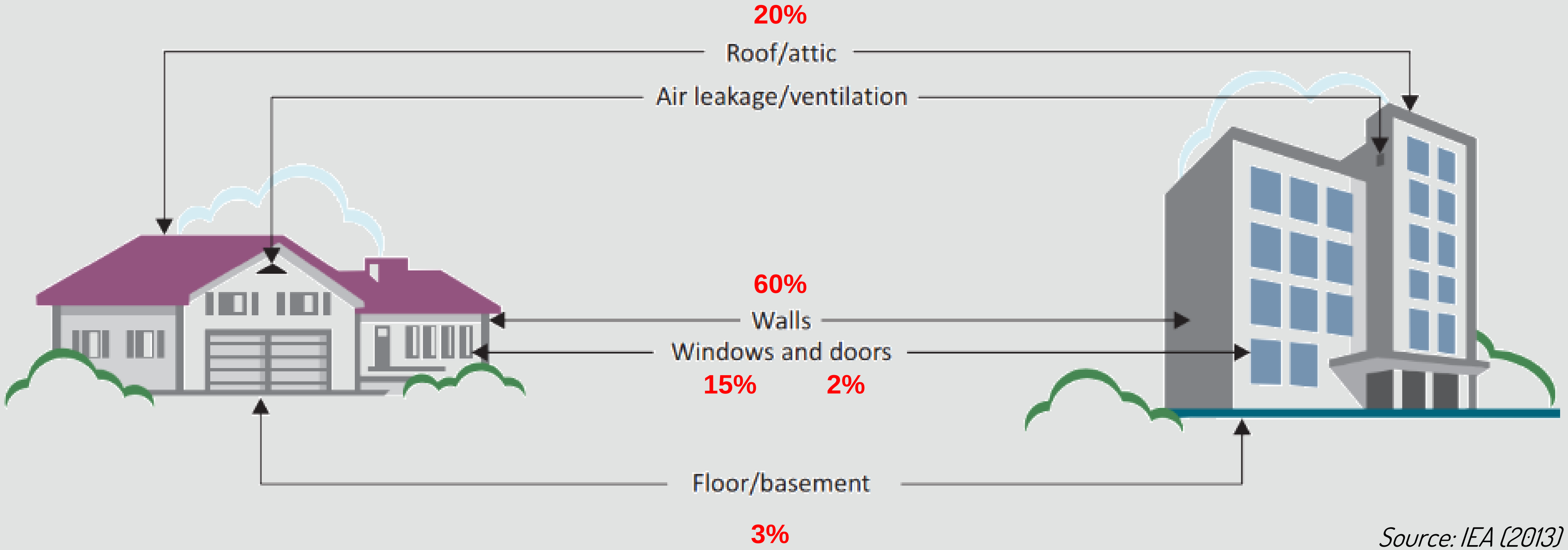
Role of Building Envelope

- Building envelope plays a key role in determining how much energy is needed to bring a home/room/building to comfortable levels in terms of heating, cooling, lighting, and ventilation.
- It includes walls, floors, roofs, ceilings, doors, and windows.
- Improved building envelope ➔ Less thermal losses ➔ Improved indoor comfort levels ➔ Reduced energy consumption
- Building envelope helps preserve the heating and cooling power produced inside the house and avoids energy loss from the interior to the exterior or vice versa.



Role of Building Envelope

What Building Envelope Includes



Source: IEA (2013)

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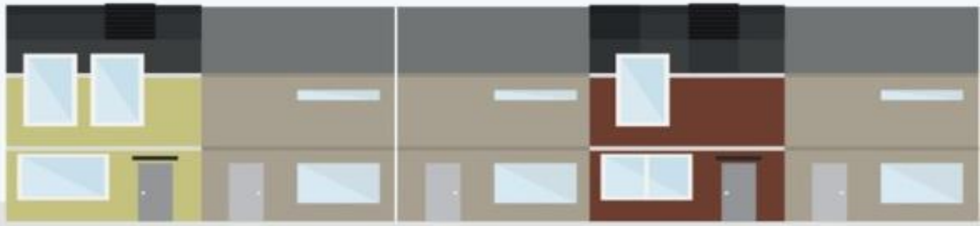

Role of Building Envelope

- Globally, space heating and cooling make up more than 30% of buildings energy consumption, going up to 50% in colder climates with more than 60% in the residential sector in these climates.
- Building Envelope protects from wind, rain, solar irradiation, heating and cooling loses, visibility and glare, fire, and noise
- Functions of BE:
  - Adding structural support
  - Controlling moisture and humidity
  - Regulating temperature
  - Controlling air pressure changes

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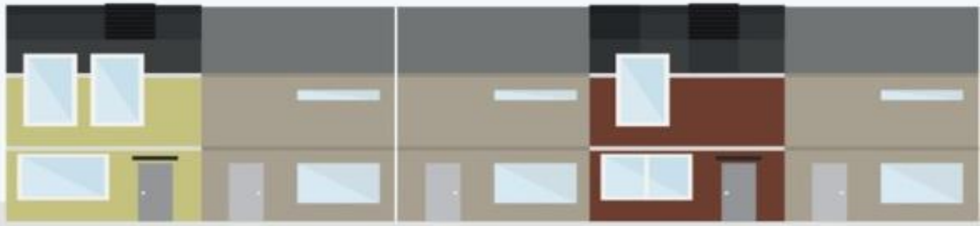
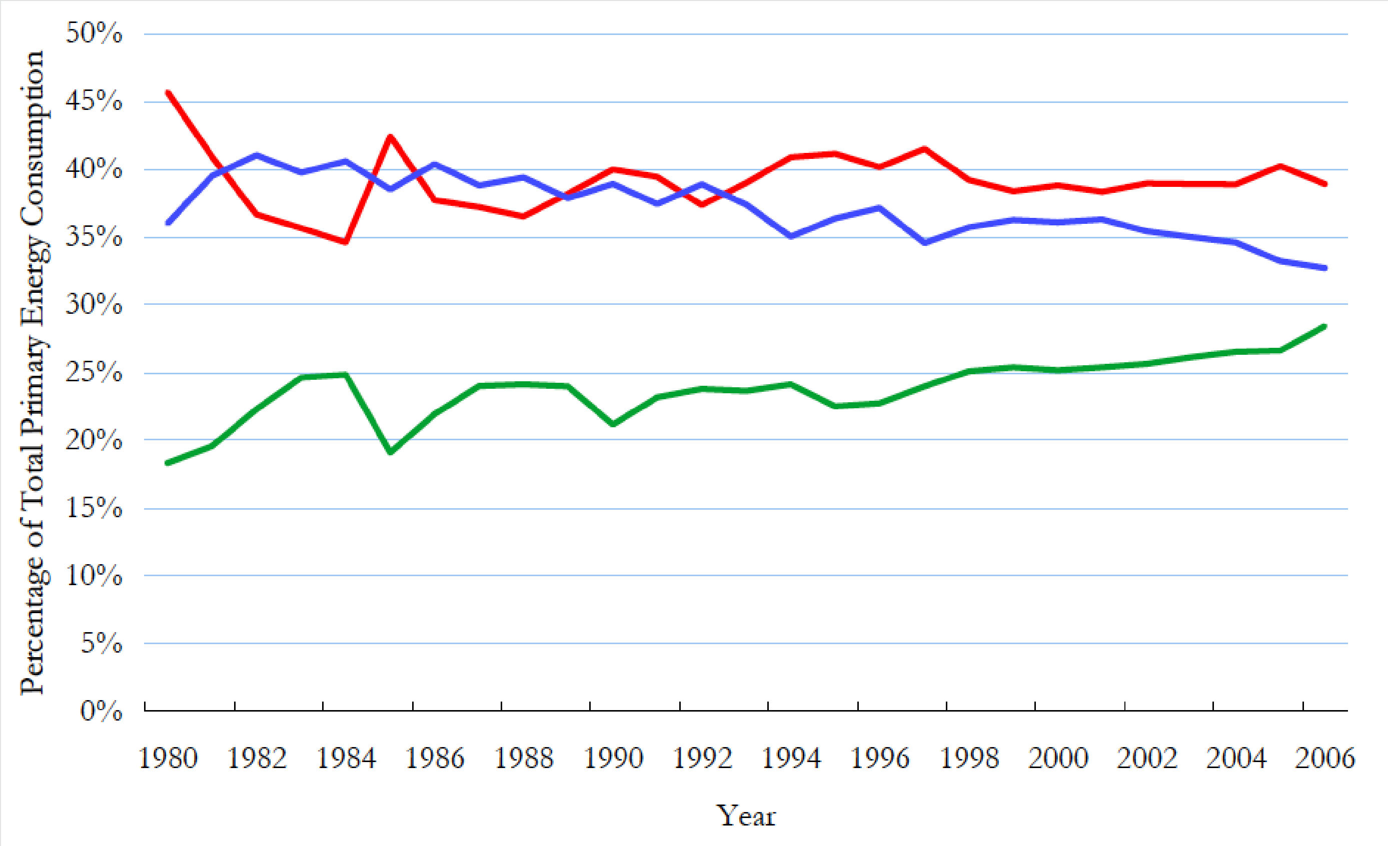
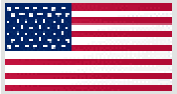


Role of Building Envelope





Buildings

Industry

Transportation

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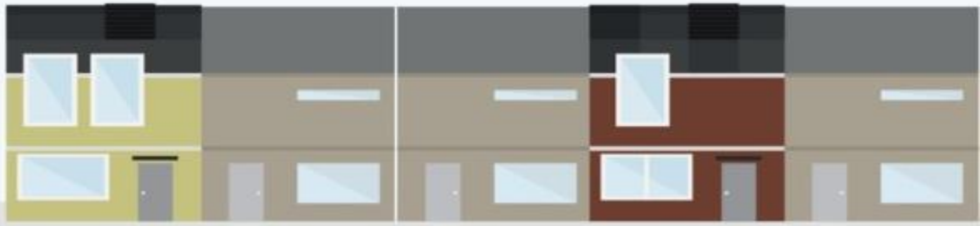
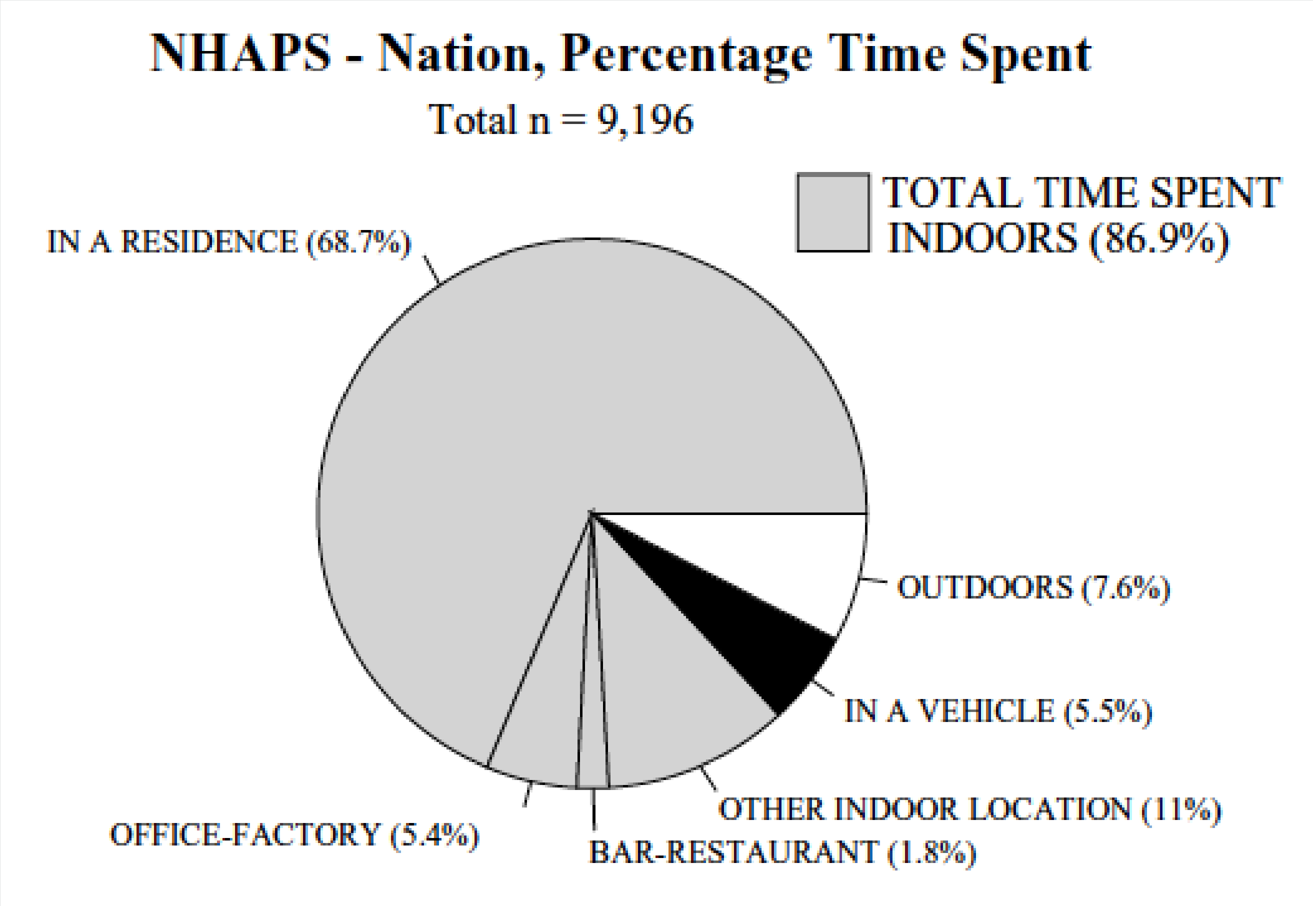
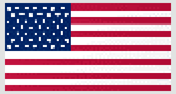


Role of Building Envelope





Source: Klepeis (2001)

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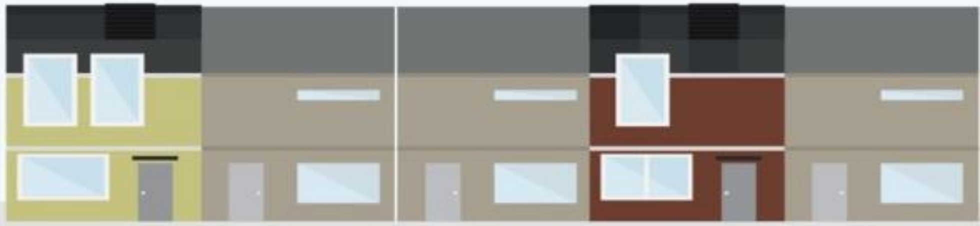
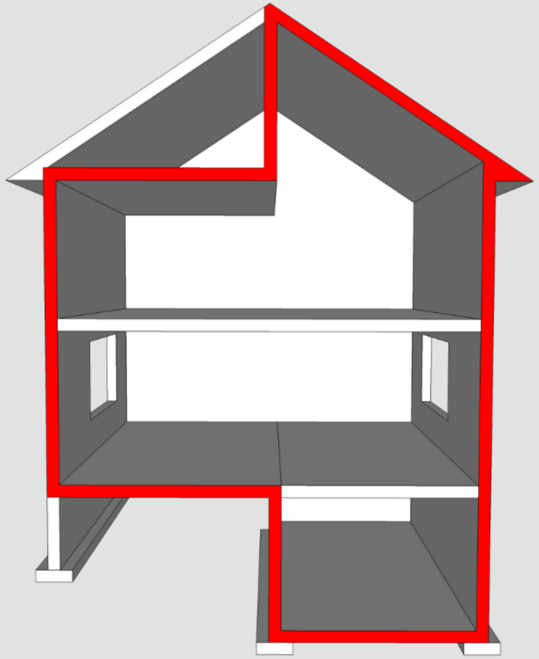


Role of Building Envelope

What Makes a Good Building Envelope?

It needs to meet the indoor thermal, acoustic, and visual comfort along with requirements for humidity conditions for both comfort, and mold and mildew growth prevention



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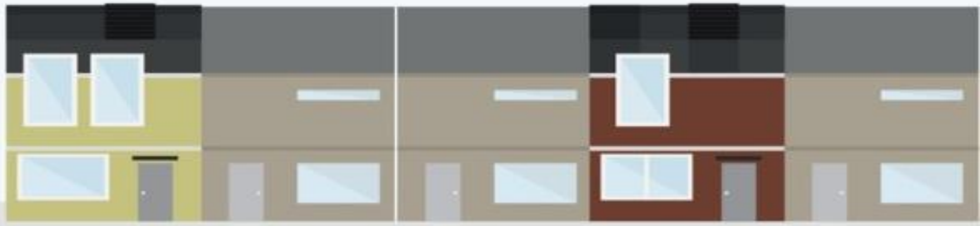

Role of Building Envelope

Kef Factors:

- **Thermal Insulation:** high levels of wall, roof, and floor insulation in walls ➔ reduces heat loss in cold climates and cooling loss in hot climates
- **Windows:** high-performance windows, with low thermal transmittance and climate-appropriate solar heat gain coefficients (SHGC)
- **Walls:** highly reflective surfaces in hot climates using white and light colors
- **Air Tightness:** properly sealed structures ➔ low air infiltration rates, with controlled ventilation for fresh air
- **Thermal bridges**: minimize the presence of components that easily conduct heat such as high thermal conductive fasteners and structural members, , known as thermal bridges

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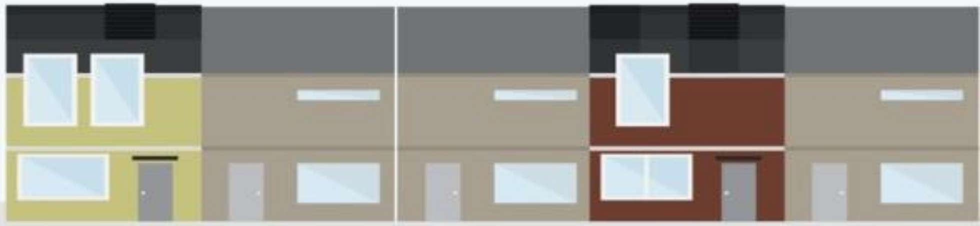
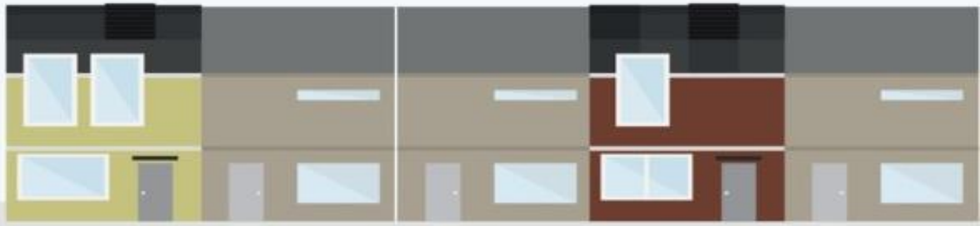


Role of Building Envelope

Impact of Improved Thermal Performance

1. Reduction of annual energy consumption and operating costs for heating cooling, and humidity control
2. Reduces peak loads which leads to a reduction in the sizing of heating, cooling and energy generation equipment ➔ Reduction in investment cost
3. Higher thermal comfort as a result of warmer surface temperatures on the interior surfaces in winter and lower temperatures in summer ➔ lower risk of mold growth on internal surfaces

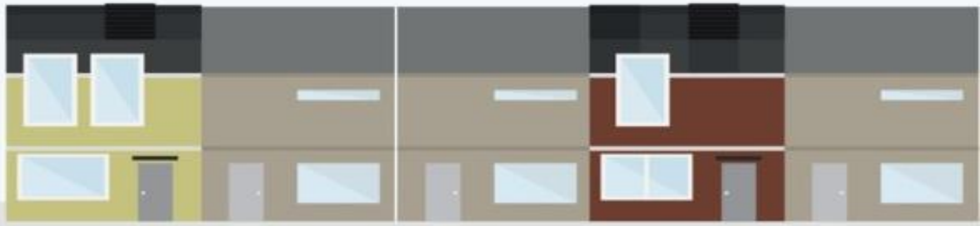


Role of Building Envelope

Available Building Envelope Technologies in Developed Economies

Type of economy	*Climate*	*Technology*	
		New construction	*Retrofit*
		*Insulation, air sealing and double-glazed low-e windows for all buildings**	
Developed	Hot climate	• Architectural shading • Very low-SHGC windows (or dynamic shades/windows) • Reflective walls/roofs • Advanced roofs (integrated design/BIPV) • Optimised natural/mechanical ventilation.	• Exterior window shading and dynamic glass/shading • Reflective roofing materials and coatings • Reflective wall coatings • Window film with lower SHGC • New low-SHGC windows.
	Cold climate	• Highly insulated windows • Passive heating gain (architectural feature /dynamic glass/shades) • Passivhaus-equivalent performance based on LCC limitations.	• Highly insulated windows • Low-e storm or interior panels • Insulated shades and other insulating attachments (low-e films) • Exterior insulating wall systems • Interior high-performance insulation.

Source: IEA (2013)



Role of Building Envelope

Available Building Envelope Technologies in Developing Economies

Type of economy	Climate	Technology	
		New construction	Retrofit
		Insulation, air sealing and double-glazed low-e windows for all buildings*	
Developing	Hot climate	• Exterior shading and architectural features • Low-SHGC windows • Reflective roofs and wall coatings • Optimised natural/mechanical ventilation.	• Exterior shading • Reflective coatings (roof and wall) • Low-cost window films • Natural ventilation.
	Cold climate	• Highly insulated windows (possibly double-glazed with low-e storm panel) • Passive heating gain (architectural feature) • Optimised low-cost insulation and air sealing.	• Low-e storm or interior panels • Insulated shades and other insulating attachments (low-e films) • Exterior insulating wall systems • Cavity insulation, lower-cost (e.g. expanded polystyrene) interior insulation.

Source: IEA (2013)

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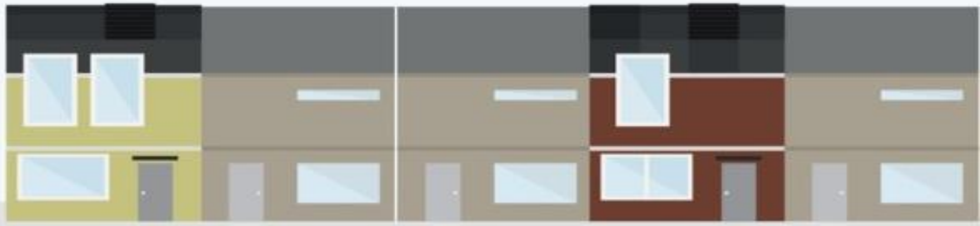
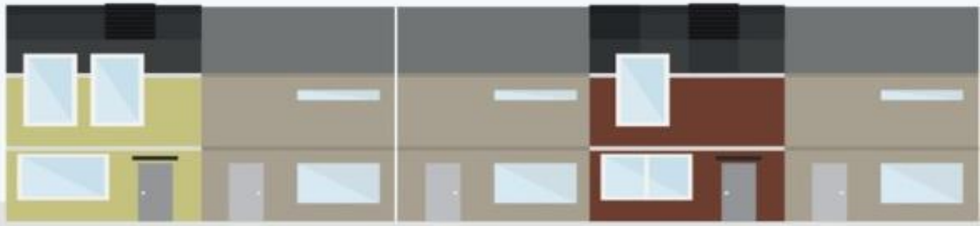


Role of Building Envelope

Passive Design

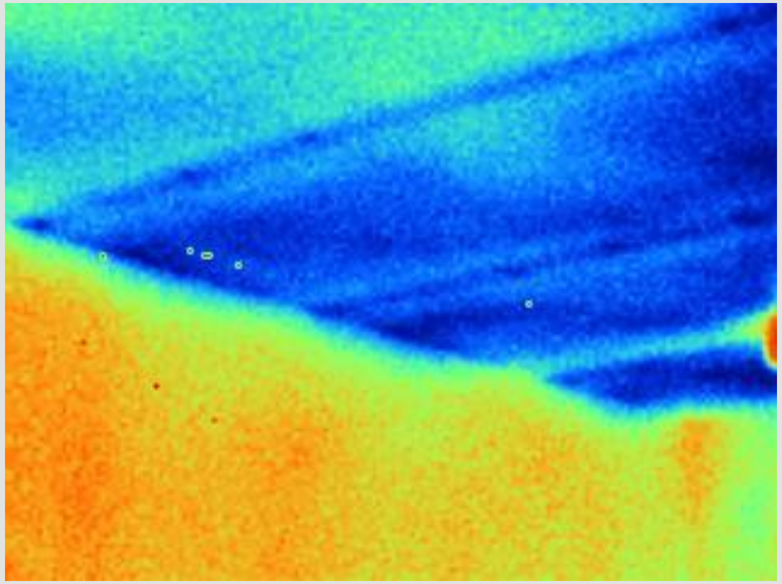
- A design that takes advantage of climatic conditions to maintain a comfortable temperature range in the building
- Results ➔ reduction in cooling and heating demand
- Methods:
  - Climate-specific design
  - Proper building orientation
  - Enhanced building envelope design
  - Effective shading using eaves, window awnings, shutters, pergolas and plantings, etc…



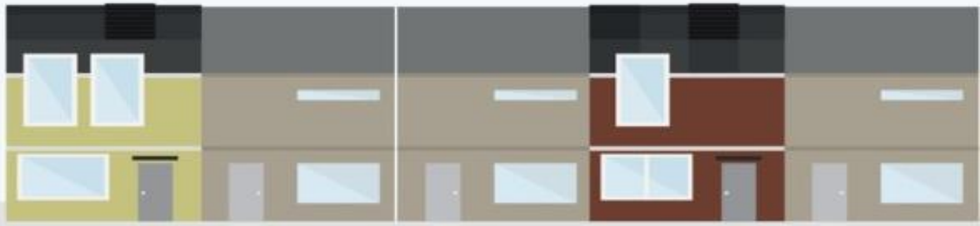
Thermal Insulation (1/8)

Uses

- Thermal insulation is used to reduce heating and cooling losses.
- Insulation’s ability to resist heat flow is referred to as R-Value



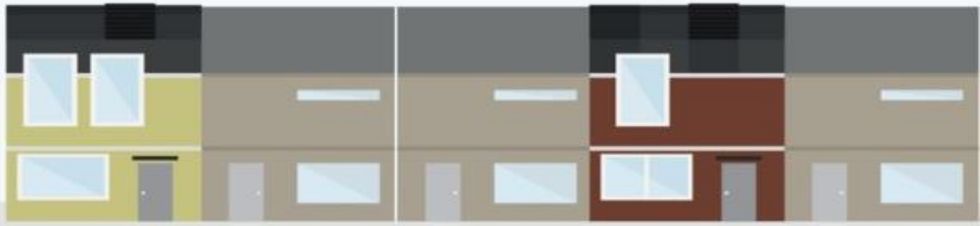
Missing insulation in the ceiling



Thermal Insulation (2/8)

Types – LOOSE-FILL

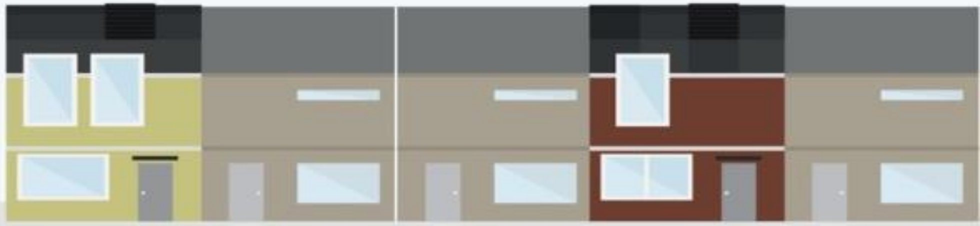
Insulation Type	R-value/in	Cost/m^2	Advantages	Disadvantages
Cellulose	3.1–3.7	Low €0.03 (R-13) €0.09 (R-38)	+ Better air barrier + Continuous insulation barrier ➔ maintain rated R-value + High use of recycled content	- Weight➔ settling & reduction in R-value over time - High cost for wall-cavity - Requires fire-retardant chemicals ➔ impacted by water vapor sorption
Fiberglass	2.2–2.9 (3.4–4.2) dense-pack	Low €0.04 (R-11) €0.10 (R-26)	+ Better air barrier + Continuous insulation ➔ achieve rating	- May settle over time. Less than with cellulose - Higher installation costs
Mineral Wool (Rock / slag wool)	2.2–2.9	Low €0.05-0.09	+ Non-combustible + Good sound attenuation	- Potential creation of airborne respirable particles



Thermal Insulation (3/8)

Types – BATTS

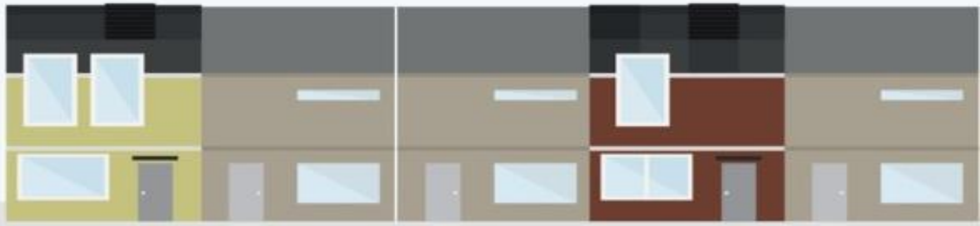
Insulation Type	R-value/in	Cost/m²	Advantages	Disadvantages
Fiberglass Batts	2.2–2.9	Low Unfaced: €0.04 (R-11) €0.10 (R-38) Kraft-faced: €0.04–1.12	+ Low cost + Very low installation cost + Good fire protection	- Known carcinogen
Cotton Batts	3.0–3.7	Medium €0.05 (R-11) €0.06 material cost only	+ High recycled content 75% + Easier installation + Good sound absorption + Less respiratory problems (vs fiberglass)	- (Unfaced only) vapor retarder must be added separately - Water leakage can affect fire retardant - not always readily available
Plastic fiber (PET) Batts	3.8–4.3	N/A	+ Recycled content + Less skin irritation	- Melts at a low temperature - More difficult to handle



Thermal Insulation (4/8)

Types – SPRAY-IN FOAMS

Insulation Type	R-value/in	Cost/m^2	Advantages	Disadvantages
Polyurethane foam	5.6–6.2	€0.16	+ High R-value + Provide a vapor barrier	- More expensive - Use fluorocarbons
Low-density urethane foam	3.6	€0.12	+ Use water or CO_2 as blowing agent	
Icynene foam	3.6–4.3	N/A	+ Fits different construction + No VOC emission + Good sound attenuation	- More expensive
Wet-spray cellulose	2.9–3.4	Low	+ High recycled content + Fits unfinished spaces with exposed studs	- Delay to fully dry - Excess water ➔ rot / mildew
Spray-in fiberglass	3.7–3.8	Low	+ Popular choice for hard to reach areas	- Overfluffing ➔ less - Material ➔ less R-value
Cementitious	3.9	€0.14	+ Best near obstructions + Works well at low T + Non-toxic, Non-flammable	- Costly to retrofit



Thermal Insulation (5/8)

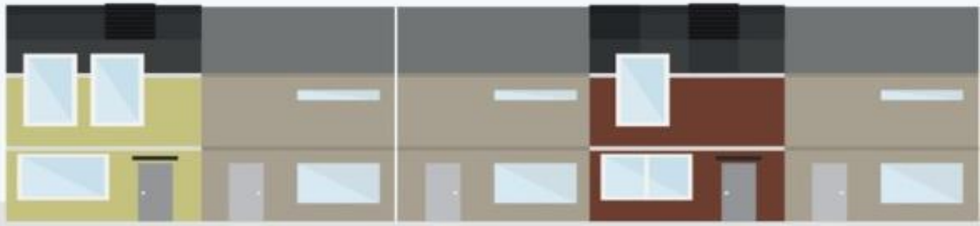
Types – RIGID FOAMS

Insulation Type	R-value/in	Cost/m^2	Advantages	Disadvantages
Expanded Polystyrene	3.9(16kg/m^3) 4.2(32kg/m^3)	Low-Medium €0.06-€ 0.10	+ Good moisture resistance + Maintains rated R-value	
Extruded Polystyrene	5.0	Medium €0.07 (R-5) €0.15 (R-15)	+ Excellent moisture resist. + R-value increases at low T + Suitable for below-grade	
Polisocyanurate	5.6–7.0	Medium €0.07 (R-3.9) €0.19 (R-29)	+ High R-value + Good compressive strength	- R-value degrades over time
Polyurethane	5.6–7.0	N/A	+ High R-value	
Phenolic	8.2 (close) 4.4 (open)	N/A	+ Good fire resistance + Uses air as a blowing agent	- Shrinkage occurs over time

Thermal Insulation (6/8)

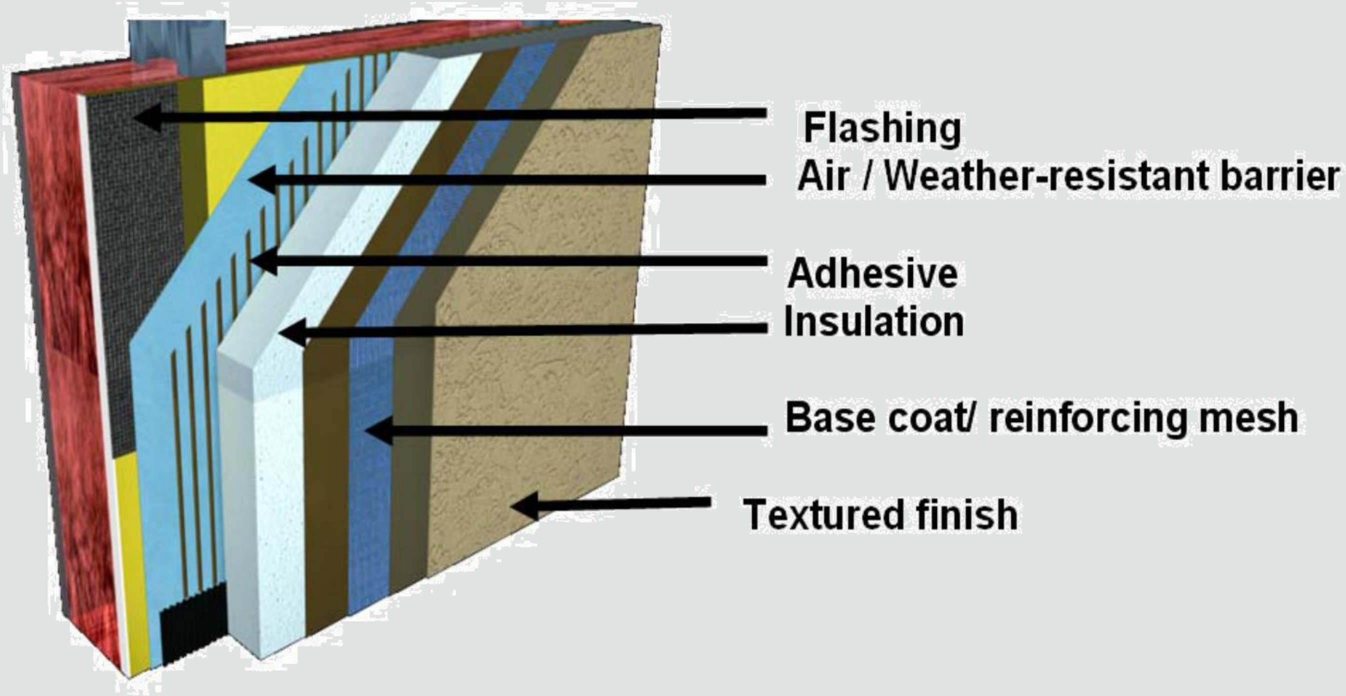
Modes of Installation

Outside Insulation **Inside Insulation**



Thermal Insulation (7/8)

Modes of Installation – EWIS

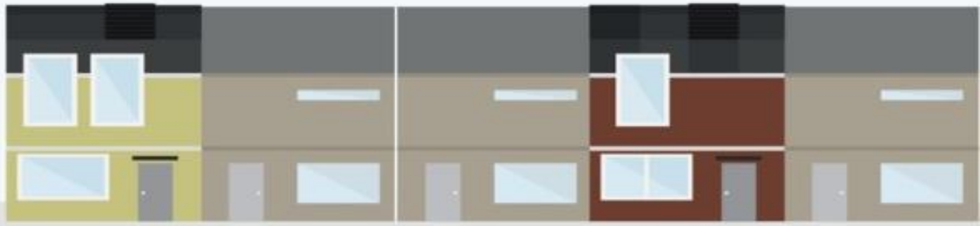


Thermal Insulation (8/8)

Modes of Installation – EWIS

2. BUILDING ENVELOPE

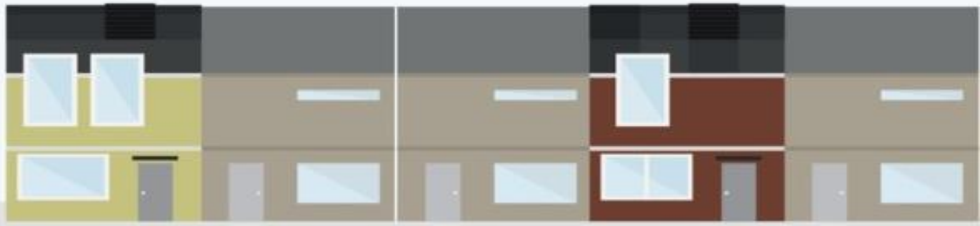
MORE—CONNECT



Building Envelope Technologies

Air Sealing

- Prevention of unnecessary air leakage avoids unwanted heat loss
- Should be considered at the design stage but can also be applied in retrofits
- Methods:
  - Caulking
  - Spray foam
  - Weather stripping
- Potential Saving: 5% to 40% of HVAC consumption

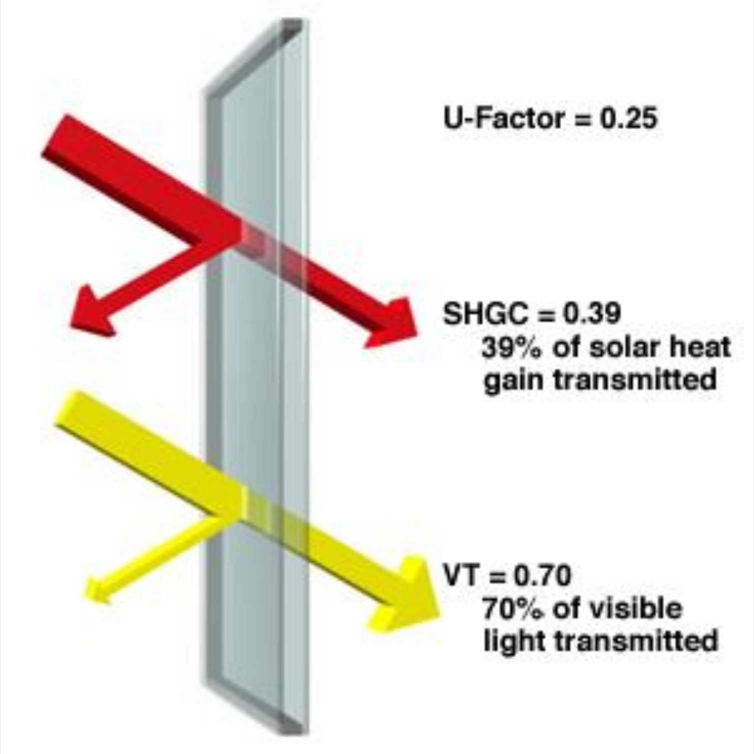


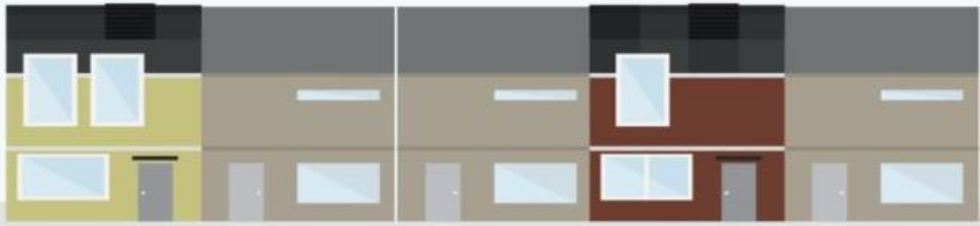
Building Envelope Technologies

Windows (1/8)

- Also known as fenestration (includes windows, exterior doors, skylights…)
- Methods:
  - Multiple glazing
  - Film Insulation
  - Coating
- Potential saving:

  10% - 40% on lighting & HVAC consumption



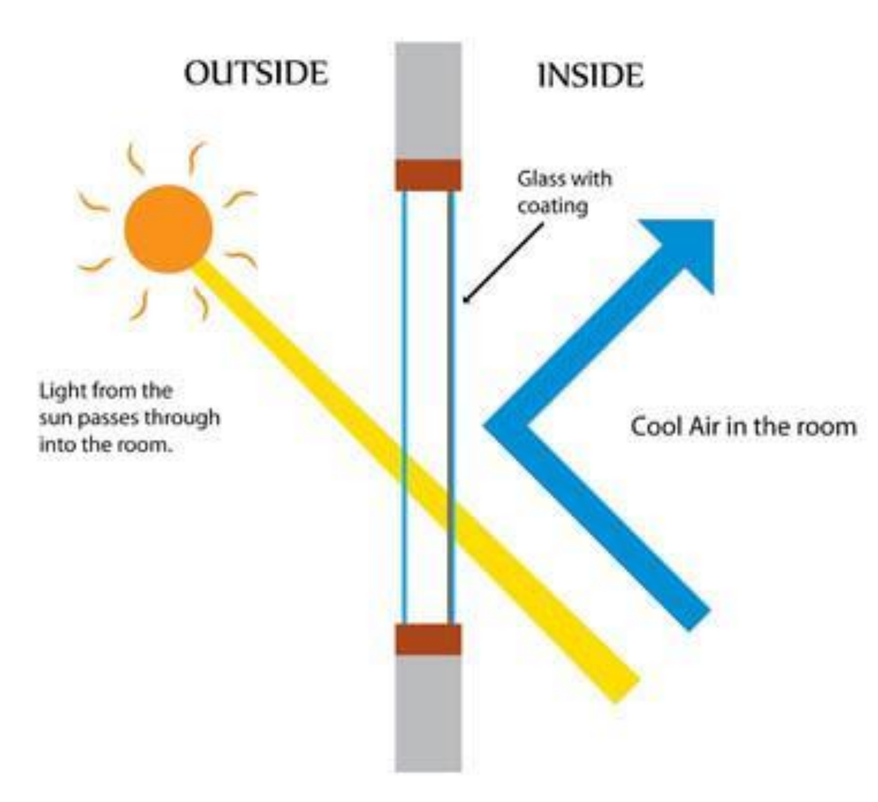


Building Envelope Technologies

Windows (2/8)

Multiple Glazing

- Could be double or triple glazing
- Consists of glass panes and air in between
- Reduces heat transfer between mediums



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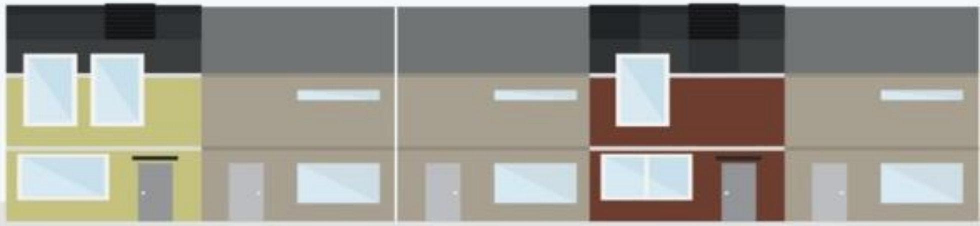
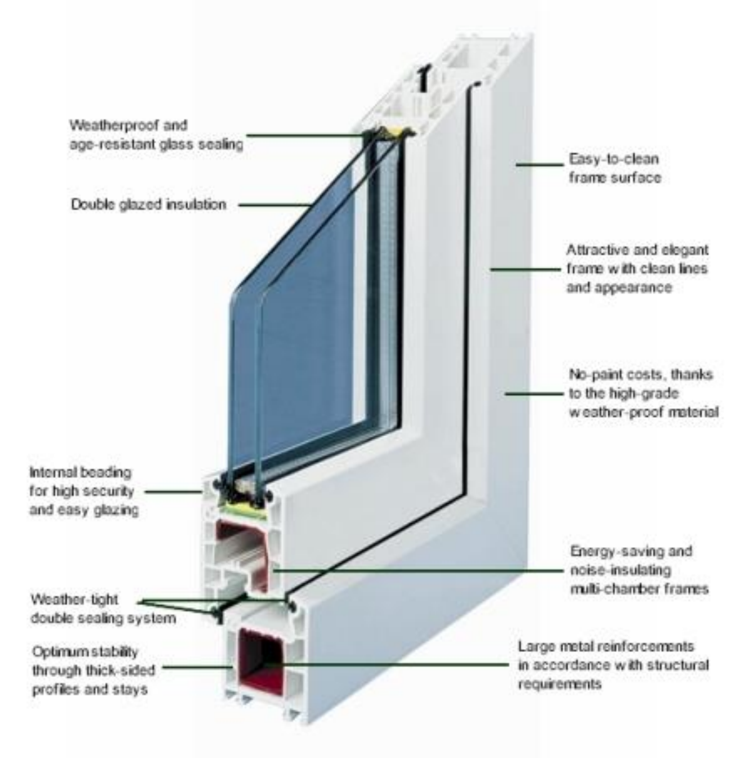
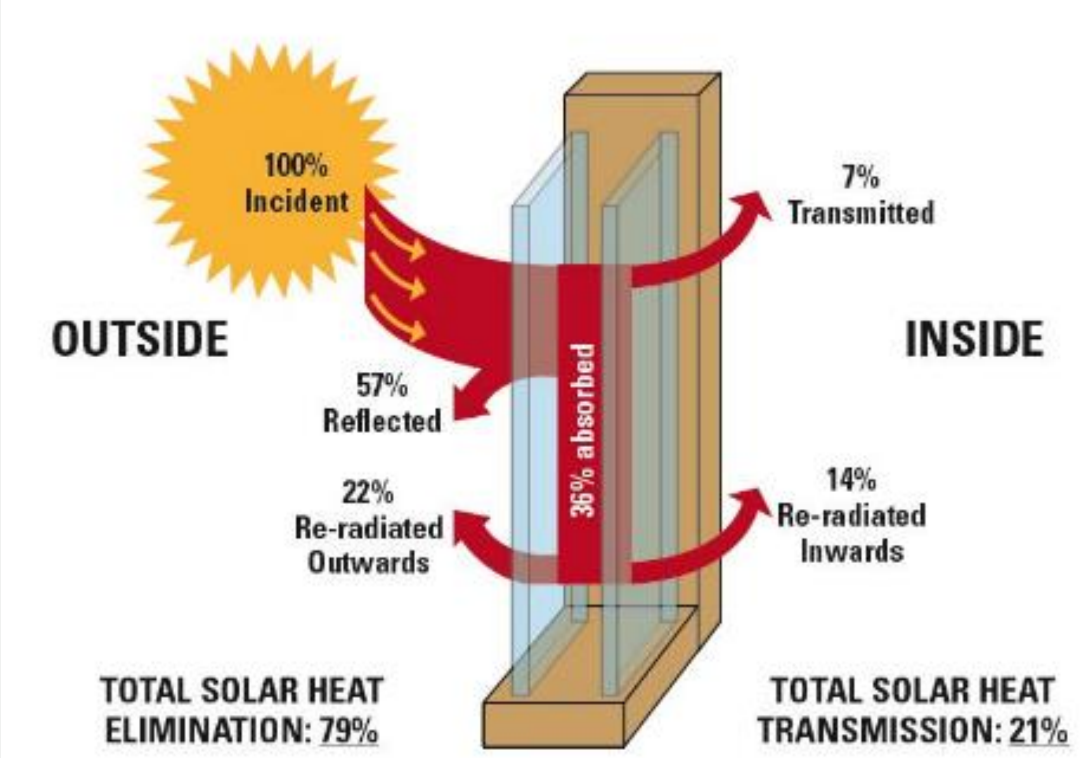


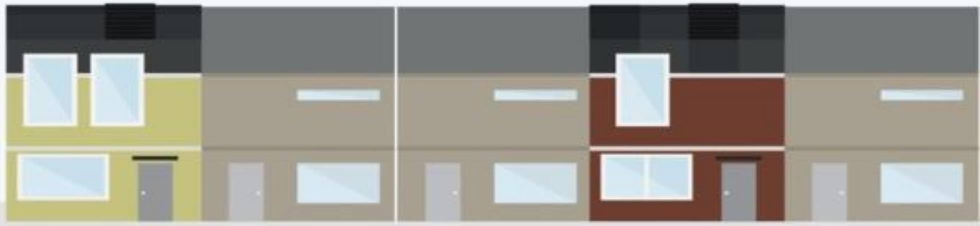
Building Envelope Technologies

Windows (3/8)

Multiple Glazing – Double Glazing



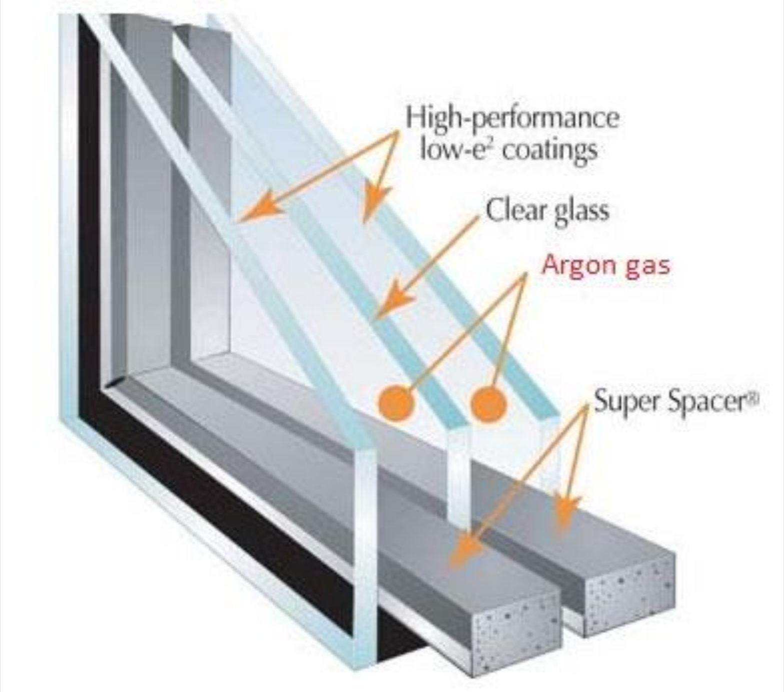


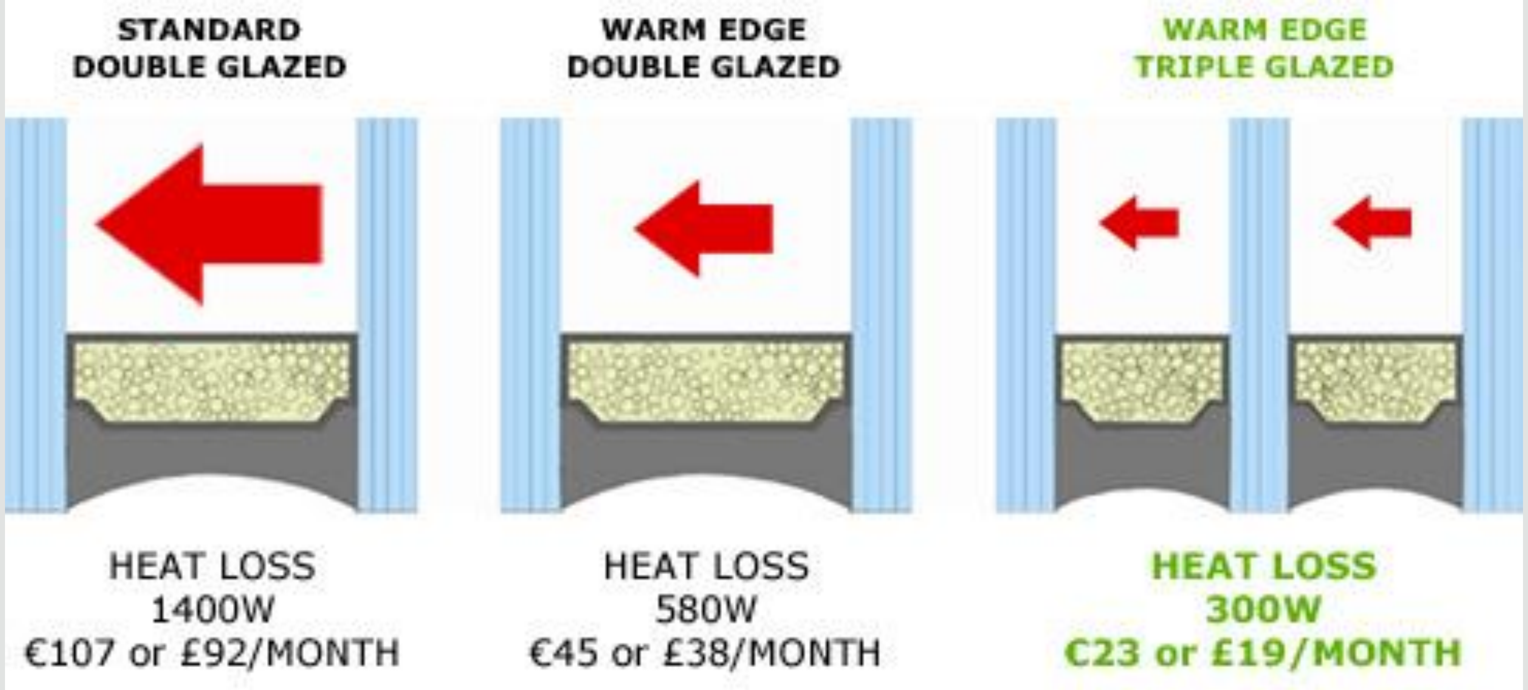


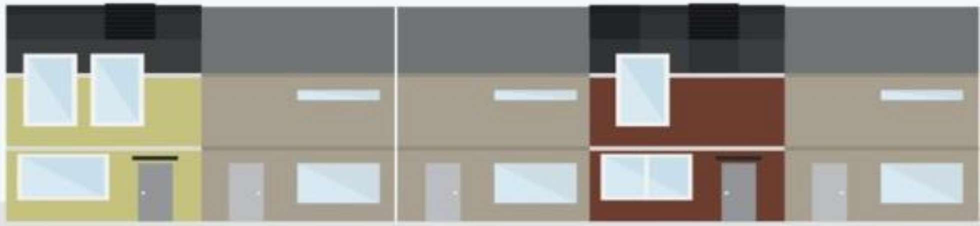
Building Envelope Technologies

Windows (4/8)

Multiple Glazing – Triple Glazing





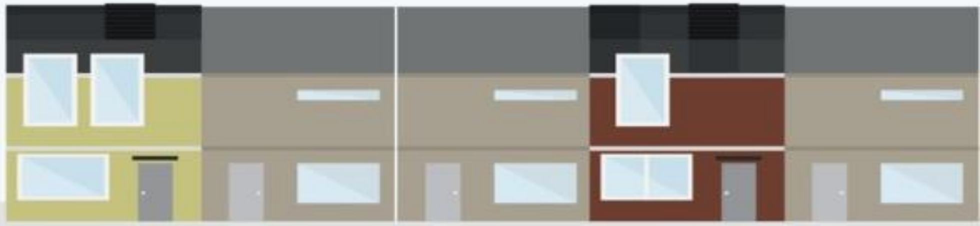


Building Envelope Technologies

Windows (5/8)

Low-E Windows

- Effectiveness Measurements:
    - **U-Value**: how much heat loss it allows
    - **Visible Light Transmittance (VLT):** how much light passes through
    - **Solar Heat Gain Coefficient (SHGC):** the fraction of incident solar radiation admitted through a window, both directly transmitted and that is absorbed and re-radiated inward.
    - **Light to Solar Gain:** the ratio between the window's Solar Heat Gain Coefficient (SHGC) and its visible light transmittance (VLT) rating.



Building Envelope Technologies

Windows (6/8)

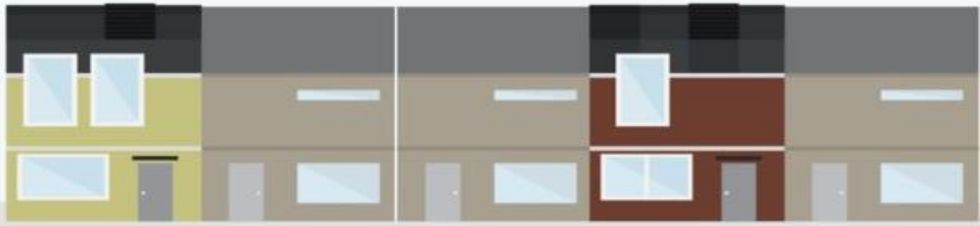
Low-E Windows – Ratings

Low-E, ½" airspace, ¼" clear	U-Value	VLT	SHGC	LSG
Pyrolytic	0.33 – 0.37	54% – 74%	0.45 – 0.66	1.09 – 1.25
Double-Silver MSVD (High VLT/Low Reflectance)	0.29 – 0.29	53% – 70%	0.28 – 0.39	1.76 – 1.98
Triple-Silver MSVD (High VLT/Low Reflectance)	0.28 – 0.29	61%	0.27 – 0.30	2.17 – 2.37

Building Envelope Technologies

Windows (7/8)

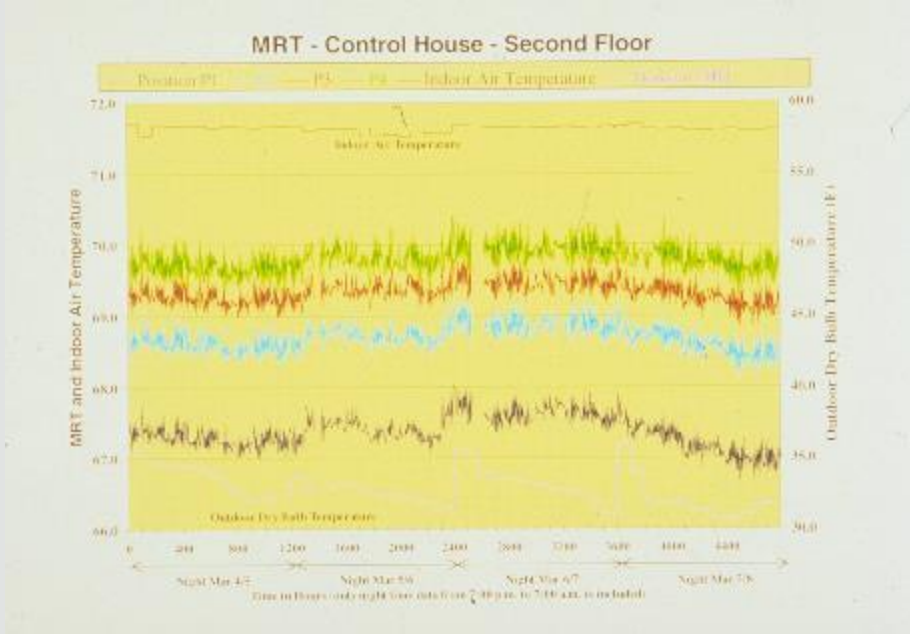
Low-E Windows – Effectiveness Assessment

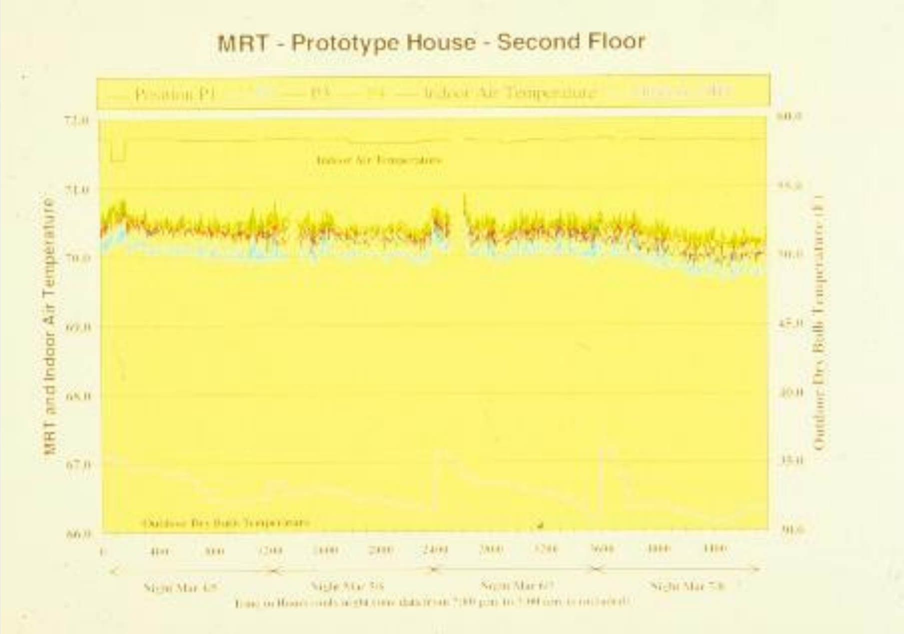


Building Envelope Technologies

Windows (8/8)

Low-E Windows – Effectiveness





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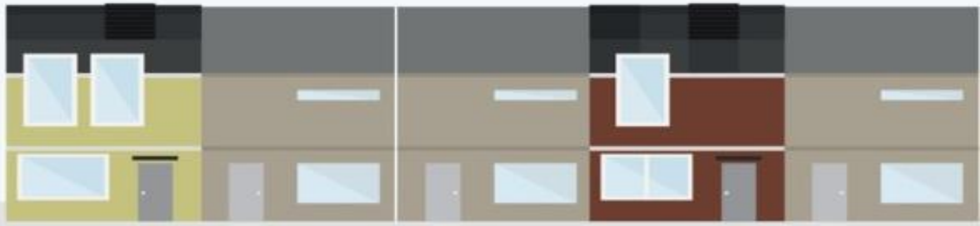
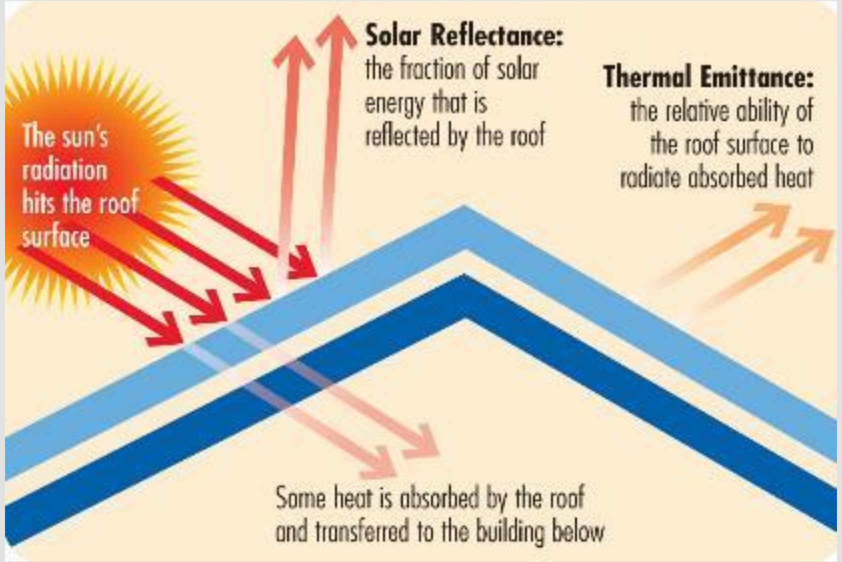


Building Envelope Technologies

Cool Roof

- Material with a reflective surface installed in the roof
- Measured by solar reflectance and thermal emittance
- Potential Saving:
    - 2-10% reduction in cooling cost.



2. BUILDING ENVELOPE

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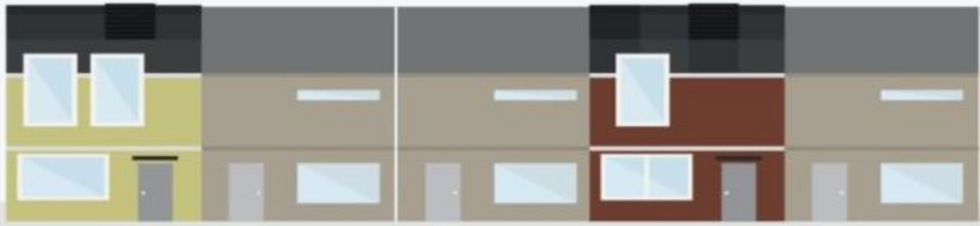
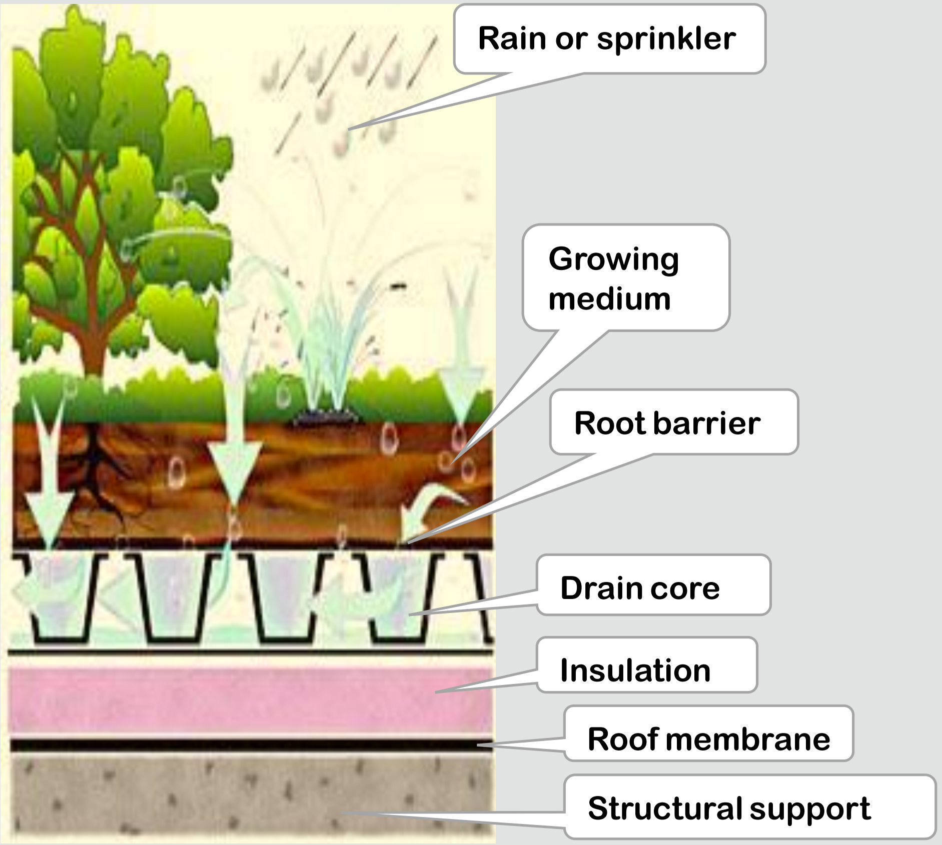
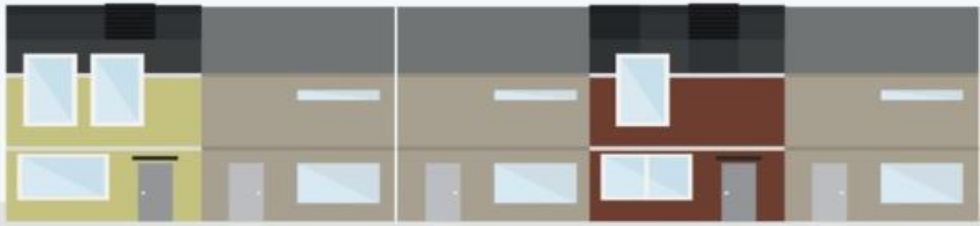


Building Envelope Technologies

Green Roof

- Roof with vegetation and a growing medium, over a waterproofing membrane
- Acts as roof insulation
- Steps
  - Check building codes
  - Test structure for extra weight
  - Plan access to the roof
  - Design irrigation & drainage systems
  - Select plants and growing media





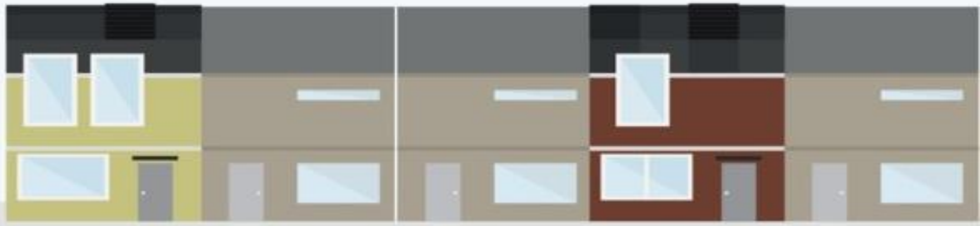
Policies, Codes and Regulations

The European Energy Efficiency Plan

- Adopted on 8 March 2011, (COM 2011 (109) final)
- Provides strategic framework for EE policy in Europe up to 2020 and beyond
- Messages include:
  - Conditionality on the spending of public funds
  - Innovative financial instruments
  - Energy service companies
  - Increased role of energy companies

- The 2010 Energy Performance of Buildings Directive (EPBD) & the 2012 Energy Efficiency Directive (EED) are the EU's main legislation related to energy consumption of buildings.

2. BUILDING ENVELOPE



Policies, Codes and Regulations

Energy Performance of Buildings Directive (EPBD)

- Energy performance certificates to be included in all ads for buildings sales/rent
- Inspection schemes for heating & ACs should be established in EU countries
- All new private buildings ➔ nearly zero energy buildings by Dec 2020
- All new public buildings ➔ nearly zero energy buildings by Dec 2018
- EU countries must set MEP requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.)
- Financial measures to improve the EE in buildings

2. BUILDING ENVELOPE

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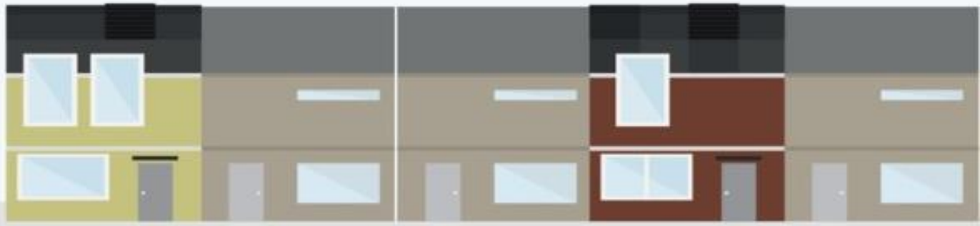
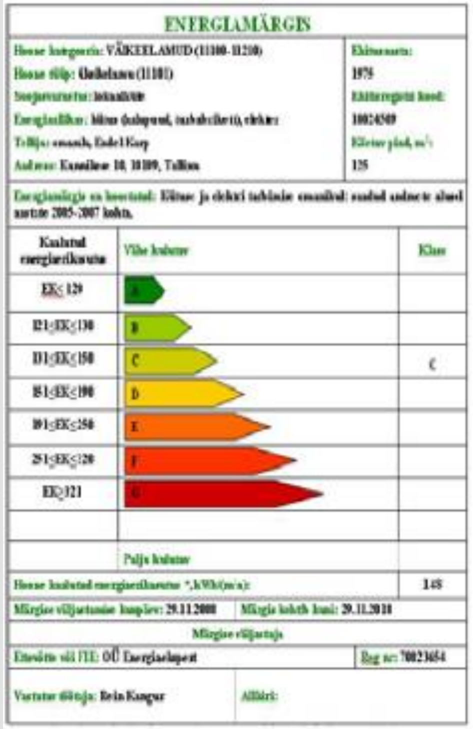
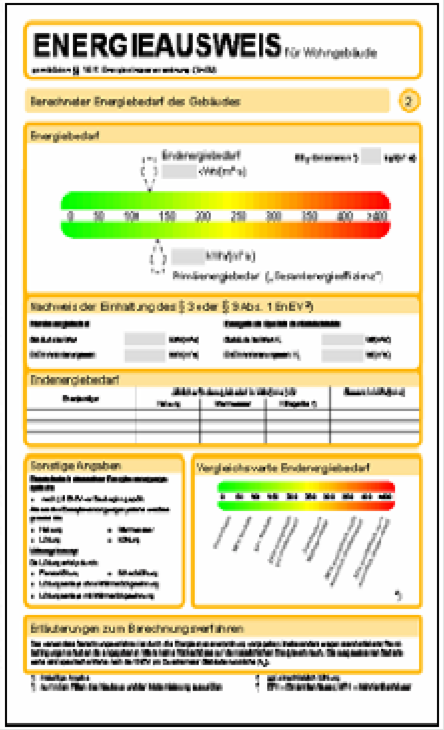
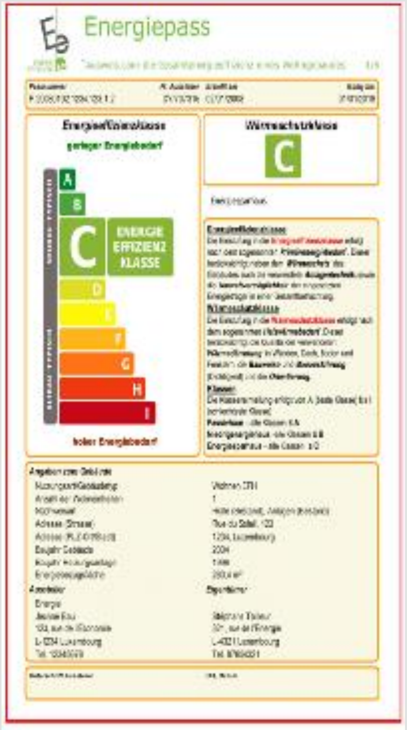


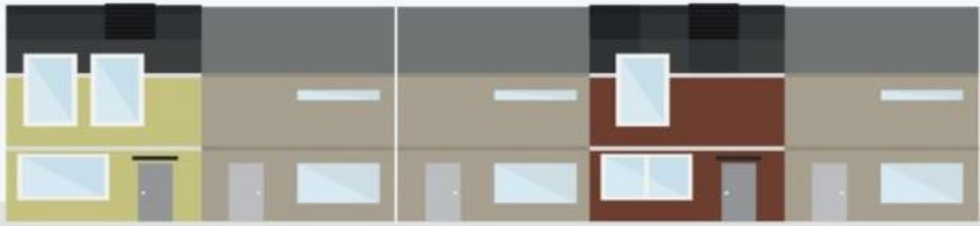
Policies, Codes and Regulations

Energy Performance of Buildings Directive (EPBD)









Policies, Codes and Regulations

Energy Performance of Buildings Directive Recast

- Published in OJ: June 2010

  Transposition July 2012

  Application by Jan/July 2013
- Continuity with 2002 Directive: Main principles are kept, but made more effective (certificates, inspections)
- Elimination of the 1000 m^2 threshold for existing buildings
- Obligatory use of performance indicator given in the certificate

2. BUILDING ENVELOPE

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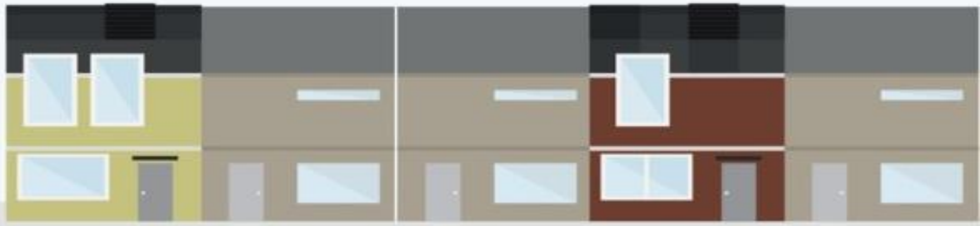

Policies, Codes and Regulations

Energy Efficiency Directive (EED)

- EU countries make energy efficient renovations to at least 3% of buildings owned and occupied by central government
- EU governments should only purchase buildings which are highly energy efficient
- EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans (NEEAP)

2. BUILDING ENVELOPE

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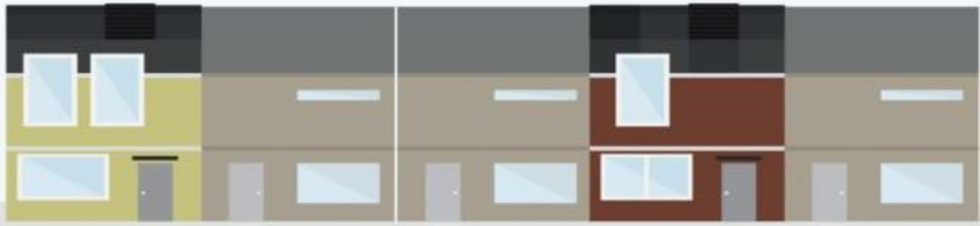
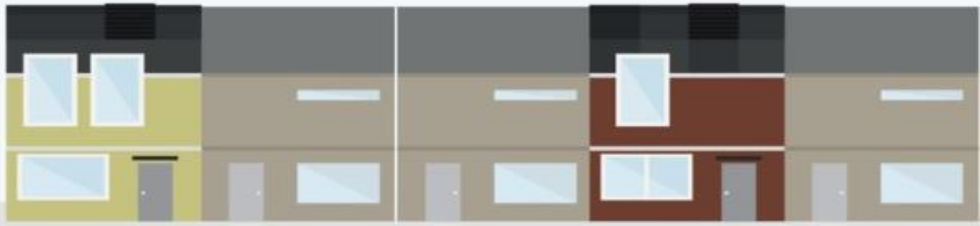


Policies, Codes and Regulations

Supporting Policies

- There have been various pieces of EU-wide legislation to improve the energy performance of buildings to mitigate GHG emissions
  - Energy Performance in Building Directive (2002)
  - Energy Efficiency Action Plan (2006)
  - End-use Efficiency and Energy Services Directive (2006)
- These have been implemented at a sub-national level through mechanisms such as the building regulations in the UK that developed its own targets:
  - Energy White Papers 2003, 2007
  - Climate Change Act (2008);

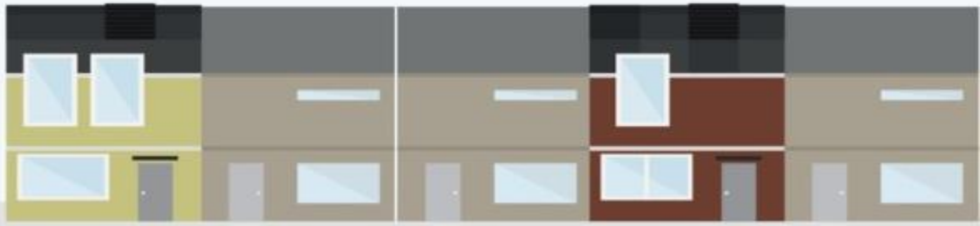
  ➔deep carbon reductions (80% by 2050)



Policies, Codes and Regulations

Supporting Policies - PassivHaus (1/3)

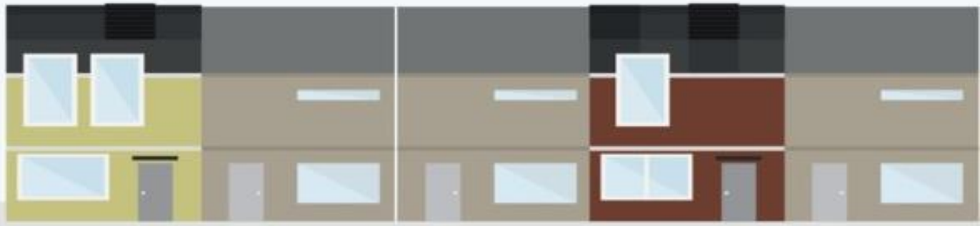
- A voluntary standard for energy efficiency in a building, reducing its ecological footprint ➔ reduced energy consumption for space heating or cooling.
- A similar standard, MINERGIE-P, is used in Switzerland.
- The standard applies to residential properties, office buildings, schools, supermarkets, etc…
- PassivHaus standard is becoming adopted mainly in Northern EU countries.



Policies, Codes and Regulations

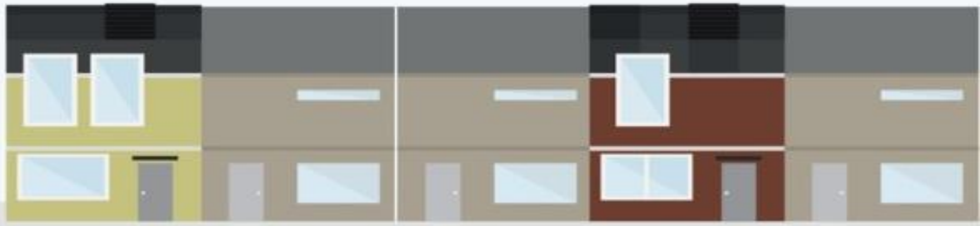
Supporting Policies - PassivHaus (2/3)

- **Wall Insulation:**
  - ✓ U-values < 0.15 W/m2K
- **Building Construction:**
  - ✓ Thermal bridge free
  - ✓ Air-tightness of construction better than 0.6 air changes per hour (ACH) at 50 Pa with ventilation openings closed = 0.03 ACH at normal conditions)
- **Glazing:**
  - ✓ U-value <0.85 W/m^2K including installation, frame and glazing edge losses
  - ✓ Solar transmittance >50%
  - ✓ High efficiency ventilation system with heat recovery (MVHR);



Policies, Codes and Regulations

Supporting Policies - PassivHaus (3/3)



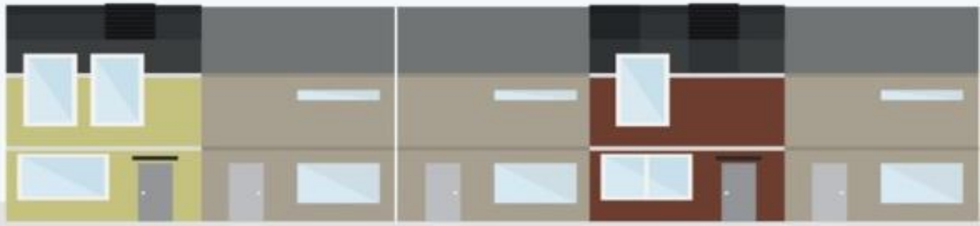
Policies, Codes and Regulations

Supporting Policies – Zero-Carbon House (1/3)

- Similar to PassivHaus with micro power generation

Definitions:

- **Autonomous ZEB:** demand met by on-site generation, no external network
- **Net-zero site energy:** Annual supply & onsite demand offset by local generation
- **Net-zero source energy:** Annual supply & primary energy demand offset by local generation
- **Lifecycle net-zero energy buildings:** Annual supply & primary energy with embodied energy demand offset by local generation



Policies, Codes and Regulations

Supporting Policies – Zero-Carbon House (1/3)

Standards

- England & Wales are the first to develop zero carbon standards for new homes
- Code for Sustainable Homes (CSH) (DCLG, 2008a) defined voluntary levels of performance (Codes 1 to 6)
- Two of these levels are described as zero-carbon buildings:
  - **Code 5** equates to a 100% reduction in regulated energy use, offset by RE. Energy use from appliances is not offset (unregulated energy use).
  - **Code 6** proposed zero-carbon including appliances by 2016. ➔ 140% reduction in regulated energy uses (heating and cooling) ➔100% reduction in regulated use + 40% from local electrical generation technologies (PV) to offset unregulated energy use

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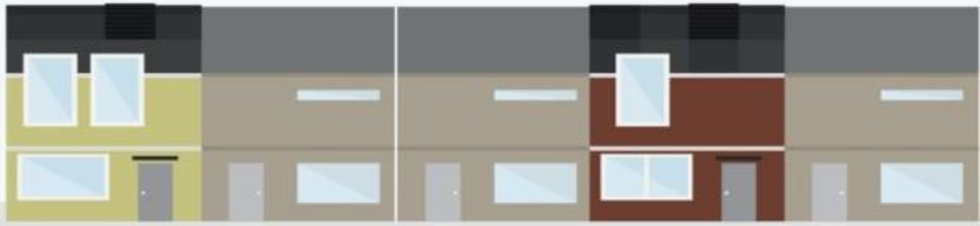


Policies, Codes and Regulations

Performance-based Requirements in New Buildings (1/2)

	Single Family Houses	Apartment Blocks	Offices	Educational Buildings	Hospitals	Hotels & Restaurants	Sports facilities	Wholesale & retail
	H: 66 kWh/m^2a	H: 66 kWh/m^2a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a	H: 22.75 kWh/m^3a C: 1 kWh/m^3a
Br	E70		E75	E75				E75 (services)
Wl	E<100, E_{spec}<170 kWh/m^2a, Overheating<17500 Kh/an	E<100, E_{spec}<170 kWh/m^2a, Overheating<17500 Kh/an	E<100	E<100				
Fl	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60				
	F:122-146 H&C: 82.5-102.5 kWh/m^2a	F: 90-146 H&C: 50.0-102.5 kWh/m^2a	F: 80-132 H&C: 40.0-82 kWh/m^2a	F: 56-98 H&C: 40-82.0 kWh/m^2a	F: 180-242 H&C: 50-102.5 kWh/m^2a	F: 176-230 H&C: 50-102.5 kWh/m^2a	F: 90-134 H&C: 40-82 kWh/m^2a	F: 90-134 H&C: 40-82 kWh/m^2a
	Space heating demand (effective energy): 5 litre heating oil equivalent per m^2 (based on MuKEn 2008)							
	H: 54 kWh/m^2a	H: 42 kWh/m^2a	H: 46 kWh/m^2a	H: 43 kWh/m^2a	H: 44 kWh/m^2a	H: 58 kWh/m^2a	H: 40 kWh/m^2a	H: 36 kWh/m^2a
	A or B category on the EPC scale							
	F: 142 kWh/m^2a	F: 120 kWh/m^2a	F: 179 kWh/m^2a	F: 130 kWh/m^2a	F: 310 kWh/m^2a	F: 294 kWh/m^2a	F: 145 kWh/m^2a	F: 183 kWh/m^2a
	New buildings must not exceed a defined primary energy demand for heating, hot water, ventilation, cooling and lighting installations (lighting installations only for commercial) based on of a reference building of the same geometry, net floor space, alignment and utilisation.							
	P: 52.5+1650/A kWh/m^2a	P: 52.5+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a	P: 71.3+1650/A kWh/m^2a
	P: 180 kWh/m^2a	P: 150 kWh/m^2a	P: 220 kWh/m^2a	P: 300 kWh/m^2a	P: 400 kWh/m^2a	P: 300 kWh/m^2a	P: 300 kWh/m^2a	P: 300 kWh/m^2a
	The Primary energy requirement for new and renovated building in Greece is = 0.33 – 2.73 x Reference Building energy performance							
	The energy performance requirements is not expressed in units of kWh/m^2a							
	This is based on thermal transmittance (heat loss) measured in units of W/K. For a single family house, a typical value is 134 W/K							

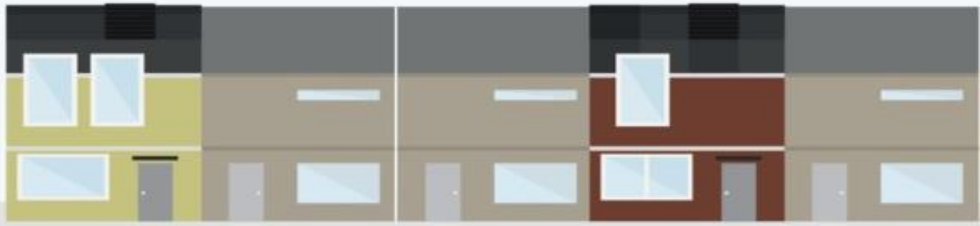
2. BUILDING ENVELOPE

MORE — CONNECT

Policies, Codes and Regulations

Performance-based Requirements in New Buildings (2/2)

	Single Family Houses	Apartment Blocks	Offices	Educational Buildings	Hospitals	Hotels & Restaurants	Sports facilities	Wholesale & retail
H1	P_{FF}: 130 kWh/m^2a P_{ESH}: 250 kWh/m^2a	P_{FF}: 130 kWh/m^2a P_{ESH}: 250 kWh/m^2a	n/a	n/a	n/a	n/a	n/a	n/a
-H2	P_{FF}: 110 kWh/m^2a P_{ESH}: 190 kWh/m^2a	P_{FF}: 110 kWh/m^2a P_{ESH}: 190 kWh/m^2a	n/a	n/a	n/a	n/a	n/a	n/a
-H3	P_{FF}: 80 kWh/m^2a P_{ESH}: 130 kWh/m^2a	P_{FF}: 80 kWh/m^2a P_{ESH}: 130 kWh/m^2a	n/a	n/a	n/a	n/a	n/a	n/a
	P: 110-230 kWh/m^2a	P: 110-230 kWh/m^2a	P: 132-260 kWh/m^2a	P: 90-254 kWh/m^2a				
	MPEPC = 0.6 & MPCPC = 0.69	MPEPC = 0.6 & MPCPC = 0.69	MPEPC & MPCPC should not exceed 1	MPEPC & MPCPC should not exceed 1				
	Regulations for new buildings are based on a set limit for heating, DHW, cooling and lighting. Only Class A+ to C buildings comply with requirements for new buildings							
	Min Class C buildings: 80 kWh/m^2a for buildings over 3000 m^2, 100 kWh/m^2a for buildings between 501 and 3000 m^2, 115 kWh/m^2a for buildings up to 500 m^2.							
	P: 68388-68552 MJ/a	P: 35595-36855 MJ/a						
	N: 120-173 kWh/m^2a	N: 115 kWh/m^2a	N: 150 kWh/m^2a	N: 120-160 kWh/m^2a	N: 300-335 kWh/m^2a	N: 220 kWh/m^2a	N: 170 kWh/m^2a	N: 210 kWh/m^2a
	F: 142 kWh/m^2a H&C: 108 kWh/m^2a	F: 123 kWh/m^2a H&C: 99 kWh/m^2a	F: 174 kWh/m^2a H&C: 183 kWh/m^2a	Requirements for other non-residential buildings apply				
	P: 203 kWh/m^2a F: 80 kWh/m^2a	P: 203 kWh/m^2a F: 80 kWh/m^2a	P: 407 kWh/m^2a F:122 kWh/m^2a	P: 174 kWh/m^2a F: 52 F kWh/m^2a	P: 465 kWh/m^2a F:140 kWh/m^2a	P: 523/1395 kWh/m^2a F: 157/419 kWh/m^2a	P: 233 F:70 kWh/m^2a	P: 1279 F: 384 kWh/m^2a
	F_E: 55-95 F_{NE} 110-150 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a	F_E: 55-95 F_{NE} 100-140 kWh/m^2a
	P: 170-200 H&C: 50 kWh/m^2a	P: 170-200 H&C: 50 kWh/m^2a	P: 163-180 kWh/m^2a for social housing, for non-residential H&C: 30-50 kWh/m^2a, for non-residential (public investment) H&C: 20-40 kWh/m^2a					
	P: 80-160 H&C 42-86 kWh/m^2a	P: 63-126 H&C: 27-53 kWh/m^2a	P: 120-240 H&C: 16-56 kWh/m^2a	T: 42-84 H&C: 28-56 kWh/m^2a	T: 101-201 H&C: 27-70 kWh/m^2a	T: 94-187 H&C: 14-71 kWh/m^2a	T: 48-95 H&C: 28-56 kWh/m^2a	T: 81-161 H&C: 27-70 kWh/m^2a
	17-20 kgCO_2	16-18 kgCO_2	Other TER (Target carbon dioxide Emission Rate) values apply for non-domestic buildings					

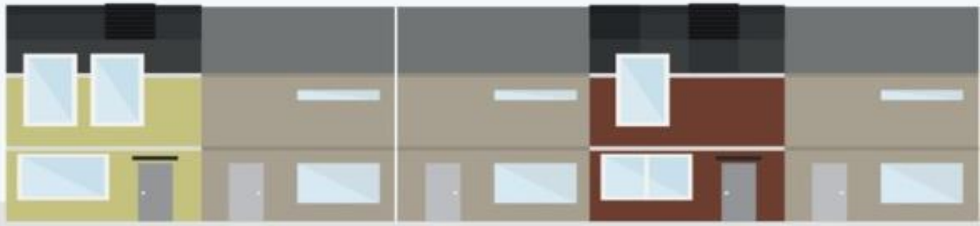


Policies, Codes and Regulations

Performance-based Requirements in New Buildings (Legend & Notes)

P:	Primary Energy
F:	Final
N:	Overall Net energy demand limit (includes all electricity for lighting and appliances)
T:	Total delivered energy
H:	Heating
C:	Cooling
H&C:	Heating and cooling
MPEPC:	Irish Maximum Permitted Energy Performance Coefficient
MPCPC:	Irish Maximum Permitted Carbon Performance Coefficient
ESH (subscript):	Space heating provided by electricity (incl. heat pumps)
FF (subscript):	Space heating provided by Fossil Fuels
E (subscript):	Electrically heated building
NE (subscript):	Non-electrically heated building

	Based on gross floor area and gross building volume
	Based on assumption of DD=2100, A/V=0.2 for SFH, A/V=0.8 other, 32% share of glazing for upper limit and DD=330, A/V=1.2, 32% glazing for lower limit
	Effective space heating demand for a typical building shape calculated on the basis of the SIA-norm 380/1:2009
	A denotes the gross heated floor area in the Danish formulate, example 73.1 P @80 m^2 58 P @300 m^2
	Heated floor area
	For a single family house with building volume 522 m^3, gross floor area 163 m^2, and height between floors 3m.
	H1, H2 and H3 represent the three main climatic regions in France
	MPEPC and MPCPC denote the Maximum Permitted Energy Performance and Maximum Permitted Carbon Performance Coefficients used in the Ireland scheme
	In Small houses, calculated overall net energy demand is limited to 120+1600/m^2 heated floor area.
	Based on formula EPH+W=73+ΔEP for A/Ve<0.2; EPH+W=55+90 A/Ve+ ΔEP for 0.2< A/Ve<1.05; EPH+W=149.5++ΔEP for A/Ve>1.05 for residential buildings
	Electricity production efficiency is approx. 0.30. For a 120 m^2 building, max energy needs (in kWh/m^2a) are 52-117 for heating, 198 for cooling, 38.9 for DHW
	Requirements by 31.12.2014
	Based on assumptions for shape factor, internal air temperature, floor to floor height, air change rate, degree days, etc.
	The UK requirements are based on achieving a % reduction in CO2 emissions over a notional building of the same size/shape.
	Electric heated buildings divided in three climatic zones: 95, 75, 55 kWh/m^2a



Policies, Codes and Regulations

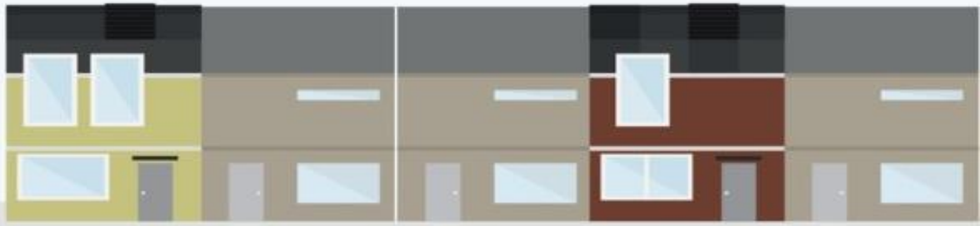
Material Test, Rating and Labelling Assessment (1/2)

Level of test and labelling infrastructure	*ASEAN*	*Brazil*	*China*	*European Union*	*India*	*Japan/ Korea*	*Mexico*	*Middle East*	*Australia/ New Zealand*	*Russia*	*South Africa*	*United States/ Canada*
Window test protocols	●	▲	●	★	▲	●	●	▲	●	★	●	★
Window labels	●	▲	▲	▲	▲	●		▲	●	▲		●
Window attachment test protocols	●			★		▲		●	▲	▲	▲	▲
Window attachment labels	▲			●		▲		●		▲		▲

★ Mature ● Established ▲ Initiating

Source: IEA (2013)

2. BUILDING ENVELOPE



Policies, Codes and Regulations

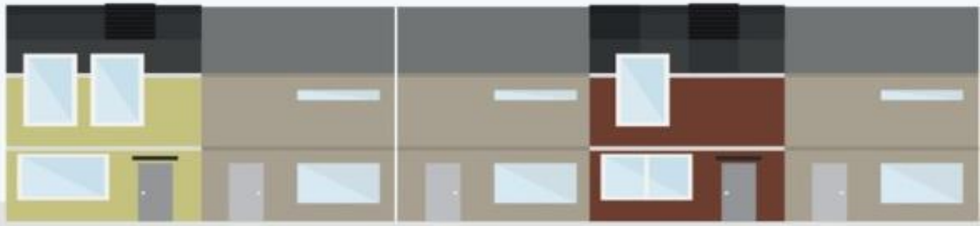
Material Test, Rating and Labelling Assessment (1/2)

Level of test and labelling infrastructure	*ASEAN*	*Brazil*	*China*	*European Union*	*India*	*Japan/ Korea*	*Mexico*	*Middle East*	*Australia/ New Zealand*	*Russia*	*South Africa*	*United States/ Canada*
Insulation test protocols and certificates	●	▲	●	★	●	●	●	●	★	★	●	★
Air sealing validation testing	●			★	▲	●		●	▲	▲		●
Cool roofs aged ratings and certificates	▲	▲	▲	▲	▲	▲	▲				▲	★
Moisture evaluation of envelopes			▲	★	▲	●		▲	▲			★

★ Mature ● Established ▲ Initiating

Source: IEA (2013)

2. BUILDING ENVELOPE



Market & Potential

Market Saturation for High-priority Building Envelope Components (1/2)

Market maturity/ saturation	ASEAN	Brazil	China	European Union	India	Japan/ Korea	Mexico	Middle East	Australia/ New Zealand	Russia	South Africa	United States/ Canada
Double-glazed low-e glass	●	▲	▲	★	▲	●	●	▲	●	●	●	★
Window films	▲	▲	▲	●	▲	●	▲	▲	●	▲	▲	●
Window attachments (e.g. shutters, shades, storm panel)	●	▲	●	★	▲	●	▲	●	●	▲	●	●
Highly insulating windows (e.g. triple-glazed)		▲	▲	●		▲		▲	▲	▲	▲	▲

★ Mature ● Established ▲ Initiating

Source: IEA (2013)

2. BUILDING ENVELOPE

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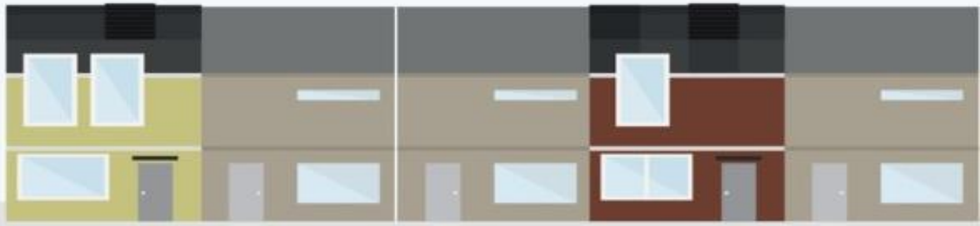


Market & Potential

Market Saturation for High-priority Building Envelope Components (1/2)

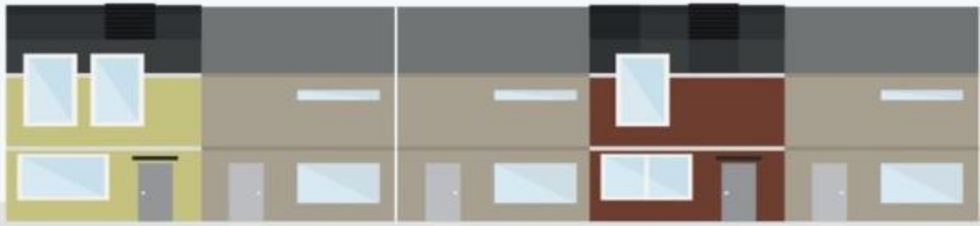
Market maturity/ saturation	*ASEAN*	*Brazil*	*China*	*European Union*	*India*	*Japan/ Korea*	*Mexico*	*Middle East*	*Australia/ New Zealand*	*Russia*	*South Africa*	*United States/ Canada*
Typical insulation	★	●	★	★	●	★	●	★	★	★	●	★
Exterior insulation	●	▲	●	★	●	●	▲	●		▲	▲	★
Advanced insulation (e.g. aerogel, VIPs)				▲		▲				▲	▲	▲
Air sealing	●	▲	▲	★	▲	●		▲	▲	▲		●
Cool roofs	▲	▲	▲	●	▲	▲	▲	▲	▲			★
BIPV/ advanced roofs	▲	▲		▲	▲	▲			▲	▲	▲	▲

★ Mature ● Established ▲ Initiating

Source: IEA (2013)

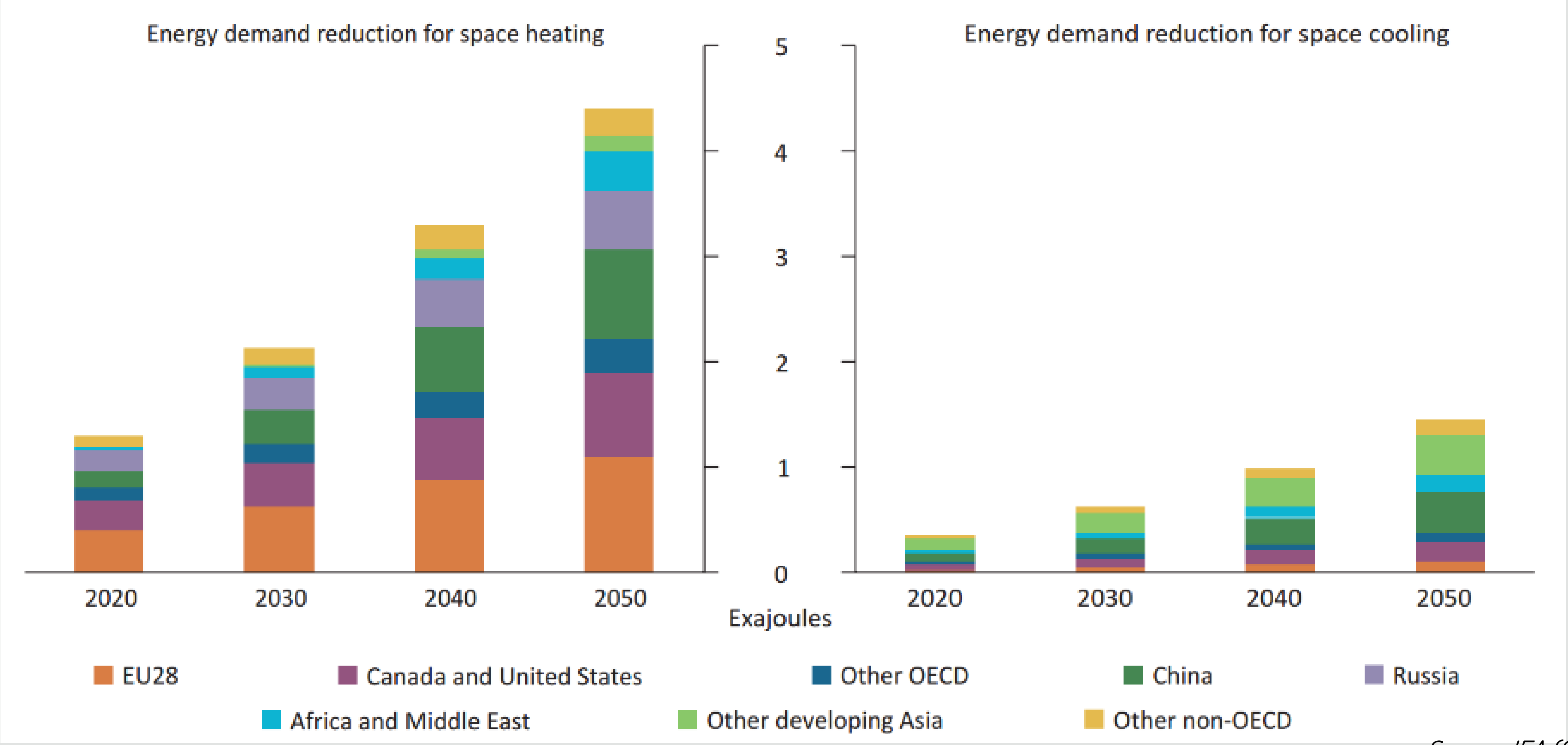
2. BUILDING ENVELOPE

MORE — CONNECT



Market & Potential

Potential Energy Reduction



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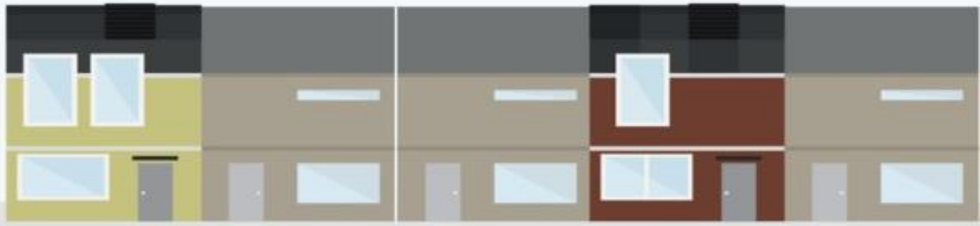


Market & Potential

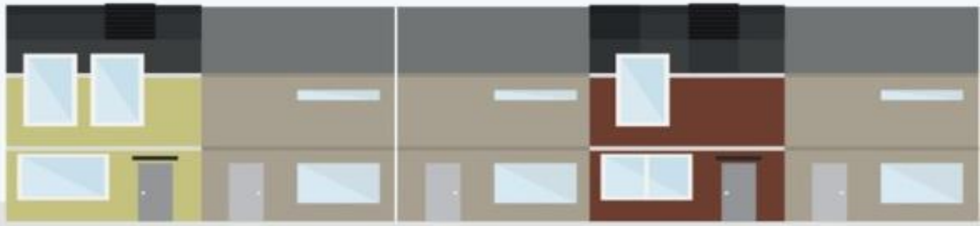
Goals for 2020-30 (1/3)

Technology	Market perspectives	Performance goals	Cost targets
Typical insulation (widely available, thermal conductivity of > 0.02 W/mK)	Highly competitive market with uniform performance metrics in all regions for existing stock and new construction.	Average U-value walls and roof, cold climate ≤ 0.15 W/m²K; hot climate ≤ 0.35 W/m²K.	LCC neutral or lower at moderate energy prices.
Advanced insulation (e.g. aerogel, VIPs)	Used for very high-performance buildings in cold climates and space-constrained applications.	Thermal conductivity of ≤ 0.015 W/mk.	Material cost less 50%, installed cost competitive with typical insulation.
Air sealing	Widely applied to over 95% of world structures with heating and cooling loads.	Retrofit ≤ 3.0 ACH or 50% reduction; New ≤ 0.5 ACH with mechanical ventilation.	Validation testing reduced by 30% to 60%; 50% lower ACH in existing buildings reduced from USD 24/m² to ≤ USD 10/m².

Source: IEA (2013)

2. BUILDING ENVELOPE

MORE—CONNECT

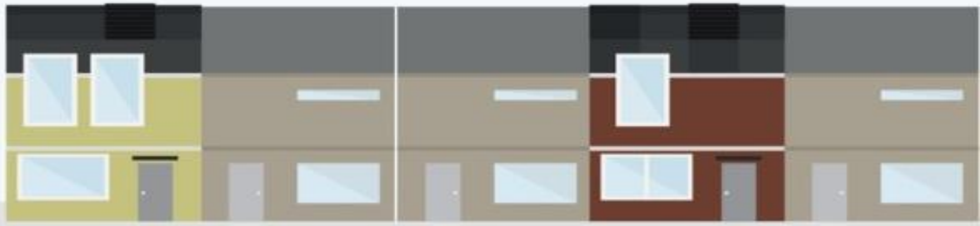


Market & Potential

Goals for 2020-30 (2/3)

Technology	*Market perspectives*	*Performance goals*	*Cost targets*
Reflective surfaces	Applied to new roofing materials and after-market coatings for hot climates and dense urban areas.	Long-lasting SR of ≥ 0.75 for white surfaces, and SR ≥ 0.40 for coloured surfaces.	Additional installed price premiums ≤ USD 10/m².
Windows (double low-e galzing, low-conductive frames)	Minimum for global market.	Whole-window performance, U-value ≤ 1.8 W/m²K.	Price premiums from single-glazed (≤ USD 40/m²), from double clear (≤ USD 5/m²).
Highly insulating windows (e.g. triple-glazed, low-e, and low-conductive frames)	Needed for cold climates for all buildings, and mixed climates for residential.	U-value ≤ 1.1 W/m²K.	Price premiums from double low-e (≤ USD 40/m²).

Source: IEA (2013)



Market & Potential

Goals for 2020-30 (3/3)

Technology	*Market perspectives*	*Performance goals*	*Cost targets*
Energy-plus windows in cold climates (highly insulating and dynamic solar)	Dynamic solar control for most service buildings that have glass to optimise daylight; and highly insulating and dynamic solar control for mixed and cold climates residential.	Whole-window performance, highly insulating U-value ≤ 0.6 W/m²K and variable SHGC 0.08-0.65.	Highly insulating dynamic SHGC price premium from double low-e (≤ USD 120/m²).
Window attachments* (automatic solar control, e.g. exterior solar shades and blinds)	Priority for existing windows but also for alternative option to dynamic glass.	Ability to reduce solar heat gain almost to zero, but preferred options would have daylight features (e.g. SHGC 0.05 to 0.5) to prevent increased lighting energy.	USD 70/m² (not including control systems that can be expensive if not used for other building systems).
Window attachments (highly insulating, e.g. cellular shades, low-e films)	Predominately retrofit market but also applicable to new zero-energy buildings.	Installed with existing windows, total performance, U-values ≤ 1.1 W/m²K.	USD 40/m².

Source: IEA (2013)

2. BUILDING ENVELOPE

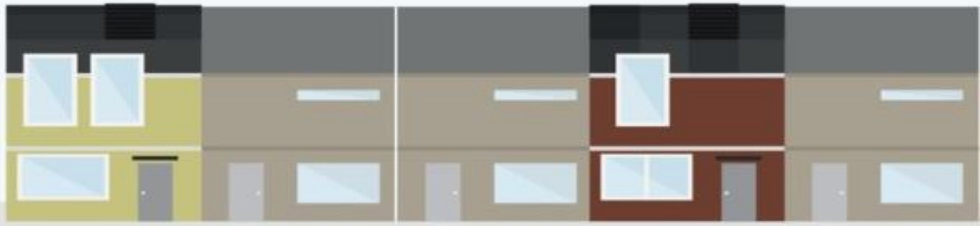
Case Studies

PassivHaus: Tevesstrasse Frankfurt, Germany

Case Studies

Zero Carbon Building: BedZED, UK (2002) (1/2)

- **Title:** The Beddington Zero Energy Development (BedZED) project
- **Location:** Hackbridge, London
- **Details:** 99 super-insulated dwellings of various sizes
- **Features:**
    - 120kWe wood-waste fuelled CHP
    - 777m^2 of photovoltaic panels
    - Potential to power up to 40 electric vehicles



Case Studies

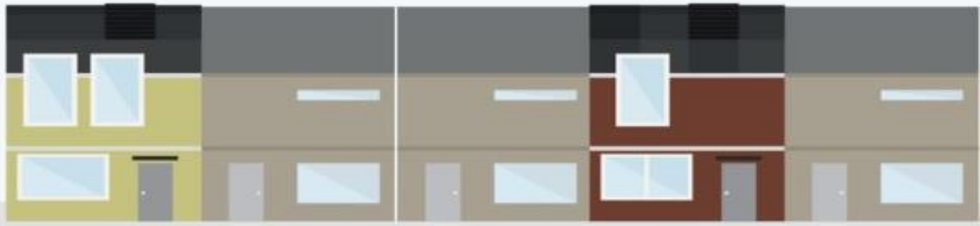
Zero Carbon Building: BedZED, UK (2002) (2/2)

- **Results:**
  - Space heating demand: 90% less than UK average
  - Electrical power consumption for appliances & lighting: 33% less than average

- **Lessons Learnt:**
  - Target not achieved because:
    - Prototype biomass CHP system was unreliable, not operating effectively
    - The PV system only offset 20% of the total energy demands

2. BUILDING ENVELOPE

MORE—CONNECT



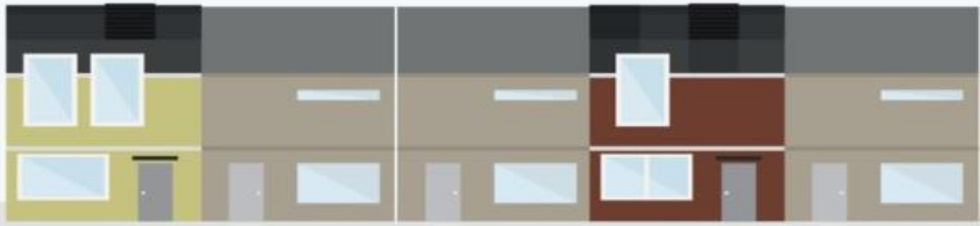
Case Studies

Zero Carbon Building: Portland House, Australia (2009) (1/2)

- **Title:** Portland House
- **Location:** Portland, Victoria
- **Details:** Demonstration family dwelling
- **Features:**
    - Super-insulated and tightly sealed fabric, thermal mass and a cooling tower
    - All appliances are low-energy
    - PV system with 1.4kWp
    - 3 Solar water heating panels
    - Reversible heat pump

2. BUILDING ENVELOPE

MORE—CONNECT



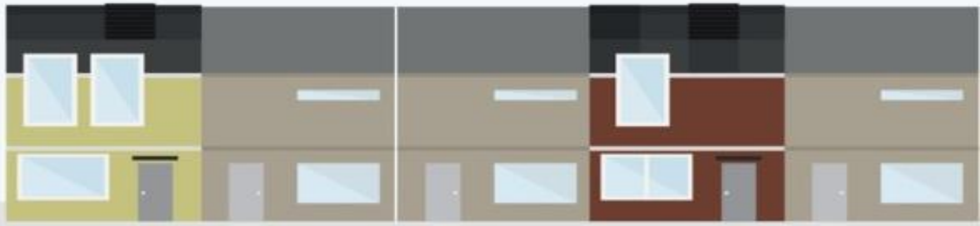
Case Studies

Zero Carbon Building: Portland House, Australia (2009) (2/2)

- **Results:**
    - PV: 93% of electrical energy consumption

- **Lessons Learnt:**
    - PV capacity to be double to meet demand

2. BUILDING ENVELOPE



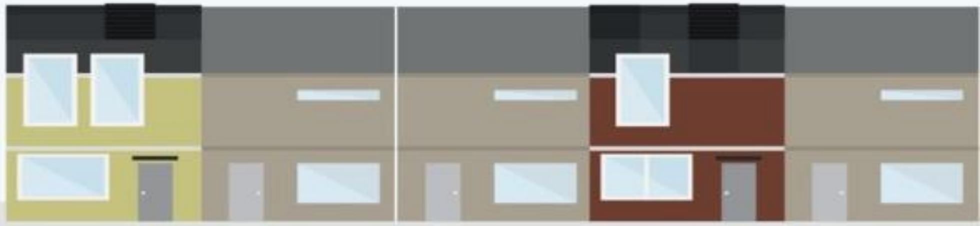
Case Studies

Zero Carbon Building: Wheat Ridge, Colorado (2005) (1/2)

- **Title:** Wheat Ridge
- **Location:** Colorado, USA
- **Details:** Humanity home 119 m^2
- **Features:**
    - Super-insulated
    - Low-e solar glass with argon fill (U-value 1.14W/m^2K)
    - 9m^2 solar water heater with 760 l thermal store
    - 4kWp roof-mounted PV system
    - Mechanical ventilation system with heat recovery

2. BUILDING ENVELOPE

MORE—CONNECT



Case Studies

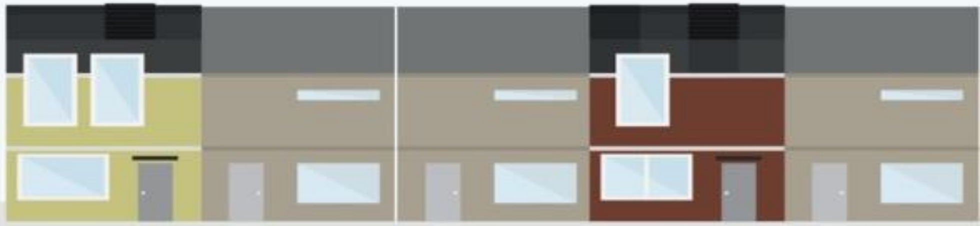
Zero Carbon Building: Wheat Ridge, Colorado (2005) (2/2)

- **Results:**
  - PV: Produced an excess of 1542 kWh in 1 year
  - Gas consumption for backup water heating: 1670 kWh
  - Net site energy requirement for all fuels: 0.6 kWh/m^2/year.

Zero Carbon Building: Simulation of a Typical Detached House (1/4)

- **Location:** Scotland
- **Details:** 136m^2 floor area
- **Occupancy:** 4
- **Climate:** Scottish West-coast climate

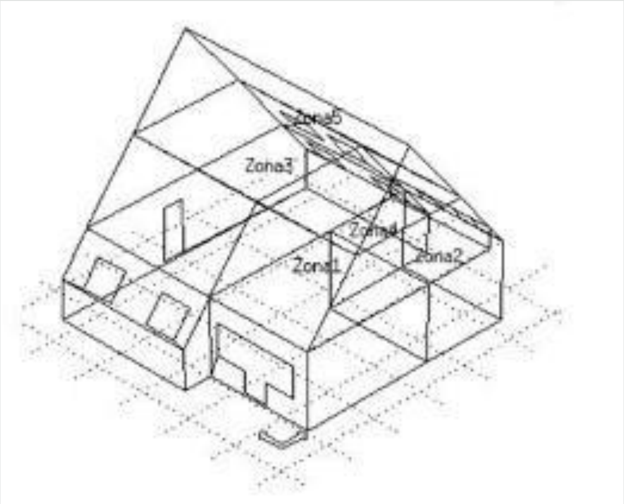
2. BUILDING ENVELOPE

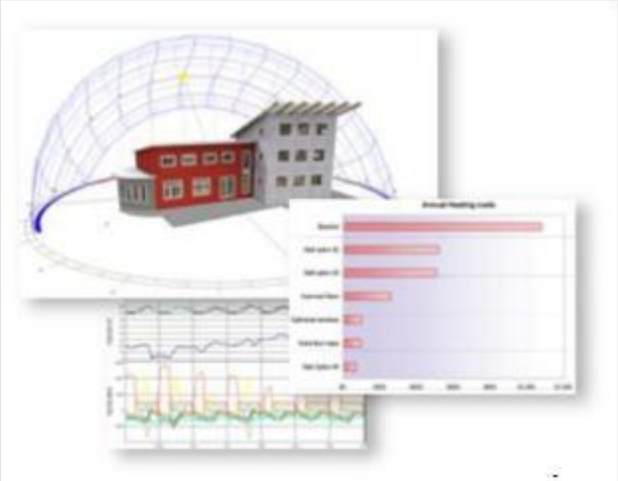


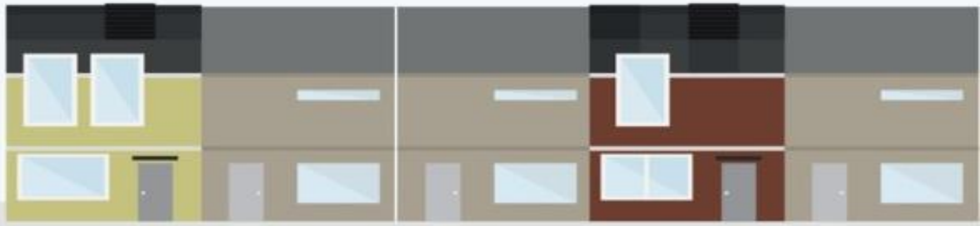
Case Studies

Zero Carbon Building: Simulation of a Typical Detached House (2/4)

- To achieve the 140% reduction target:
  - 46m^2 PV electrical generation (6 kWp)
  - Passive house building envelope
  - High efficiency MVHR
  - 4m2 Solar thermal panels
  - 2kW Biomass heating
  - high A+ rating efficiency appliances
  - high efficiency lighting







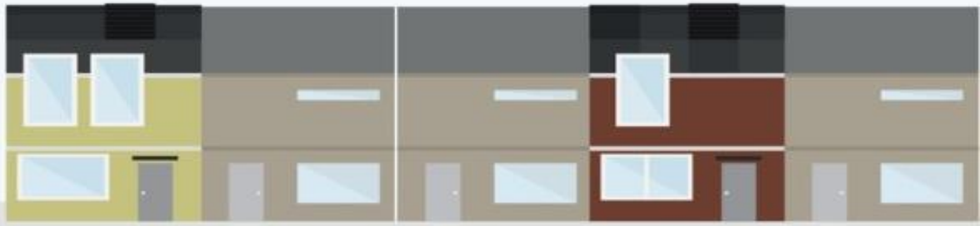
Case Studies

Zero Carbon Building: Simulation of a Typical Detached House (3/4)

- Results:

	Base Case Dwelling	Zero Carbon Dwelling
External walls W/m^2K	0.45	0.11
Floor W/m^2K	0.6	0.10
Ceiling W/m^2K	0.25	0.13
Glazing W/m^2K	2.10	0.70
Average uncontrolled infiltration ACH	0.5	0.03[1]
Heating	Gas boiler + radiators	Biomass boiler + heating coil in MVHR

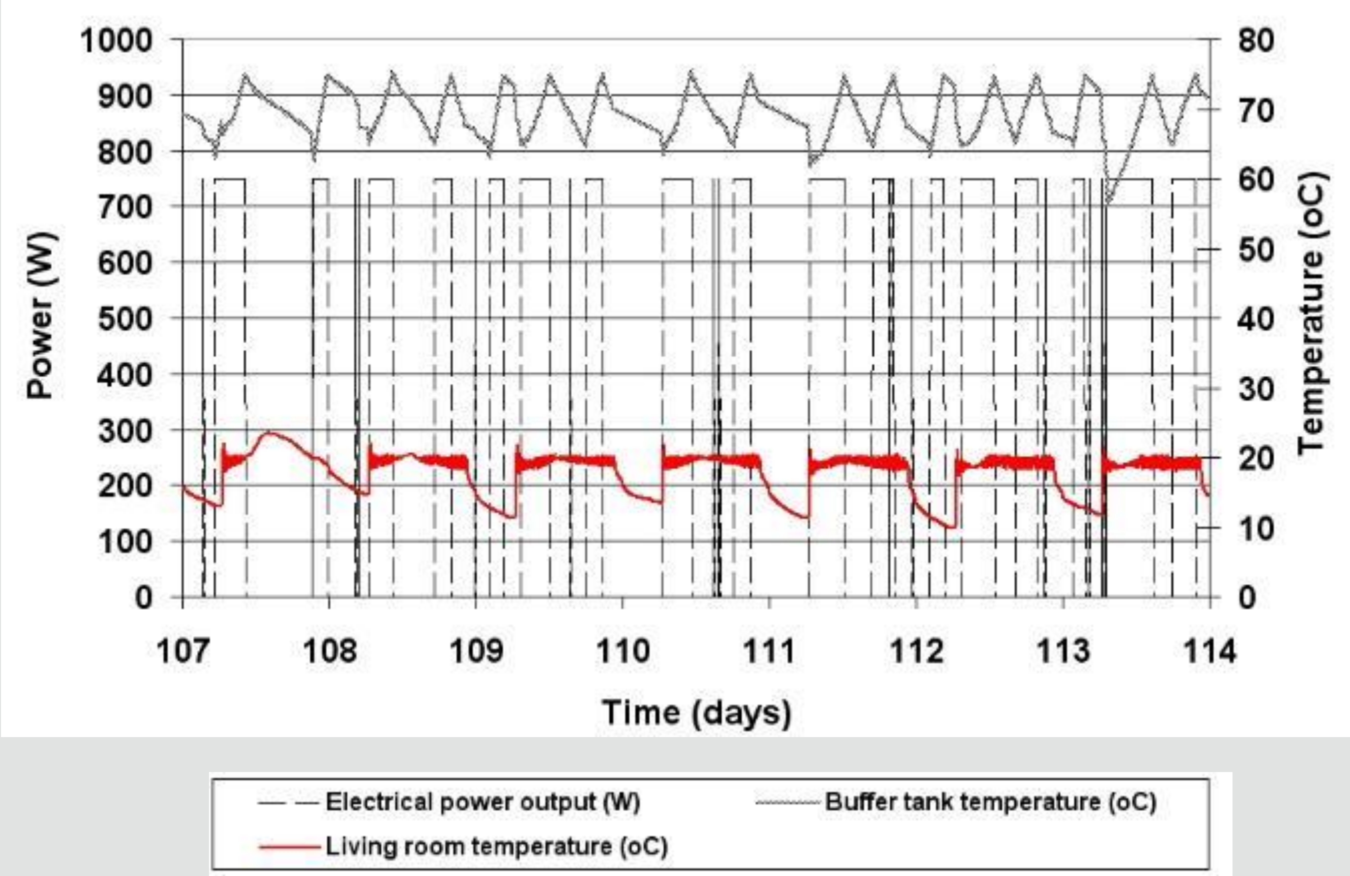
	Base Case Dwelling	Zero Carbon Dwelling
Heating demand kWh	3083	372
Hot water heating demand kWh	2342	1850
Electrical Demand kWh	5776	3240
Total Demand kWh	**11201**	**5462**
PV Output kWh	-	5023
Solar Thermal Output kWh	-	1709
Biomass boiler Output kWh	-	1172
Total Production kWh		**7904**



Case Studies

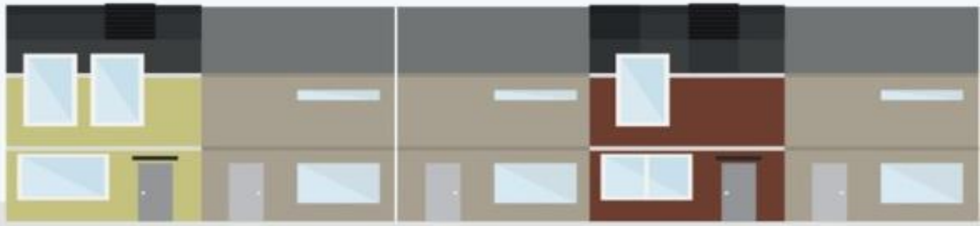
Zero Carbon Building: Simulation of a Typical Detached House (4/4)

- Results:



3. THERMAL BRIDGING

MORE—CONNECT

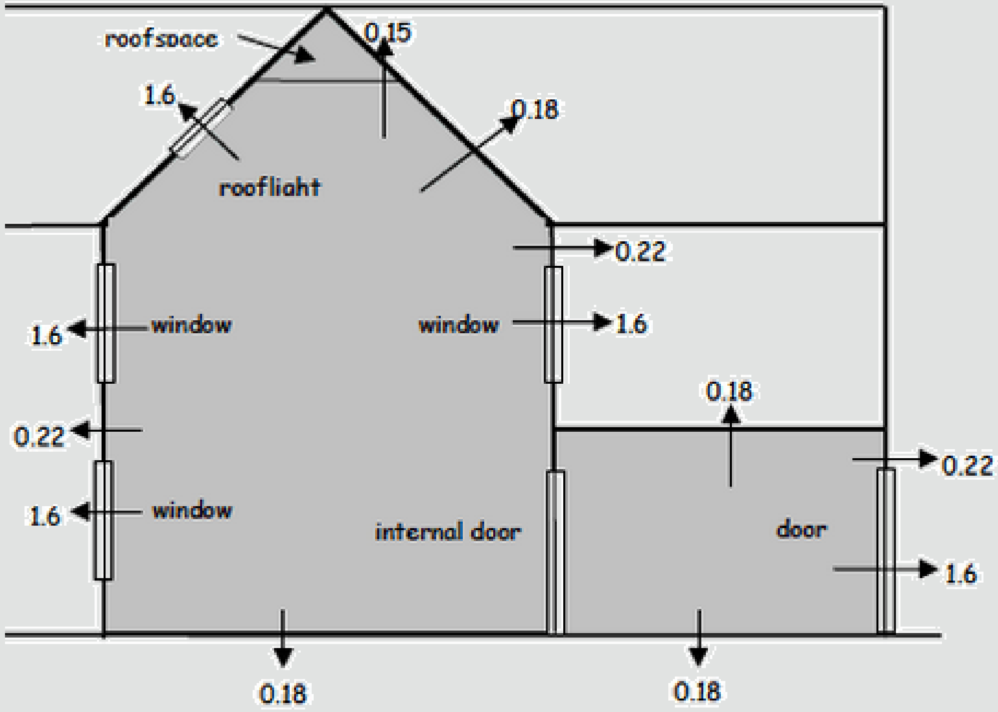


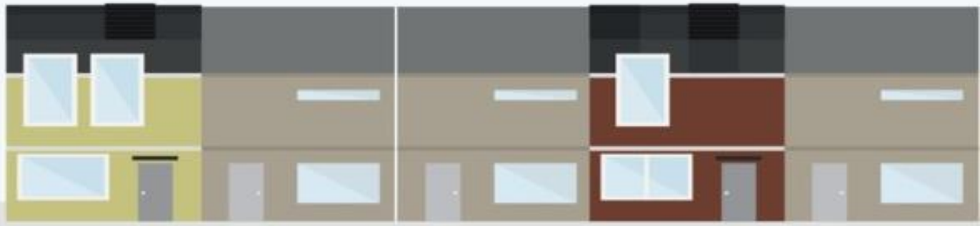
U-Values

Overview

The U-value is a measure of how effective a building element, such as a wall or roof etc., is in restricting heat loss.

- Predict composite behaviour of entire building elements – No reliance on properties of individual materials
- Form the basis of any energy or carbon reduction standards
- Knowledge of U-value calculations at design stage avoids costly changes later in projects

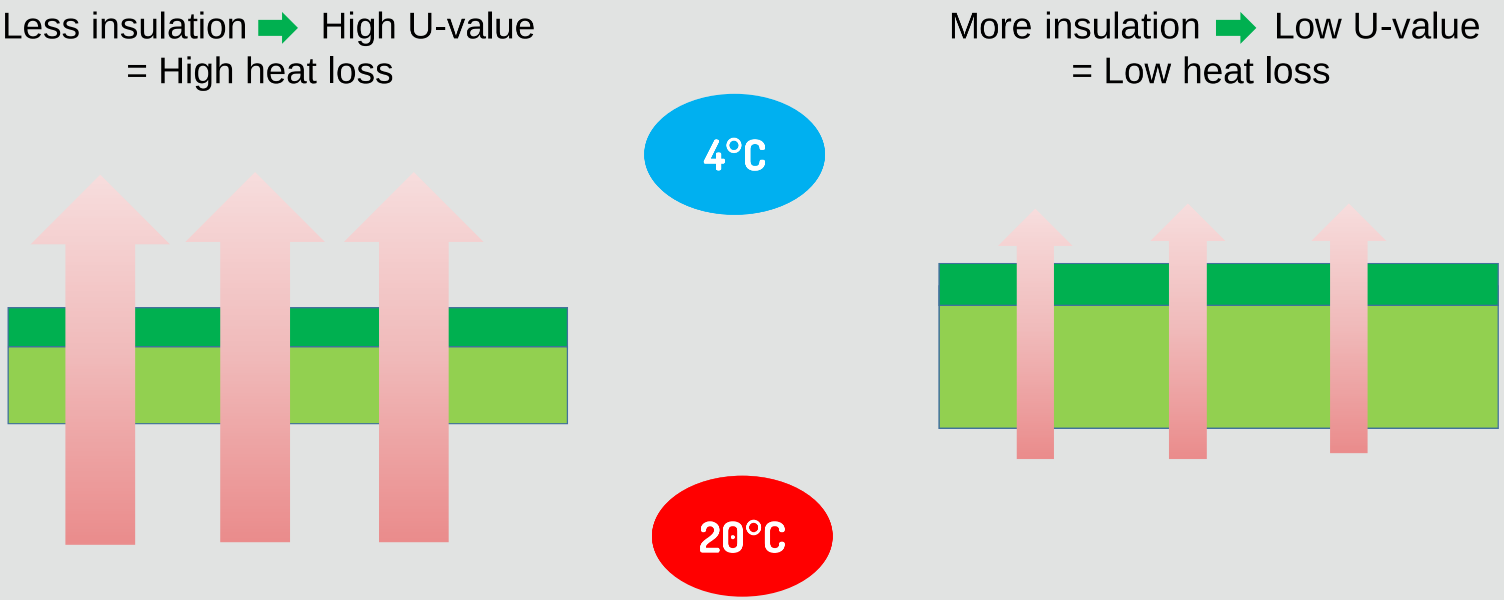




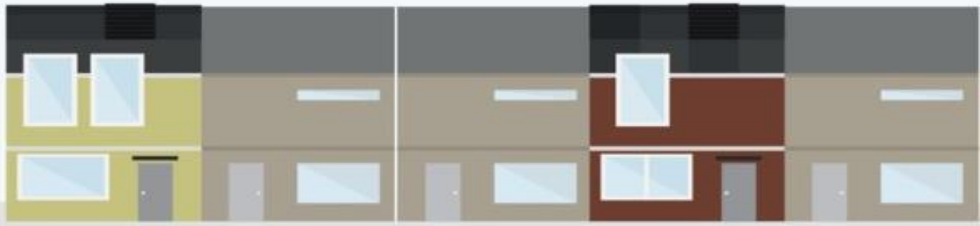
U-Values

Principles

- The U-value is the reciprocal of all thermal resistances of the materials present in the building element
- The lower the U-value, the better



3. THERMAL BRIDGING



MORE—CONNECT

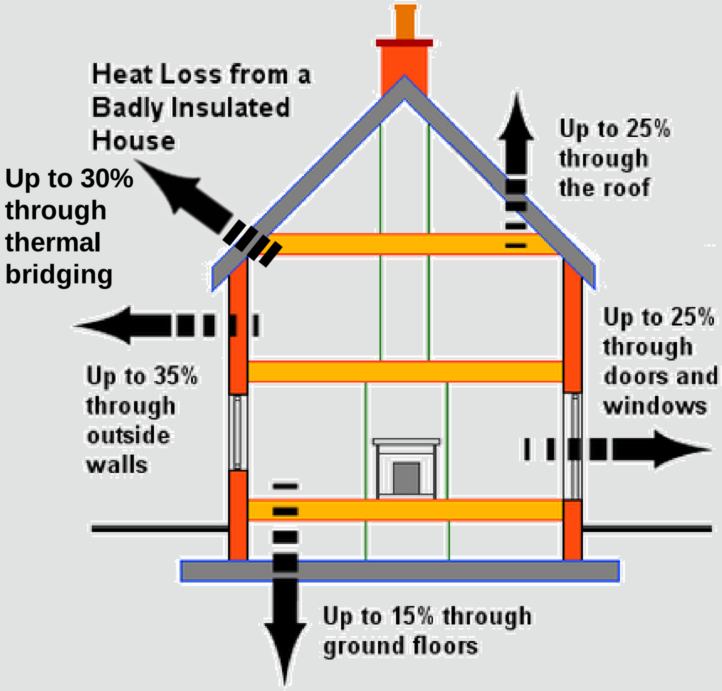
U-Values

The Importance of Thermal Insulation

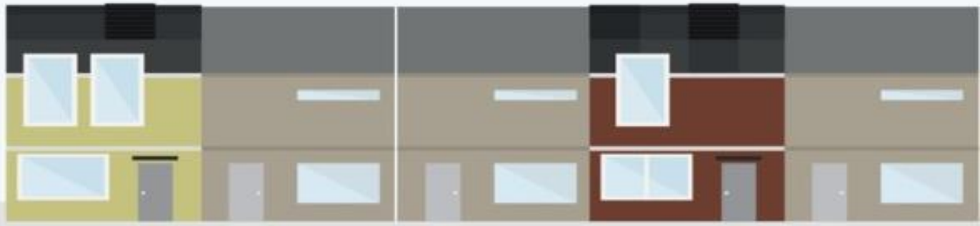
Thermal insulation works by providing resistance to heat flow, i.e. low thermal conductivies, to lowering the U-values of insulated building elements, slowing the overall heat loss from a building.

- 10 cm of glass fibre insulation installed in loft/attic spaces can reduce heat loss through the roof of a building by up to 75 %

- Installing cavity wall foam insulation to external walls can reduce heat loss through the external facade by up to 50 %



Percentage heat loss through major building elements in a poorly insulated home



U-Values

The Importance of Thermal Insulation

Some common insulation materials:

- Fibreglass Quilt:

  ρ = 12 kg/m^3 , λ = *0.04 W/mK*

- Mineral Wool Quilt:

  ρ = 12 kg/m^3 , λ = *0.05 W/mK*

- Cellulose Fibre:

  ρ = 35 kg/m^3 , λ = *0.04 W/mK*

- Natural Fibre (e.g. Straw):

  ρ = 240 kg/m^3 , λ = *0.07 W/mK*

- Natural Fibre (e.g. Sheep's wool):

  ρ = 30 kg/m^3 , λ = *0.04 W/mK*

- Expanded Polystyrene:

  ρ = 25 kg/m^3 , λ = *0.03 W/mK*

- Polyurethane foam board:

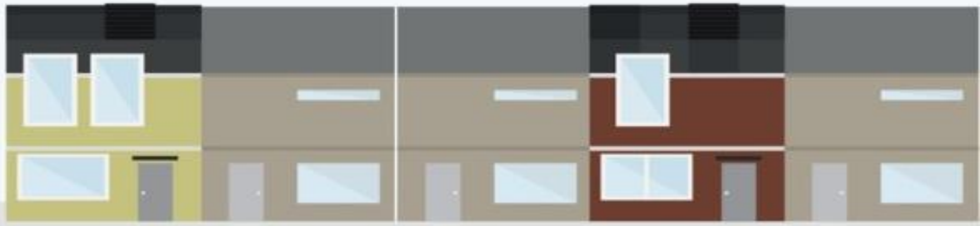
  ρ = 30 kg/m^3 , λ = *0.03 W/mK*

- Phenolic Foam

  ρ = 40 kg/m^3 , λ = *0.02 W/mK*

3. THERMAL BRIDGING

MORE—CONNECT



U-Values

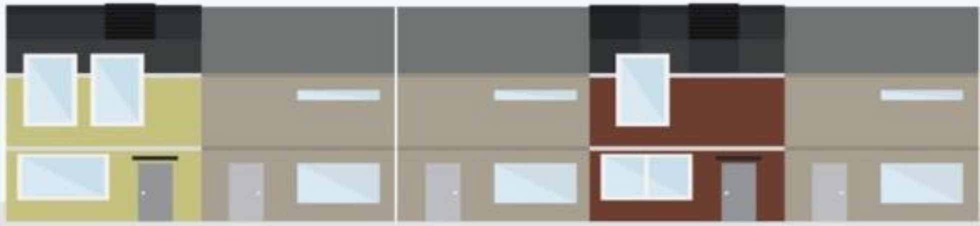
Thermal resistance

Thermal resistance, measured in m^2K/W, is defined as the temperature difference, at steady state, between two defined surfaces of a material/construction that induces a unit heat flow rate through a unit area.

Thermal resistance is proportional to the thickness of a layer of the construction and inversely proportional to its thermal conductivity.

$$\boxed{\boldsymbol{Thermal\ Resistance\ (m^2K/W) = \ Thickness\ (m)/Thermal\ Conductivity\ (W/mK)}}$$

A construction layer with a high thermal resistance (e.g. polyurethane), is a good insulator; one with a low thermal resistance (e.g. concrete) is a bad insulator.



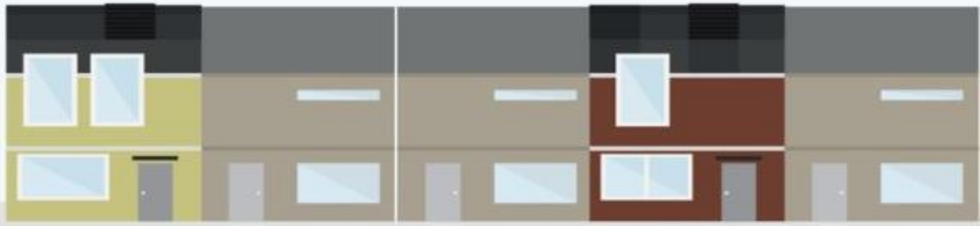
U-Values

Surface resistance

	Direction of heat flow		
Inside Surface	**Upwards**	**Horizontal ***	**Downwards**
R_{si} m^2K/W	0.10	0.13	0.17
h_{si} W/m^2K	10.0	7.69	5.88
Outside Surface			
R_{se} m^2K/W	0.04	0.04	0.04
h_{se} W/m^2K	25.0	25.0	25.0
*The values under “horizontal” apply to heat flow directions ± 30° from the horizontal plane, e.g. if a roof slope is greater than 60°, the horizontal values should be used, otherwise the upwards values are used.			

3. THERMAL BRIDGING

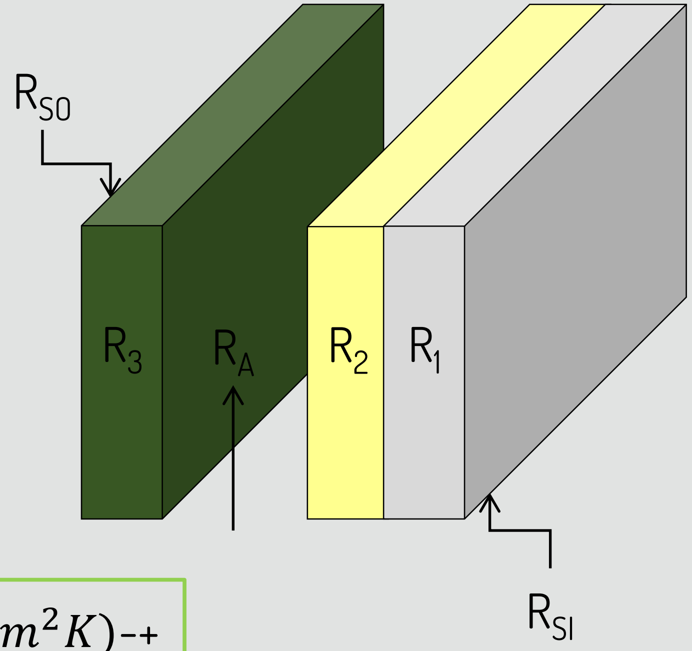
MORE—CONNECT



U-Values

U-Value Calculation

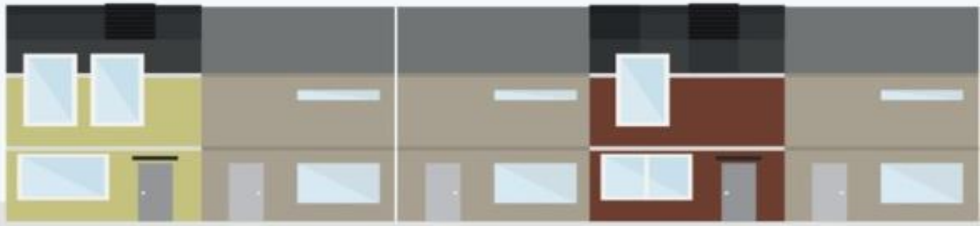
- R_{SI} = Thermal resistance of internal surface
- R_{SO} = Thermal resistance of outer surface
- R_A = Thermal resistance of unvented air cavity
- R_n = Thermal resistance of building component



$$U = \frac{1}{R_{SI}+R_{SO}+R_A+R_1+R_2+\cdots+R_n}\ (W/m^2K)\text{-+}$$

3. THERMAL BRIDGING

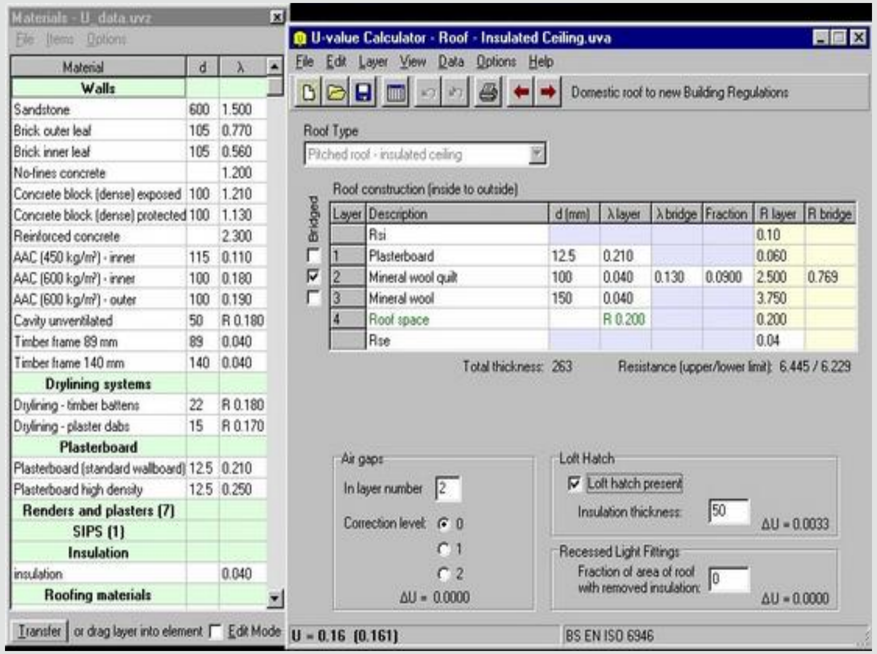
MORE — CONNECT



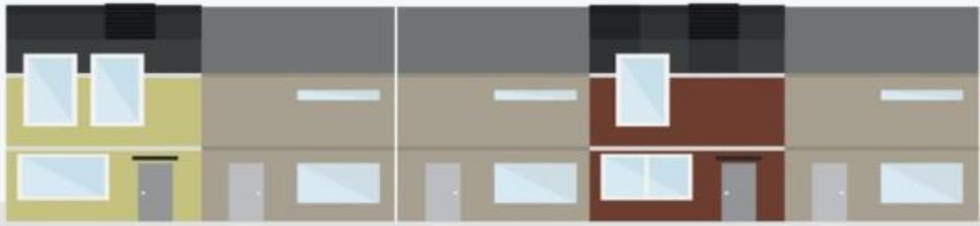
U-Values

BRE U-value Calculation Tool

- Calculates U-values in accordance with ISO standards
- Covers most building elements (those penetrated by metal may need detailed numerical analysis)
- Guidance – BR 443 (Conventions for U-value calculations)

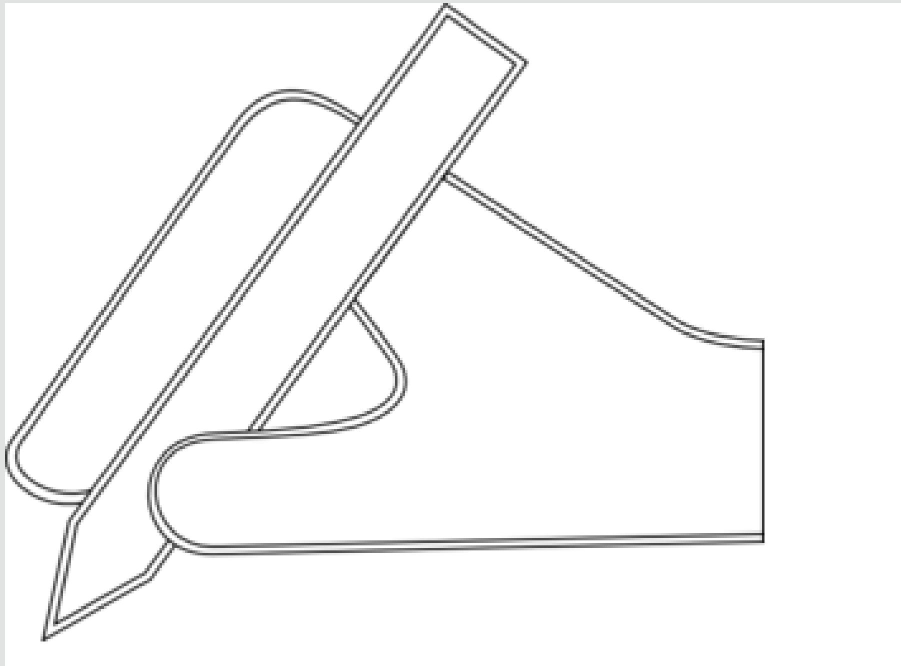


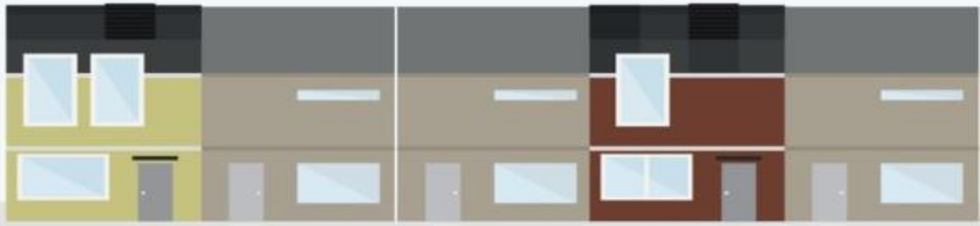
BRE U-value calculator



U-Values

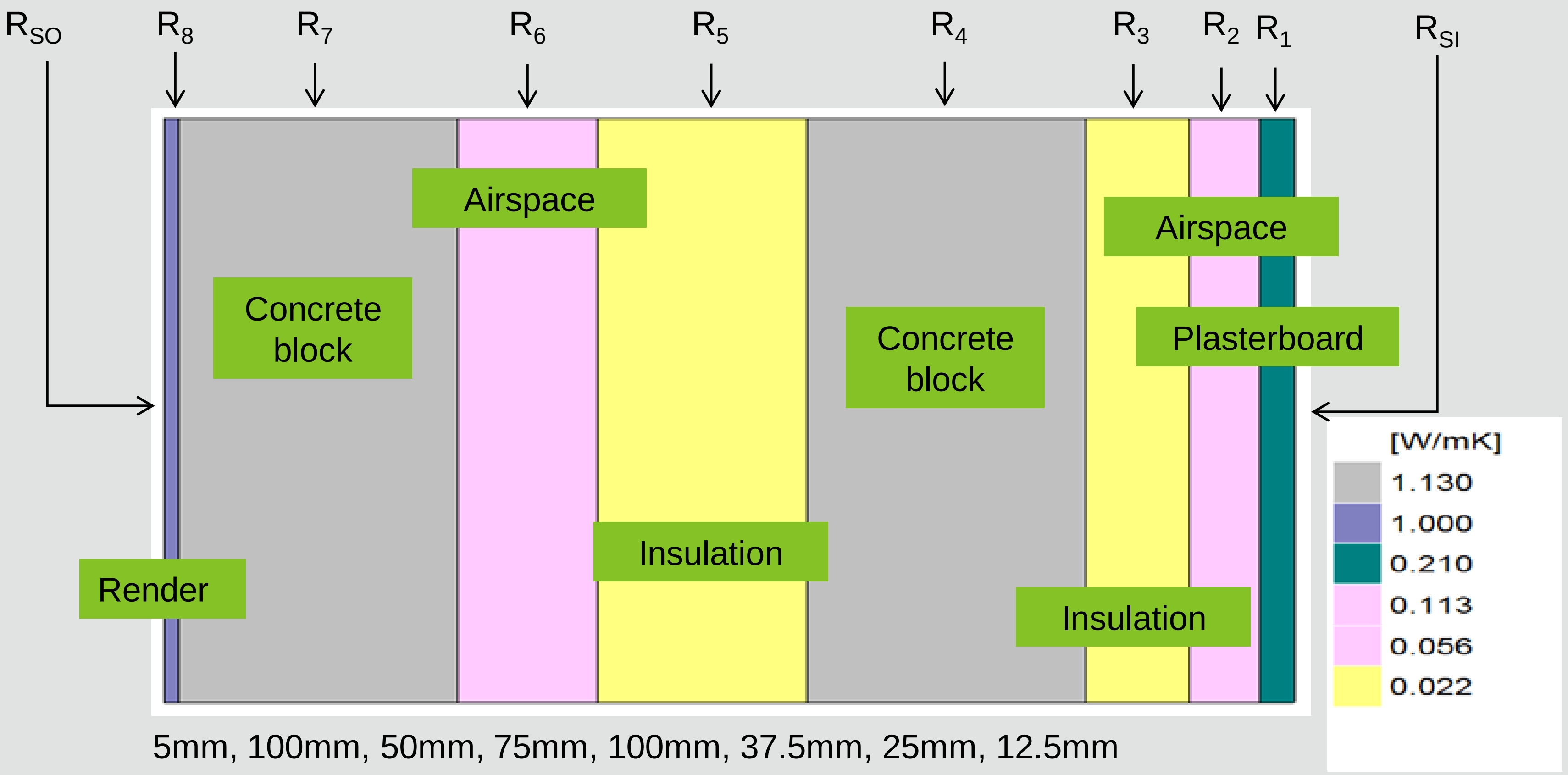
Practical U-value Calculation Tool Exercise

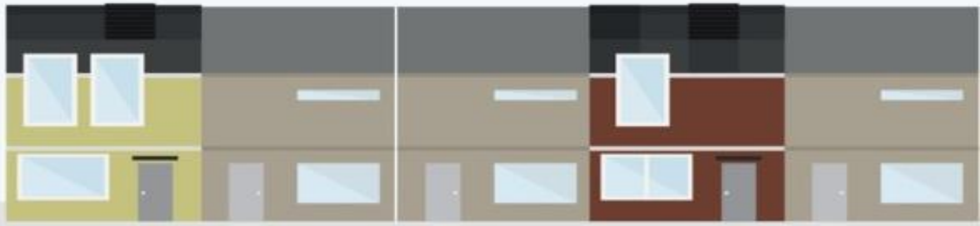




U-Values

Practical U-value Calculation: Masonry wall construction





U-Values

Practical U-value Calculation: Masonry Wall construction

How to calculate:

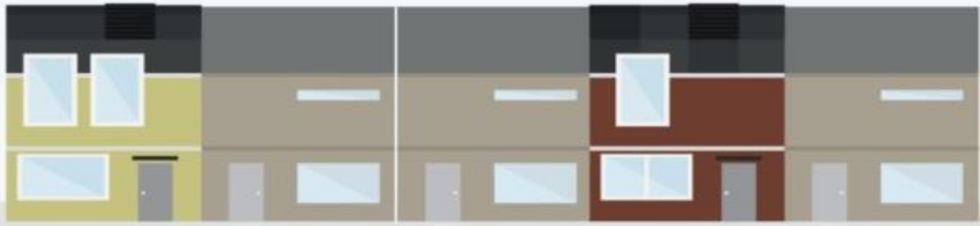
Resistance of each material:

$$R = {}^{Thickness}/_{Thermal\ Conductivity} \quad (m^2K/W)$$

U-value:

$$U = \frac{1}{R_{SI} + R_1 + R_2 + R_3 + \cdots + R_{SO}} \quad (W/m^2K)$$

Remember to include internal and external surface resistances!



U-Values

Practical U-value Calculation: Masonry Wall construction

How to calculate:

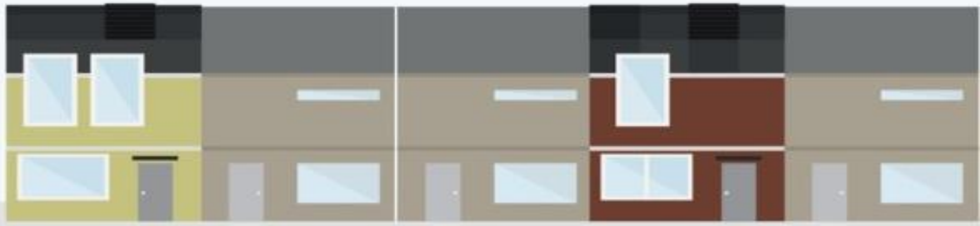
Resistance of each material:

$$R = {}^{Thickness}/_{Thermal\ Conductivity} \quad (m^2K/W)$$

U-value:

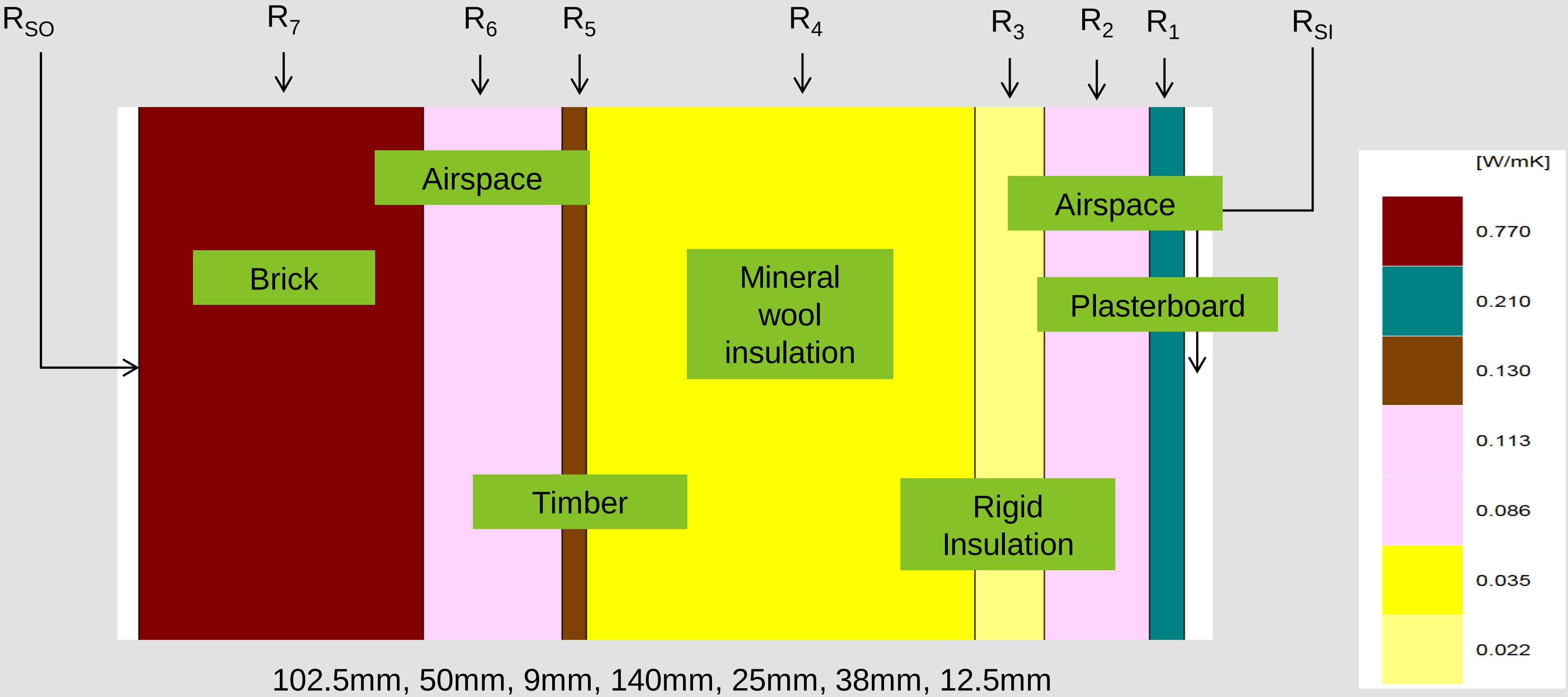
$$= \frac{1}{0.13 + 0.05 + 0.088 + 0.442 + 3.41 + 0.088 + 1.705 + 0.059 + 0.04} \quad (W/m^2K)$$

$$= 0.166 \ W/m^2K$$



U-Values

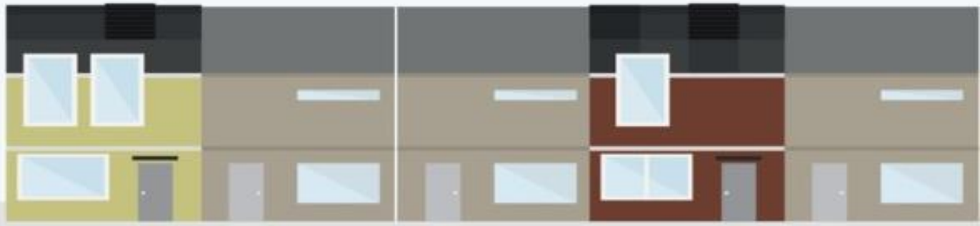
Practical U-value Calculation: Timber wall construction



102.5mm, 50mm, 9mm, 140mm, 25mm, 38mm, 12.5mm

3. THERMAL BRIDGING

MORE—CONNECT



U-Values

Practical U-value Calculation: Timber frame wall construction

How to calculate:

$$R\ (Resistance, m^2K/W) = {}^{Thickness\ (m)}\!\big/_{Thermal\ Conductivity\ (W/m\cdot K)}$$

$$U - value\ (W/m^2K) = {}^{1}\!/_{R}$$

Note that, for bridged constructions, the U-value is calculated from:

$$R_u - Upper\ limit\ resistance, and$$
$$R_l - Lower\ limit\ resistance$$

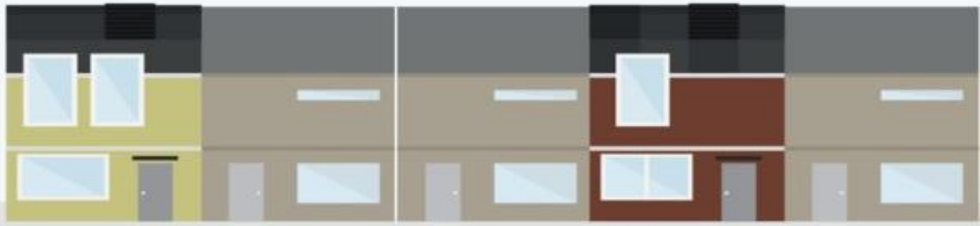
as follows:

$$R = \frac{(R_u + R_l)}{2}$$

$$R = \frac{1}{\left({}^{0.85}\!/_{R1}\right) + \left({}^{0.15}\!/_{R2}\right)}$$

3. THERMAL BRIDGING

MORE—CONNECT



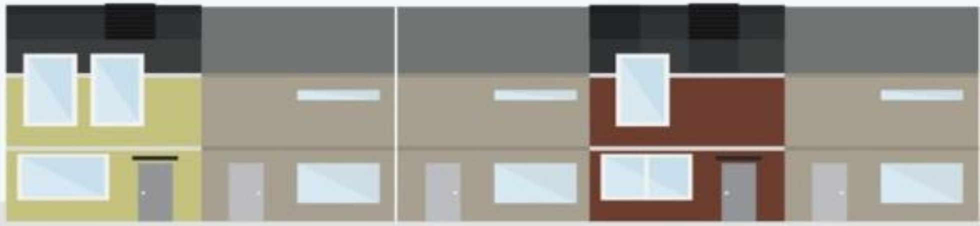
U-Values

Practical U-value Calculation: Timber frame wall construction

How to calculate:

R1			
	Thickness	Conductivity	Resistance
Rsi	-	-	0.130
R1	0.0125	0.21	0.060
2	0.038	0.086	0.442
3	0.025	0.022	1.136
4	0.14	0.035	4.000
5	0.009	0.13	0.069
6	0.05	0.113	0.442
7	0.1025	0.77	0.133
Rse	-	-	0.04
	0.377m		R1 = 6.453 m^2K/W

R2 (bridged layer)			
	Thickness	Conductivity	Resistance
Rsi			0.130
R1	0.0125	0.21	0.060
2	0.038	0.086	0.440
3	0.025	0.022	1.136
4	0.14	0.13	1.077
5	0.009	0.13	0.069
6	0.05	0.113	0.440
7	0.1025	0.77	0.133
Rse			0.04
	0.377m		R2 = 3.525 m^2K/W



U-Values

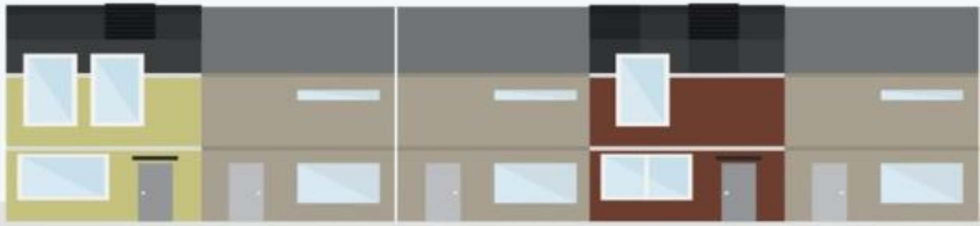
Practical U-value Calculation: Timber frame wall construction

How to calculate:

$$R_u = \frac{1}{\left({}^{0.85}/_{6.453}\right) + \left({}^{0.15}/_{3.525}\right)}$$

$$= 5.738\ m^2K/W$$

Rl – lower limit resistance			
	Thickness	Conductivity	Resistance
Rsi			0.130
R1	0.0125	0.21	0.060
2	0.038	0.086	0.440
3	0.025	0.022	1.136
4	**0.14**	**0.13**	**R'4**
5	0.009	0.13	0.069
6	0.05	0.113	0.440
7	0.1025	0.77	0.133
Rse			0.04
	0.377		**R_l = 5.291 m^2K/W**



U-Values

Practical U-value Calculation: Timber frame wall construction

How to calculate:

$$R'4 = \frac{1}{\left({}^{0.85}/_{4.00}\right) + \left({}^{0.15}/_{1.077}\right)}$$

$$= 2.843\ m^2K/W$$

$$R = \frac{(R_u + R_l)}{2}$$

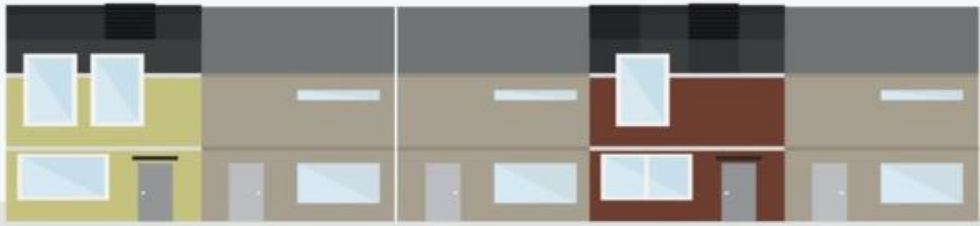
$$= \frac{(5.738 + 5.291)}{2}$$

$$= 5.514$$

$$U - value = {}^{1}/_{R}$$

$$= {}^{1}/_{5.515}$$

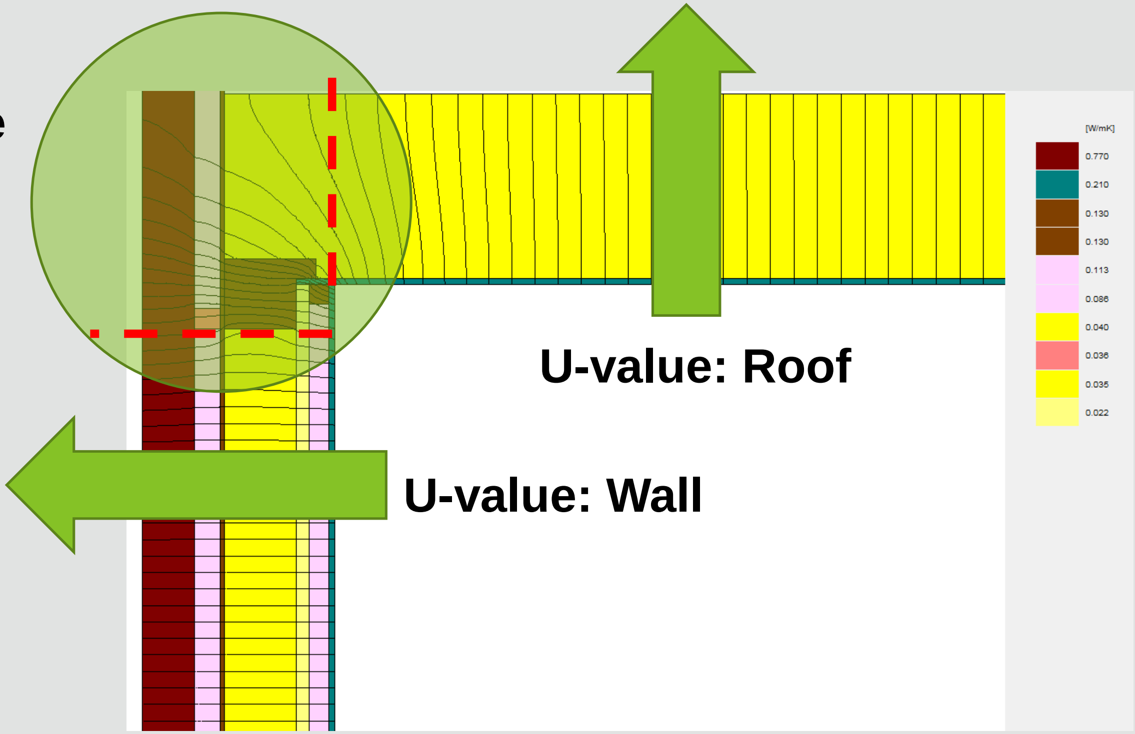
$$= \mathbf{0.18\ W/m^2K}$$

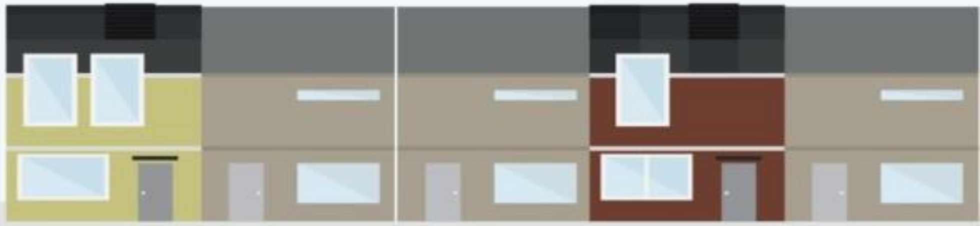


Thermal Bridges

Overview – What is thermal bridging?

Thermal bridging occurs where a more conductive (or poorly insulating) material allows an easier path for heat flow through the otherwise insulated construction. Such situations can often occur at the junctions between building elements



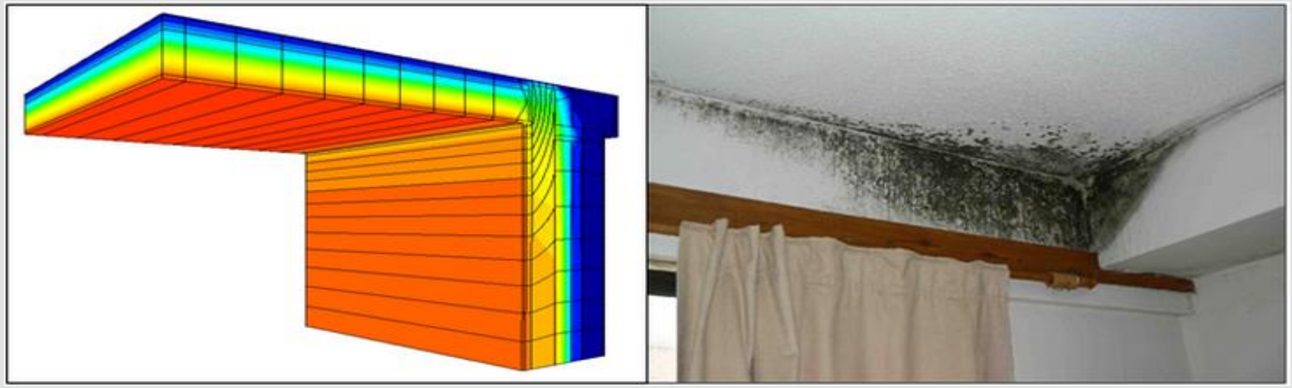


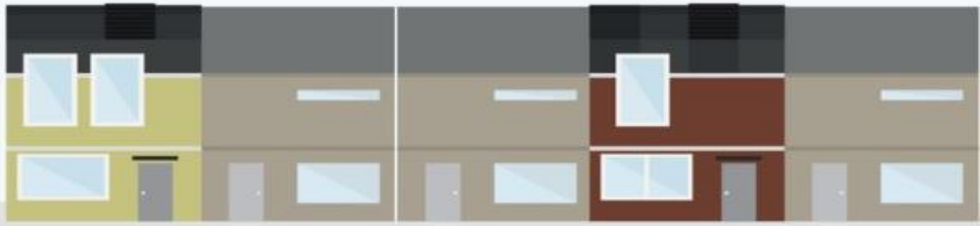
Thermal Bridges

Overview - Drivers

Legislation / energy awareness ➡ Increased insulation levels ➡ Increased importance of heat loss due to thermal bridging

- Heat finds path of least resistance
- Thermal bridging through junctionscan be responsible for up to 30 % of a dwellings heat loss
- Heat loss associated with thermal bridging = Linear thermal transmittance (Ψ-value)
- Surface temperature factor (*f*) – mould growth risk assessments





Thermal Bridges

Linear thermal transmittance (Ψ –value)

The Ψ–value, or linear thermal transmittance represents the extra heat flow through the linear thermal bridge over and above that through the adjoining plane elements.

From numerical modelling of a 2D junction, the thermal coupling coefficient between the internal and external environments is:

$$\boxed{L^{2D} = \frac{Q}{T_i - T_e} \quad (W/mK)}$$

where: -

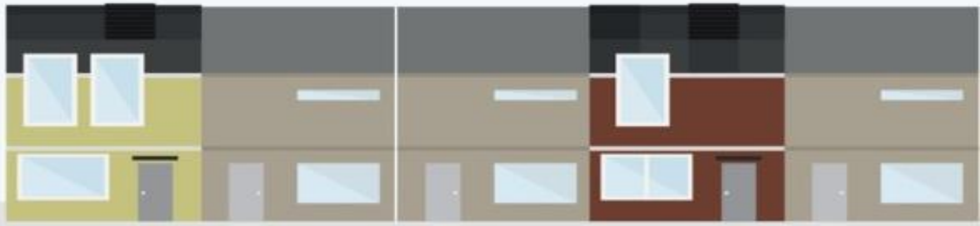
Q is the total heat flow from internal to external environment and
T_i and T_e are the temperatures of he internal and external environments

Hence, the linear thermal transmittance of the 2D junction is the residual heat flow from the internal to external environment after subtracting the 1D heat flow through the flanking elements:

$$\boxed{\Psi = L^{2D} - \sum(U \times \ell) \quad (W/mK)}$$

where:-

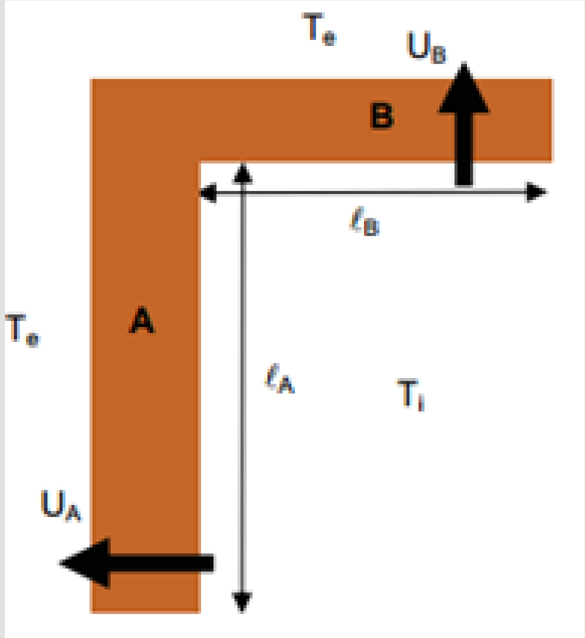
L^{2D} is the thermal coupling coefficient
U is the U-value in W/m^2K of the flanking element
ℓ is the length in metres over which U applies



Thermal Bridges

Linear Thermal Transmittance (Ψ –value) – Masonry Wall Example

The figure opposite shows a corner of a simple masonry wall with flanking elements A and B where the model is considered to extend 1 metre in the third dimension.



The linear thermal transmittance, in this case, is calculated from:

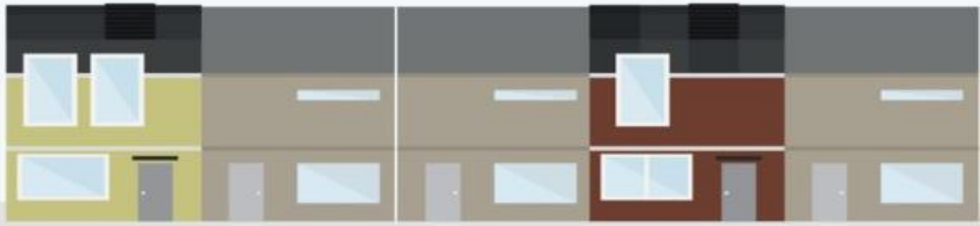
$$\Psi = L^{2D} - (U_A \times l_A) - (U_B \times l_B) \quad (W/mK)$$

where:-

L^{2D} is the thermal coupling coefficient

U_A and U_B are the U-values in W/m^2K of the flanking elements A and B

l_A and l_B are the lengths in metres over which U_A and U_B apply



Thermal Bridges

Temperature Factor, $f_{R_{si}}$

The temperature factor, $f_{R_{si}}$, is used to assess the risk of surface condensation or mould growth on any detail. It is calculated (under steady state conditions) from

$$f_{R_{si}} = \frac{T_{si} - T_e}{T_i - T_e}$$

where:-

T_{si} is the surface temperature
T_i is the internal environmental temperature and
T_e is the temperature of the external environment

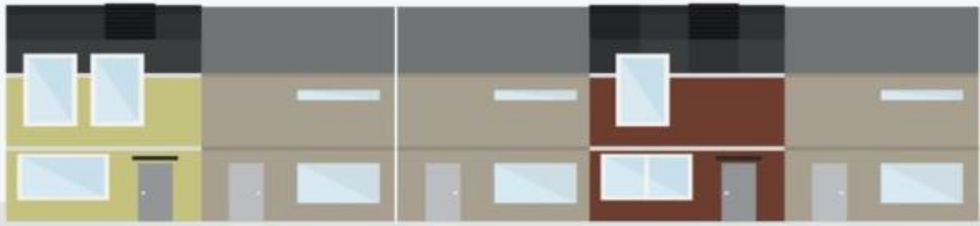
Hence the temperature factor depends only on the construction and not on the chosen environmental temperatures. Having calculated the temperature factor for a particular T_i and T_e, it can be used to calculate the surface temperature for any other set of environmental temperatures from

$$T_{si} = f_{R_{si}}(T_i - T_e) + T_e$$

To limit the risk of surface condensation and mould growth, $f_{R_{si}}$ should be greater than or equal to a critical value ($f_{RC_{si}}$):

Table 1 Critical temperature factors for avoiding mould growth in buildings

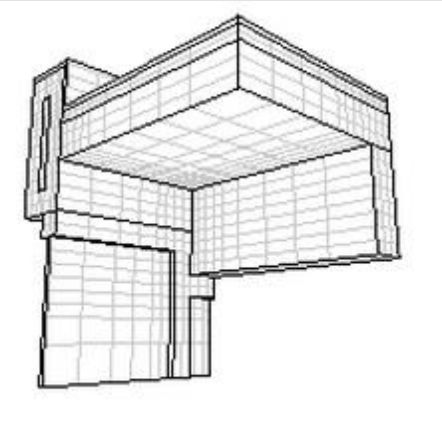
Type of building	f_{CRsi}
Dwellings; residential buildings; schools	0.75
Swimming pools (including a dwelling with an indoor pool)	0.90

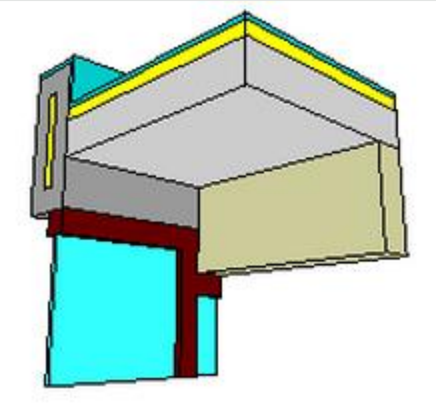


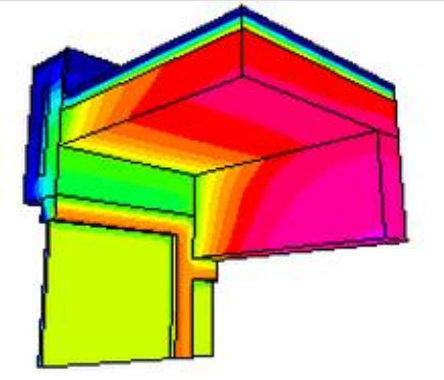
Thermal Bridges

Assessment Procedures Overview

- Assessment and review of design (simple to complex)
- From concept to performance
- Determine:
  - Level of thermal bridging
  - ‘Weak’ points in the envelope
  - Risk of condensation
- Improve performance







Thermal Bridges

Reference Documents - BR 497 / BR IP 1/06

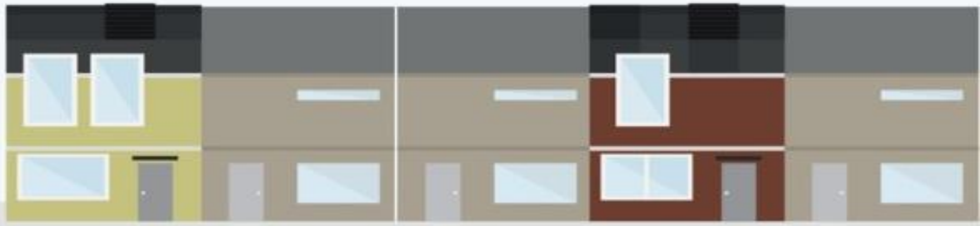
BR 497 – Conventions for Calculating Linear Thermal Transmittance and Temperature Factors:

- Conventions for numerical modellers to produce consistent, reproducible results
- Two key modelling outputs for building regulation purposes:
  - Linear thermal transmittance
  - Temperature factor

BR IP 1/06 – Assessing the Effects of Thermal Bridging at Juncitons and Around Openings:

- Guidance on assessing effects of thermal bridging at individual junctions and their effect on overall heat loss

3. THERMAL BRIDGING

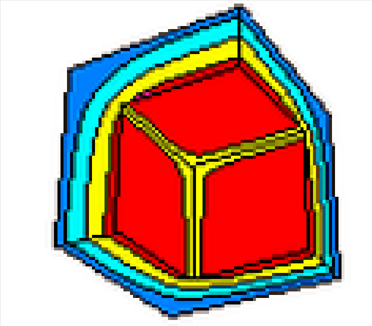


Thermal Bridges

Simulation Tools - TRISCO

Trisco software is used for modelling heat transfer through building details including the assessment of thermal bridges.

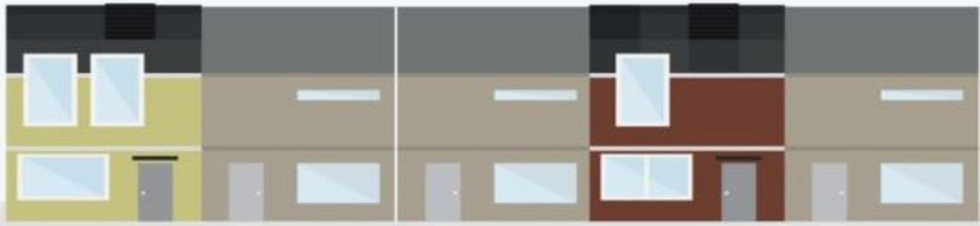
- Satisfies requirements of BS EN ISO 10211
- Requires technical knowledge of:
  - Heat transfer processes
  - Technical doucments (BR 497, BR IP 1/06, BS EN ISO 10211, BS EN ISO 10077-2)
- Knowledge of U-value calculations at design stage – Avoids costly changes later in projects
- Model ➡ Materials ➡ Boundary conditions ➡ Mesh ➡ Solver➡ Output



PHYSIBEL

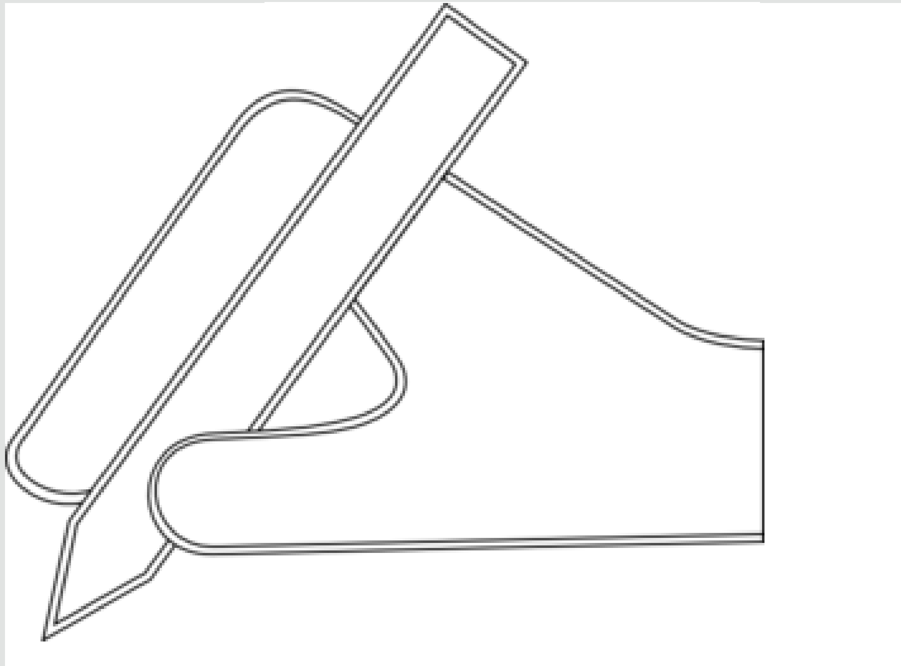
TRISCO

3D steady state heat transfer rectangular blocks



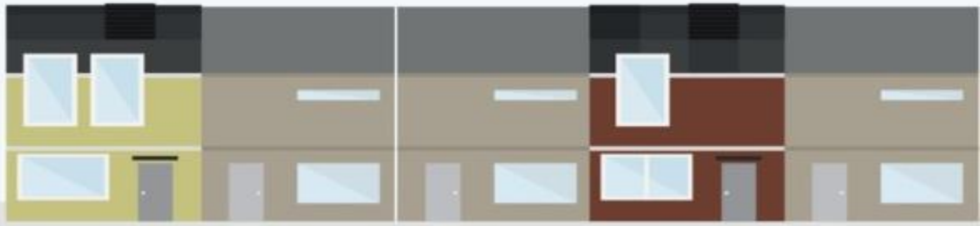
Thermal Bridges

Practical / Group Detail Review Exercise



3. THERMAL BRIDGING

MORE—CONNECT



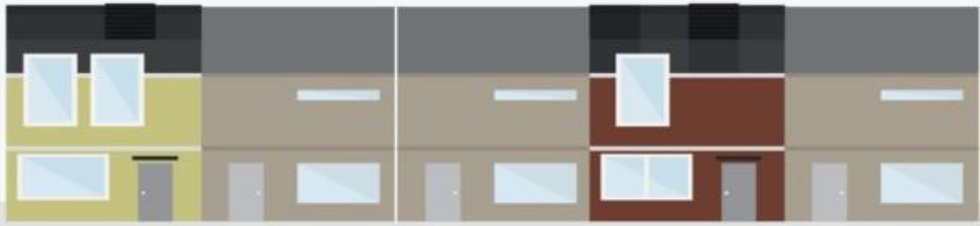
Thermal Bridges

Detail review exercise

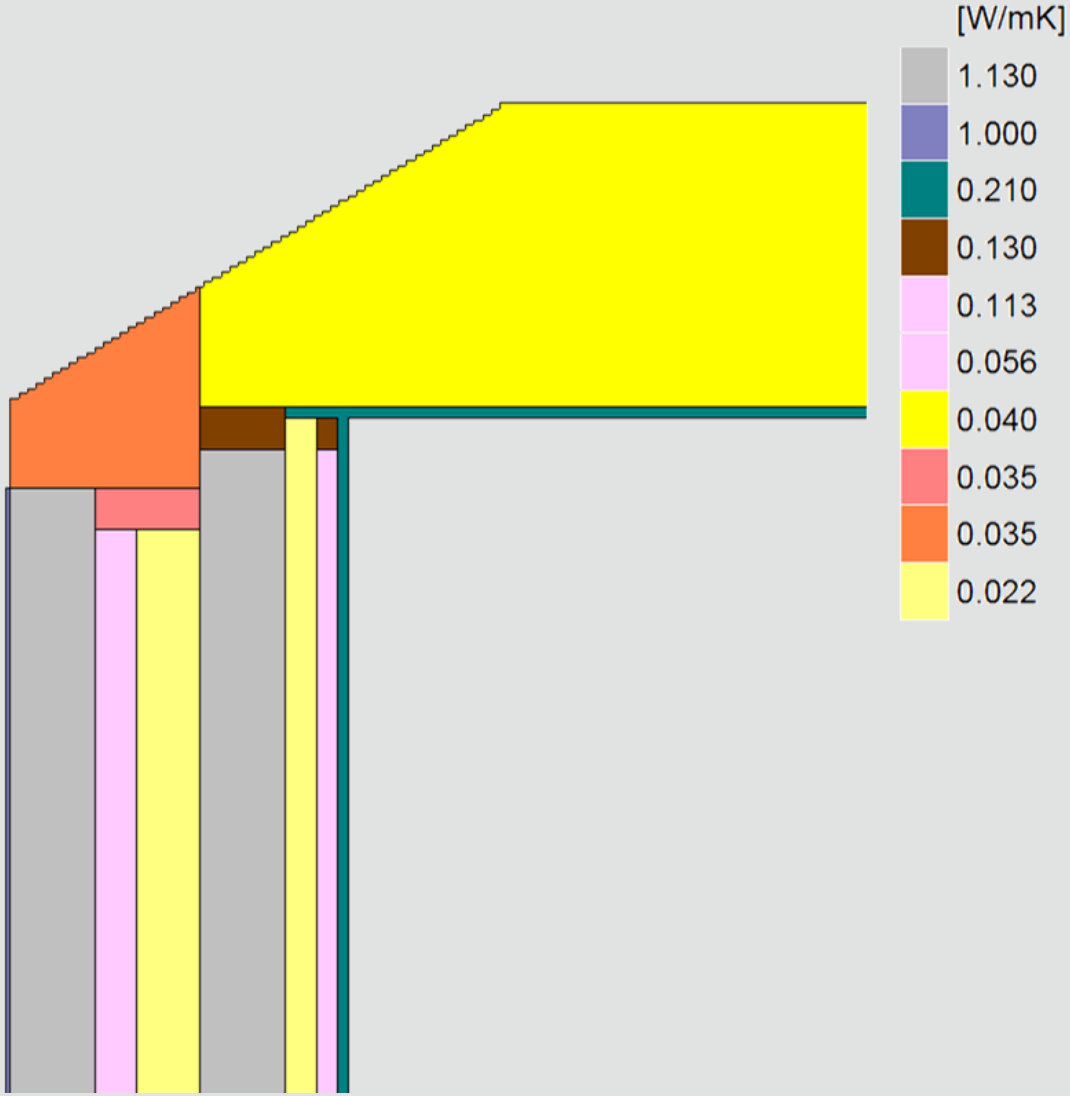
- **Review detail**
- **Identify any obvious thermal weakness**
- **Highlight expected lowest surface temperature point**
- **Mark-up sketch to show expected heat flow lines**

3. THERMAL BRIDGING

MORE—CONNECT

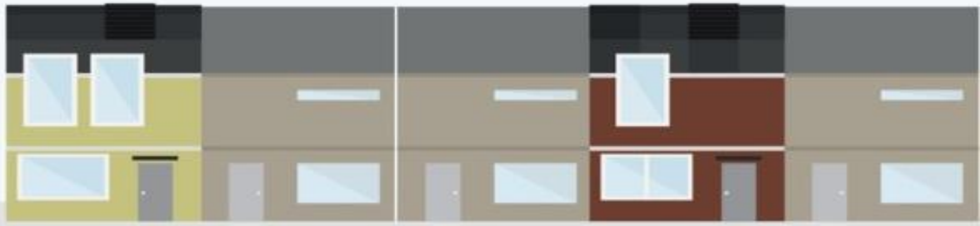


Thermal Bridges (detail 1)



3. THERMAL BRIDGING

MORE—CONNECT



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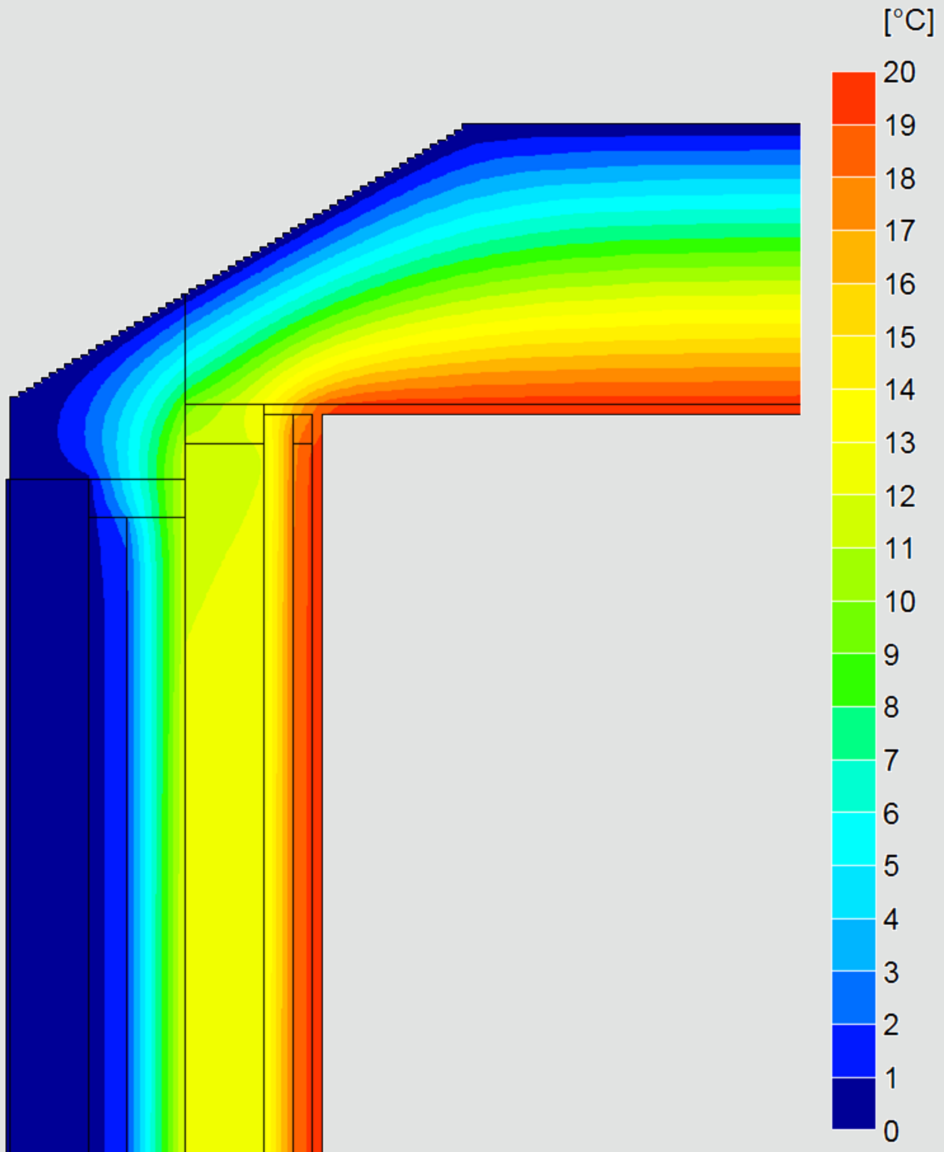
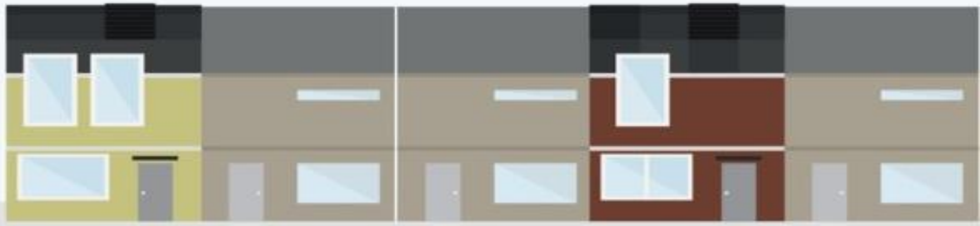


3. THERMAL BRIDGING

MORE—CONNECT



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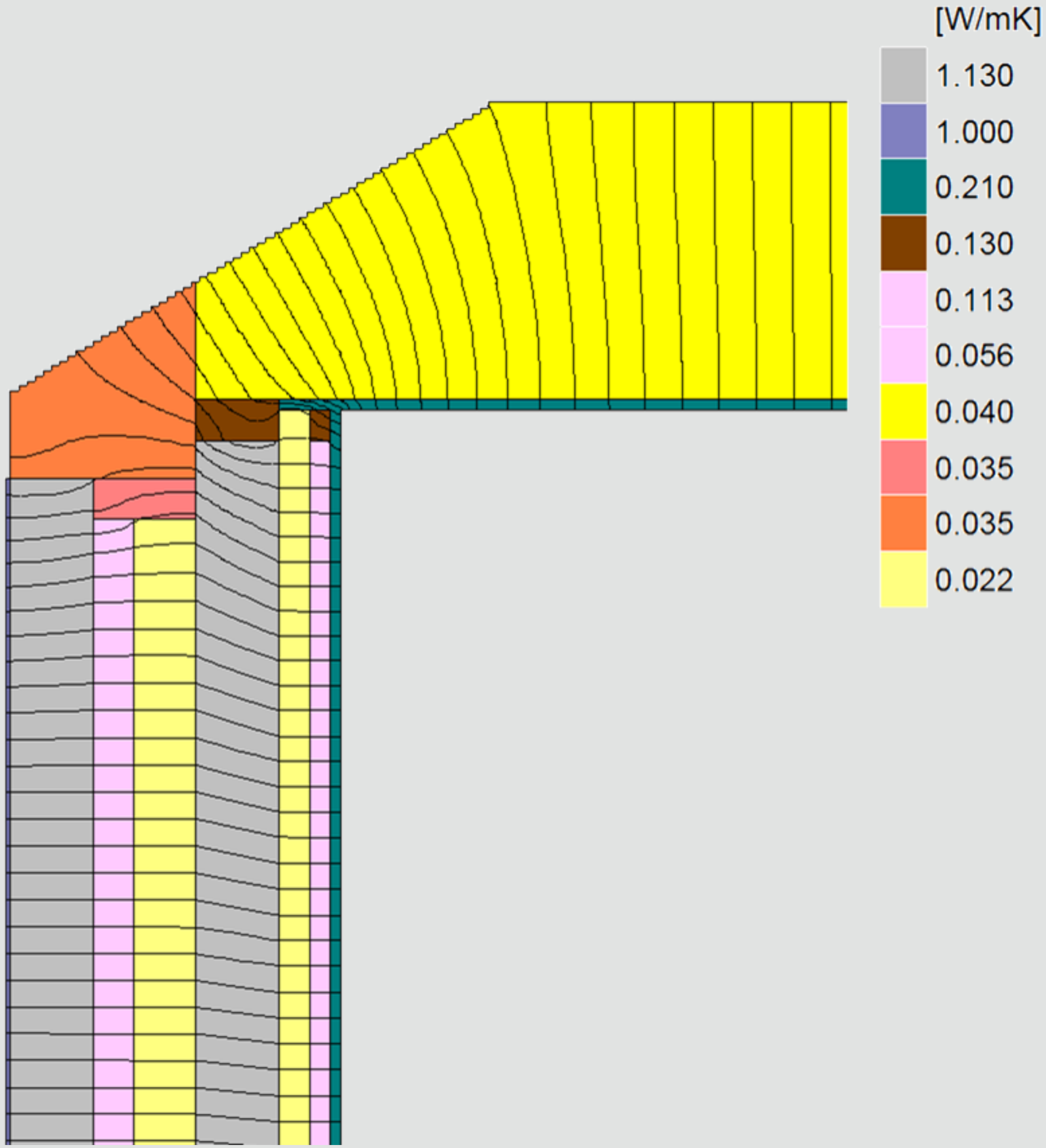
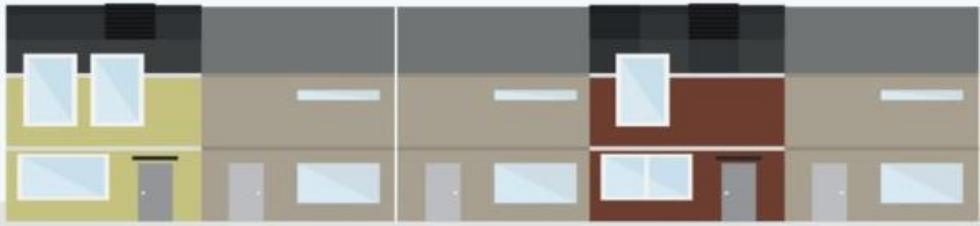
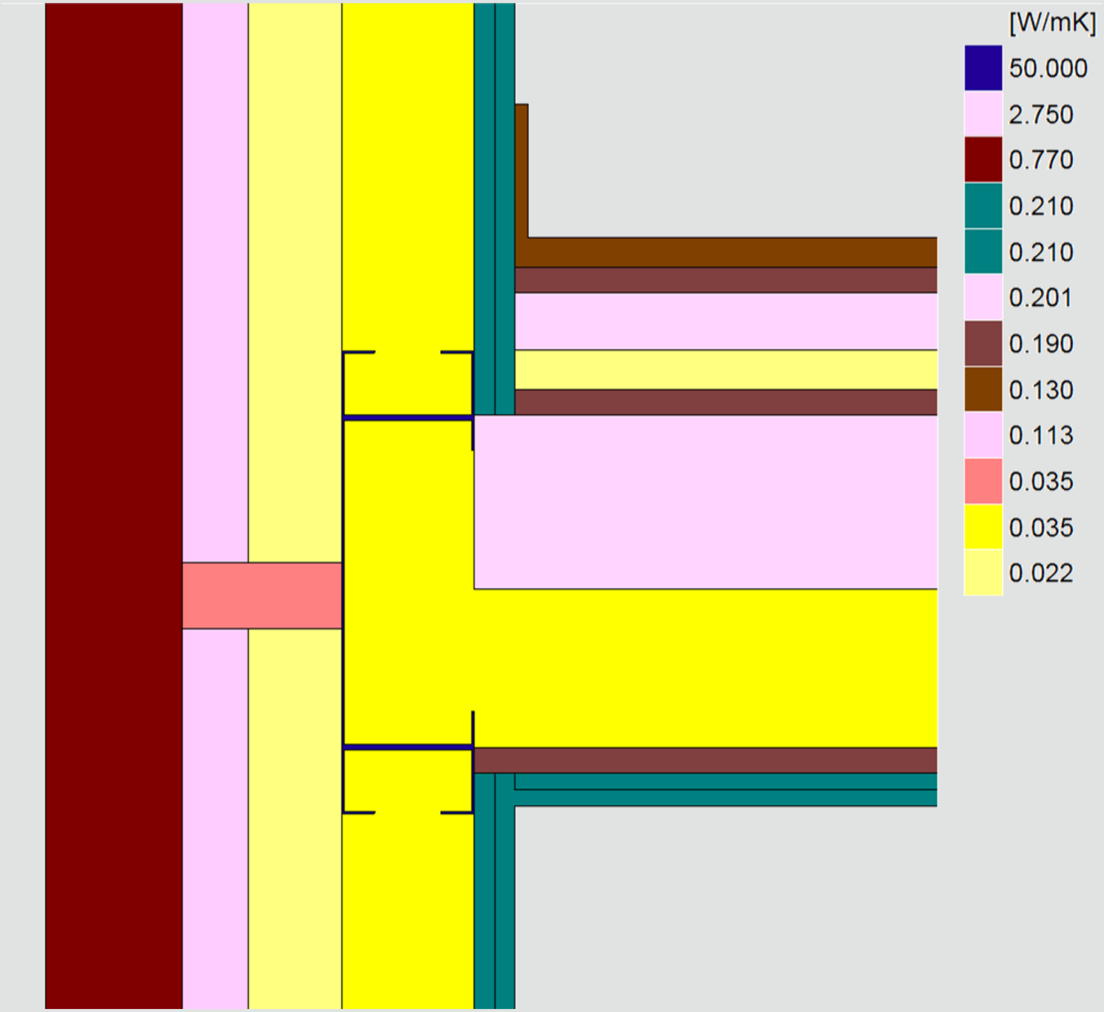


3. THERMAL BRIDGING

MORE—CONNECT

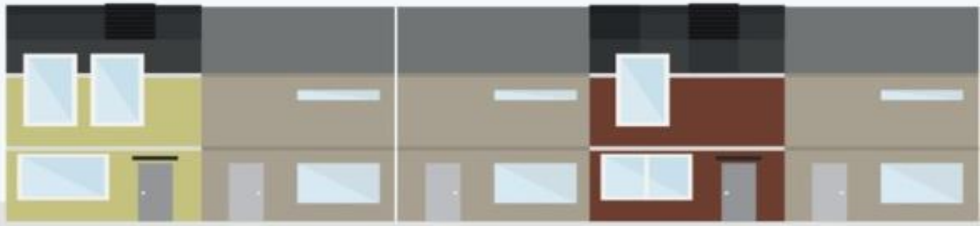


Thermal Bridges (detail 2)



3. THERMAL BRIDGING

MORE—CONNECT



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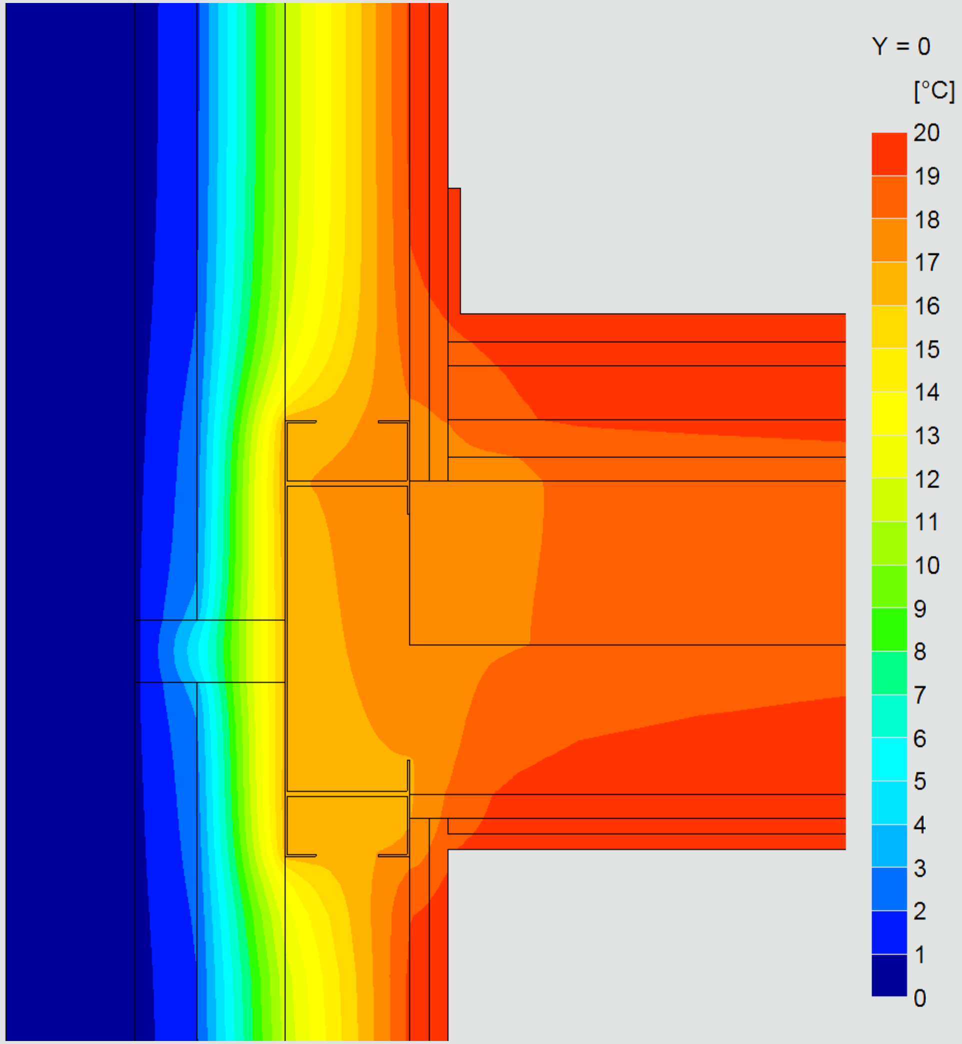
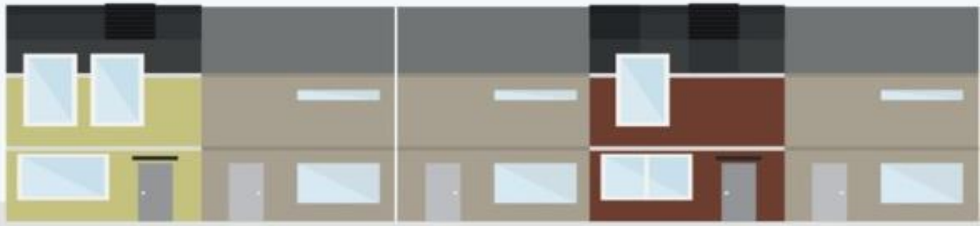


3. THERMAL BRIDGING

MORE — CONNECT



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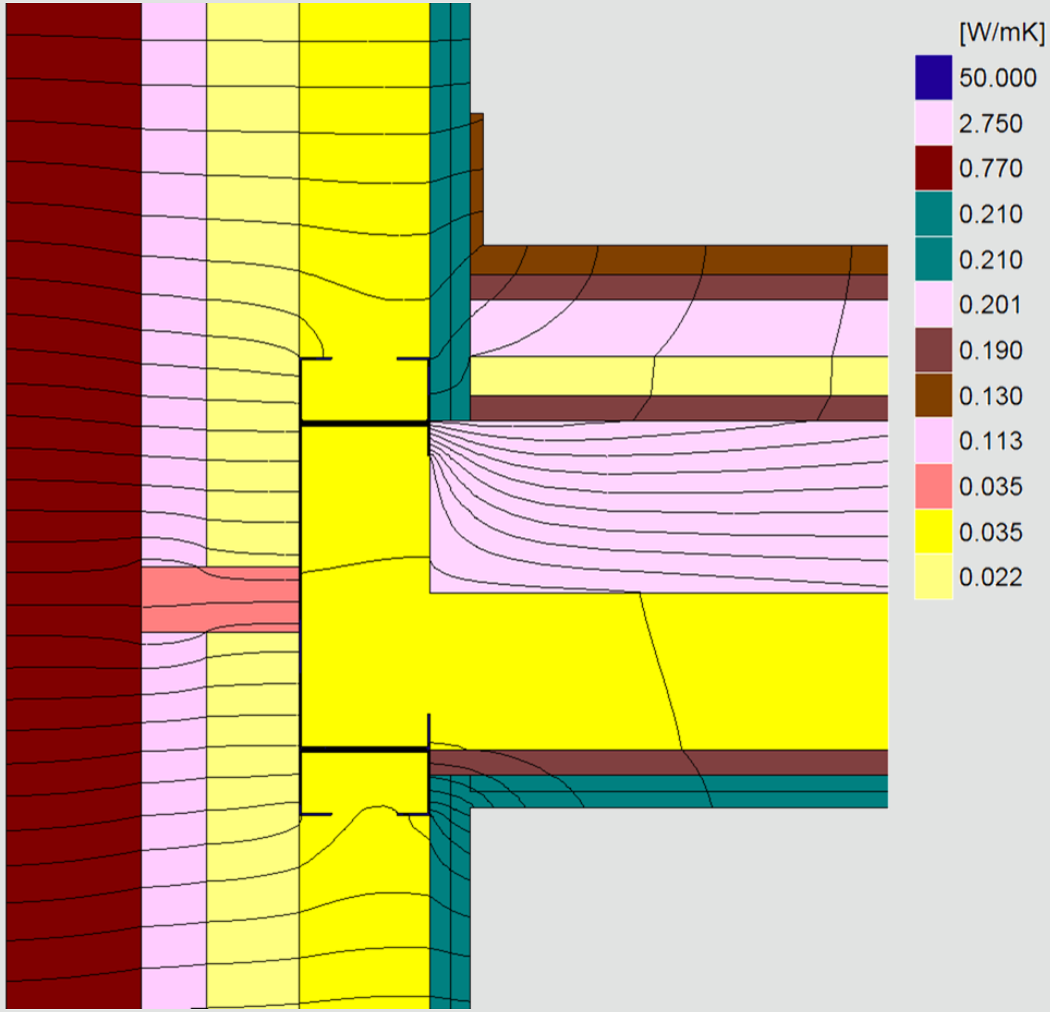

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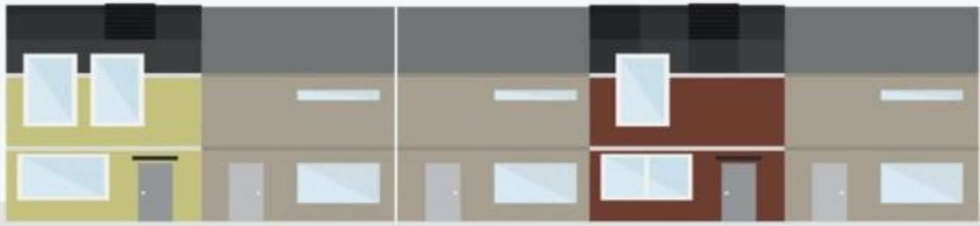
MORE—CONNECT



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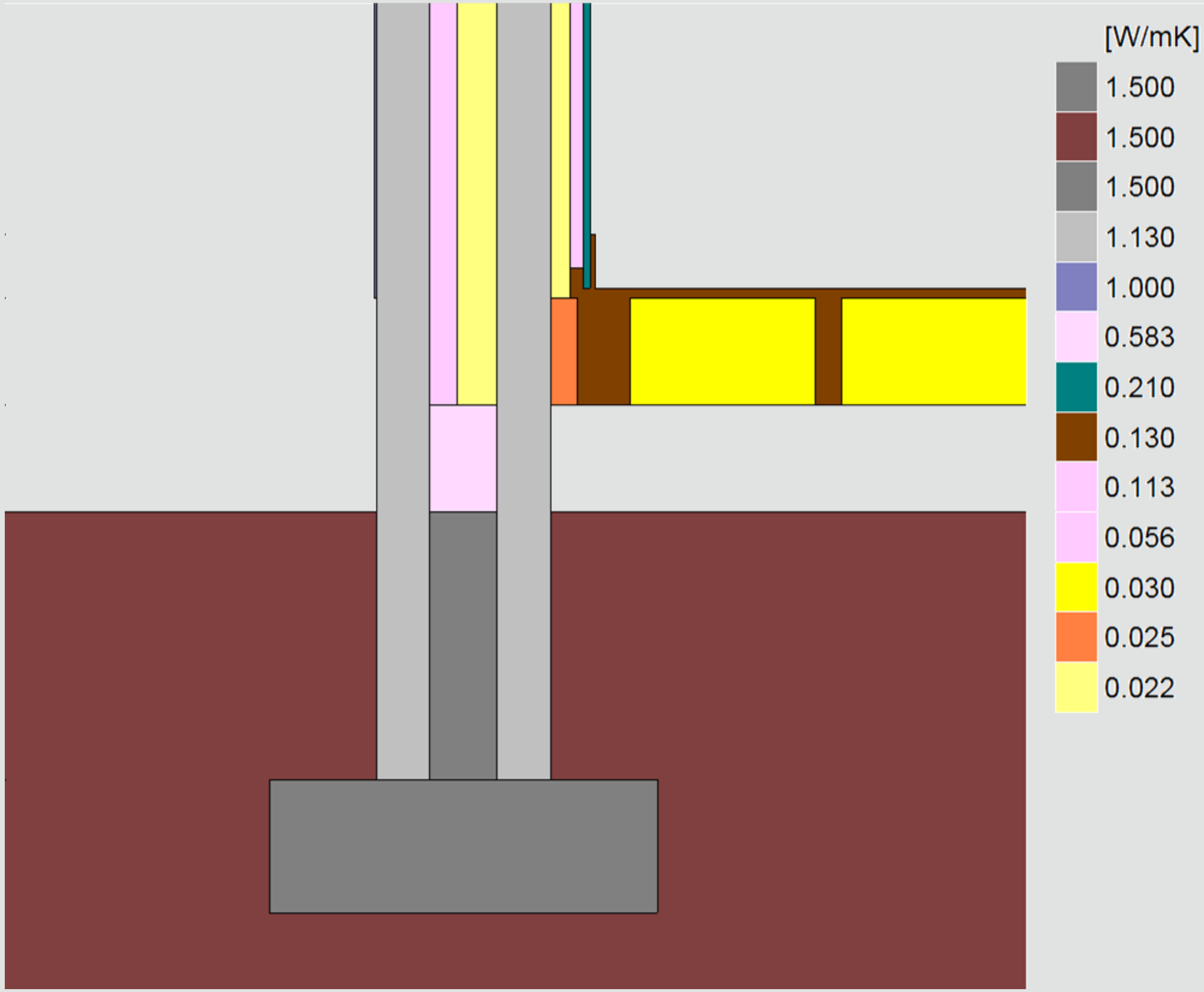
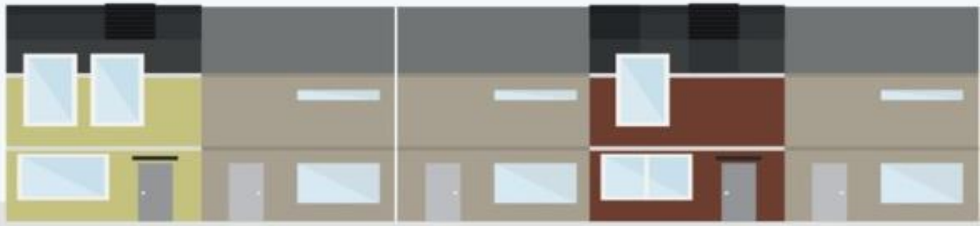
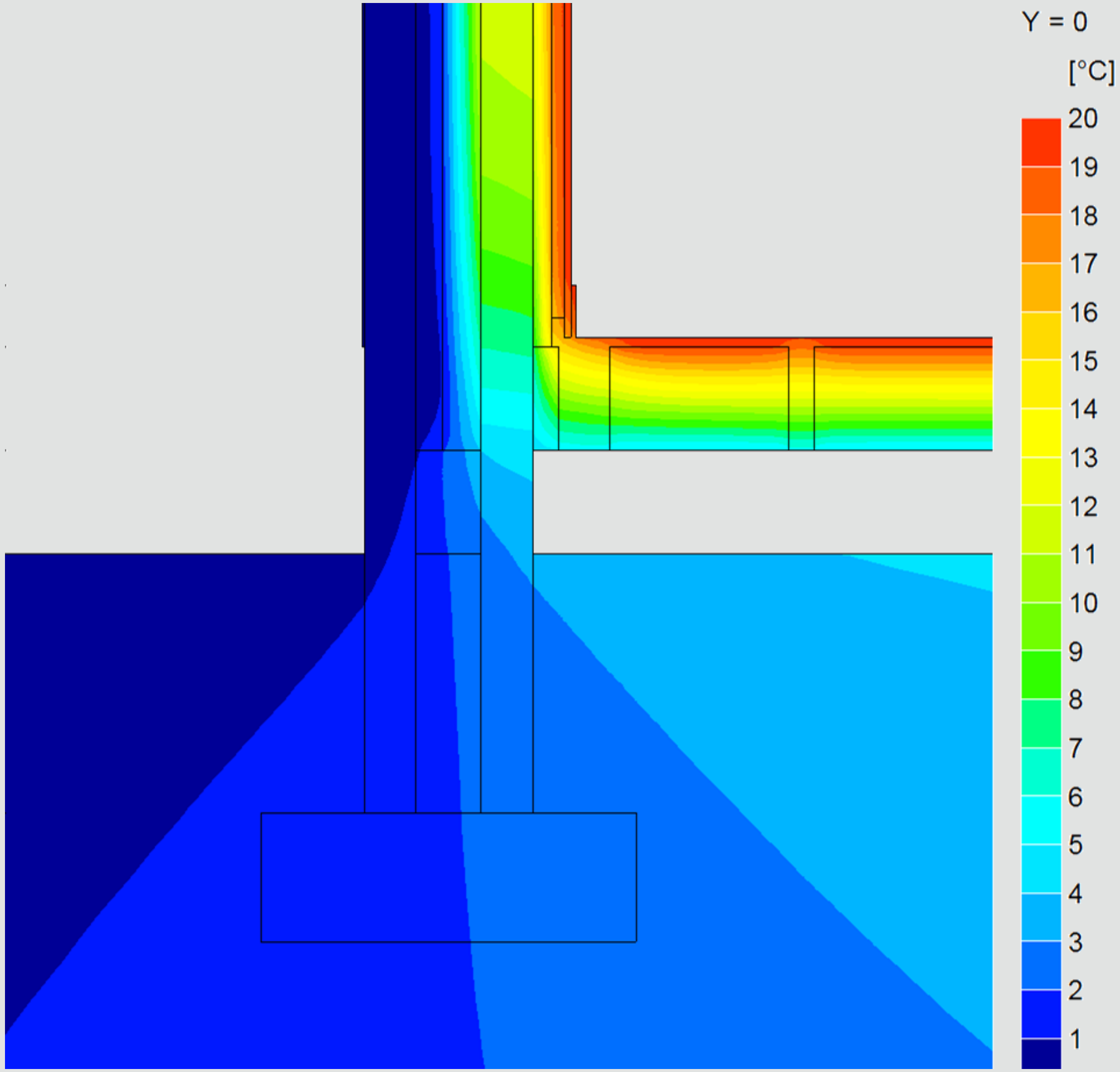


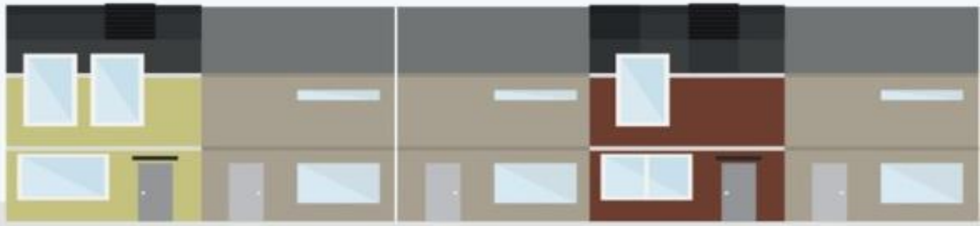
3. THERMAL BRIDGING

MORE—CONNECT



Thermal Bridges (detail 3)





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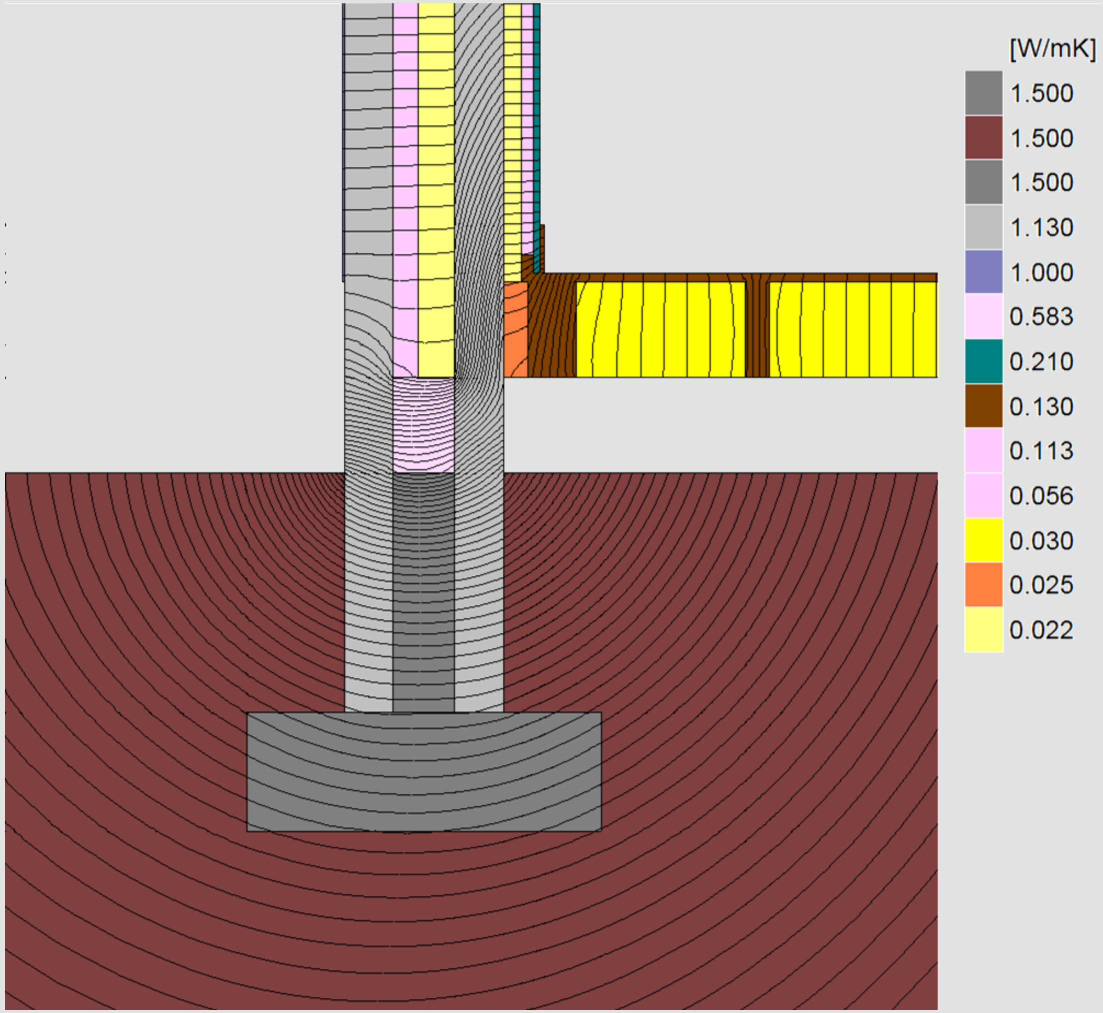
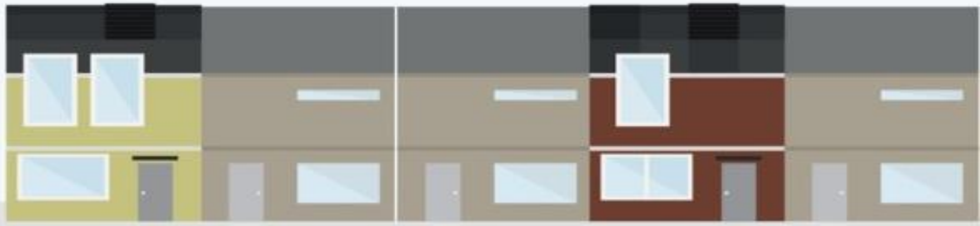


3. THERMAL BRIDGING

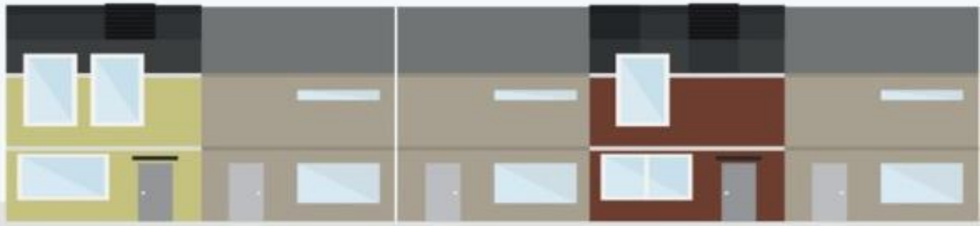
MORE—CONNECT



Impact

Impact of Poorly Insulated Buildings

- Poor internal environment
- Deterioration of health
- Increased heating bills potentially leading to fuel poverty
- Increased share of CO_2 emissions from built environment



Impact

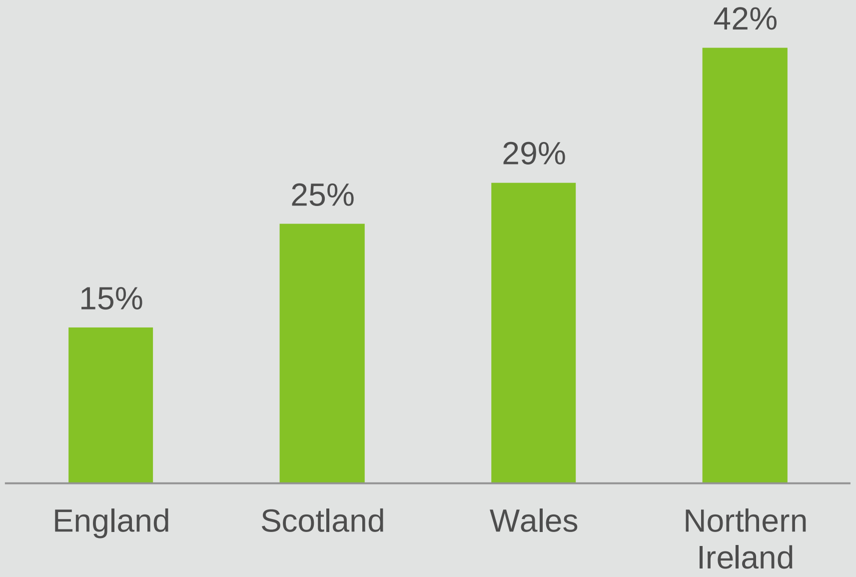
Fuel Poverty

Fuel Poverty is defined as when a household...

- *"...needs to spend more than 10 % of its income on fuel to maintain a satisfactory heating regime*

  OR

- *"...has fuel costs that are above average (the national median level), and were they to spend that amount they would be left with a residual income below the official poverty line*



Proportion of the UK population who are 'fuel poor' (%)

Impact

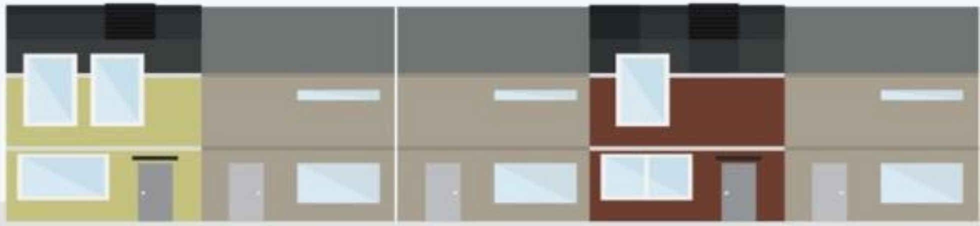
Health

A buildings thermal performance has many health implications. A cold building can lead to:

- Respiratory disease caused by
  - Dampness
  - Mould growth
- Allergies
- Reduced productivity
- Poor mental health
- Sick building syndrome
- Illness
- Death

*"The annual cost to the NHS (National Health Service) of treating winter related disease due to cold private housing is **£859 Million**."*

3. THERMAL BRIDGING



Impact

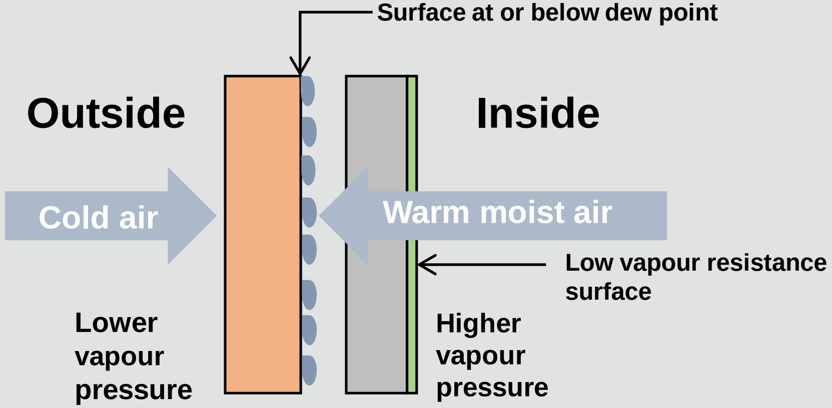
Interstitial and Surface Condensation

Potential problems:

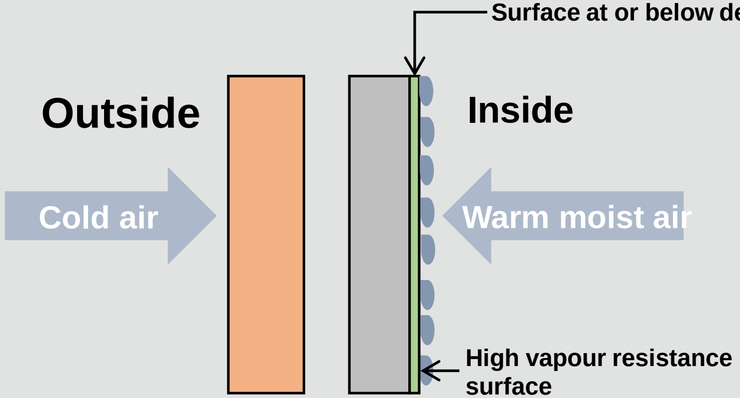
- Dampness
- Mould growth
- Buidling damage

Reduction strategies:

- Thermal insulation
- Heating – Maintaining 10°C even when unoccupied
- Ventilation
- Vapour control layers



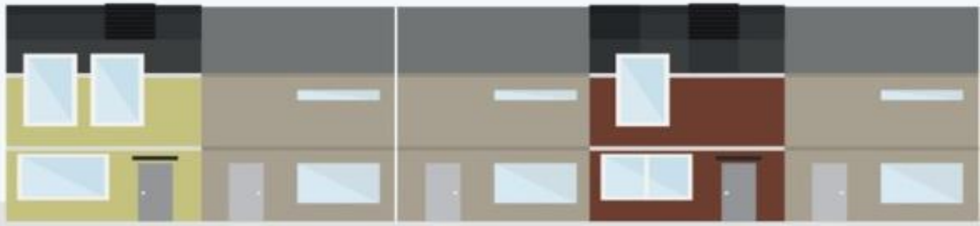
Interstitial Condensation



Surface condensation

4. THERMAL PERFORMANCE

MORE—CONNECT



On site

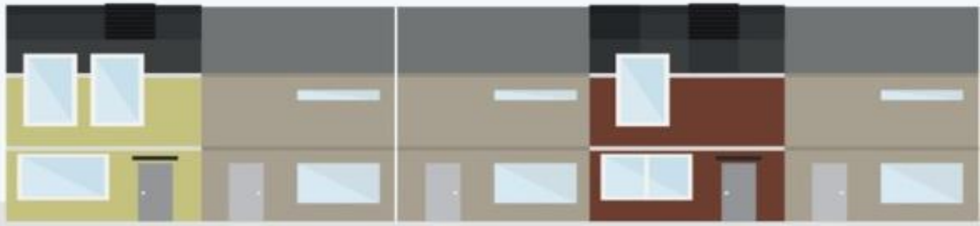
Buildability

The degree to which the design of a planned building facilitates its construction and utilisation.

- More complex building design leads to greater emphasis on achieving desired final quality of build
- Often contractors input/experience is lost due to late appointment during the building design
- With decisions taken in the early stages of design being crucial to the building construction and the overall success of a project, the contractor should be engaged as early as possible to advise on buildability

4. THERMAL PERFORMANCE

MORE—CONNECT

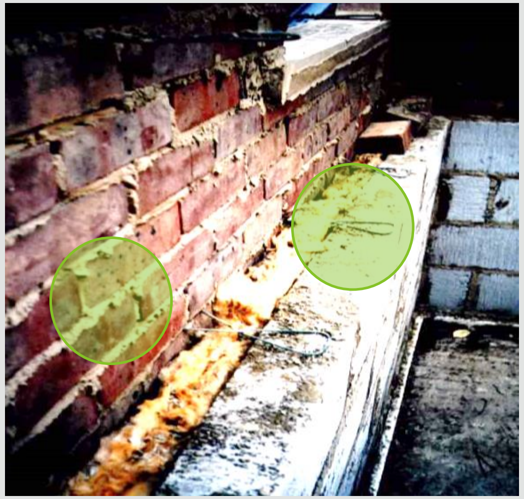


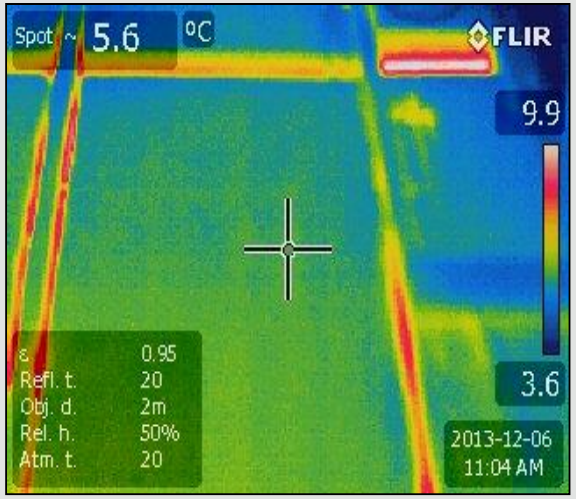
On site

Workmanship

- Mild steel wall ties bridging insulation – Very high thermal conductivity (50 W/mK) compared to low conductivity stainless steel
- Mortar squeeze/dirty cavity – impacts on the installation of insulation

- Thermal break insulation:
  - Lack of continuity
  - Insulation does not meet eaves
  - Significant heat loss





4. THERMAL PERFORMANCE

MORE—CONNECT

On site

Risks

Poor build and workmanship quality vastly increases the chances of the following problems occuring:

- Lower U-value than design specification
- Lack of continuity of insulation
  - Increased thermal bridging

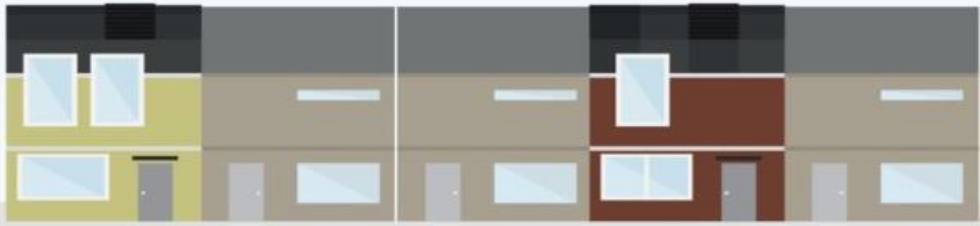
Significant heat loss

- Dampness / Mould Growth
  - Respiratory disease and other health implications
- Higher energy consumption
- Greater carbon footprint

Significant heat loss through building fabric

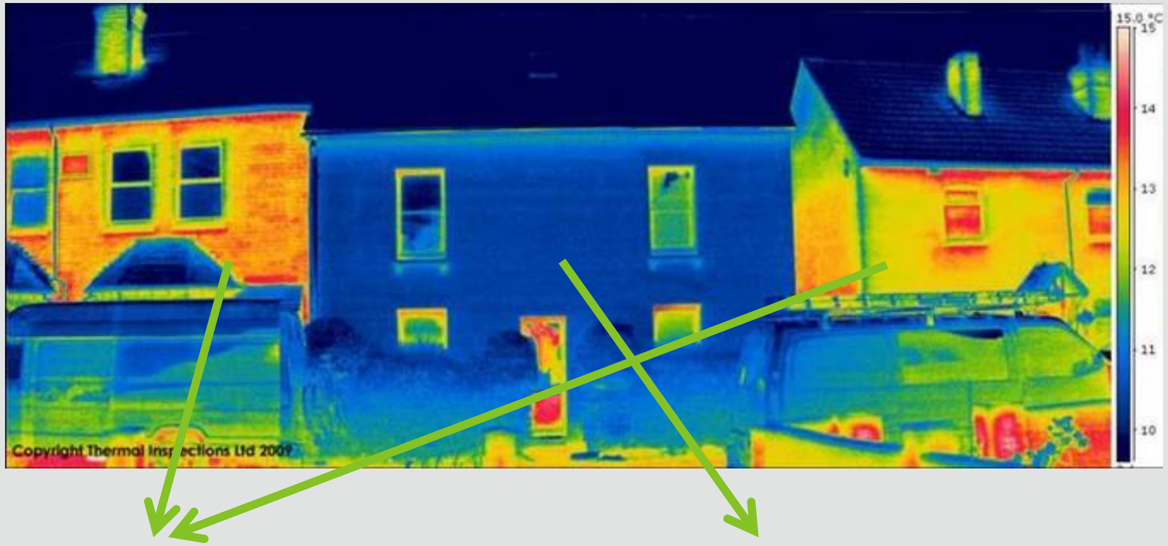
4. THERMAL PERFORMANCE

MORE—CONNECT



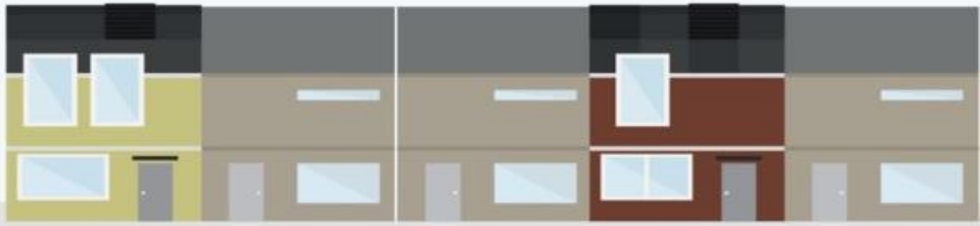
On site

Best Practice Examples



- Poorly insulated
- Significant thermal bridging
- Poor airtightness
- Standard single glazing

- Well insulated (Wall U-value ≤ 0.15 W/m^{2}K)
- Reduced thermal bridging
- Very airtight (1 m^3/h.m^2)
- Double/triple glazed (U-value ≤ 0.8 W/m^{2}K)



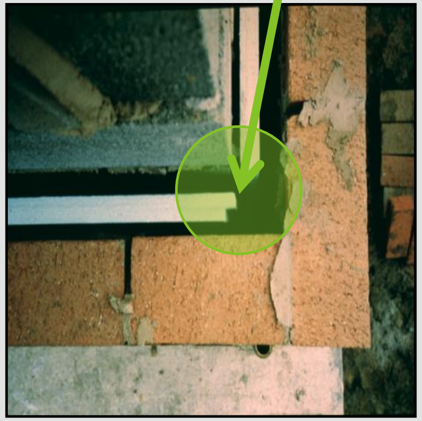
On site

Bad Practice Examples

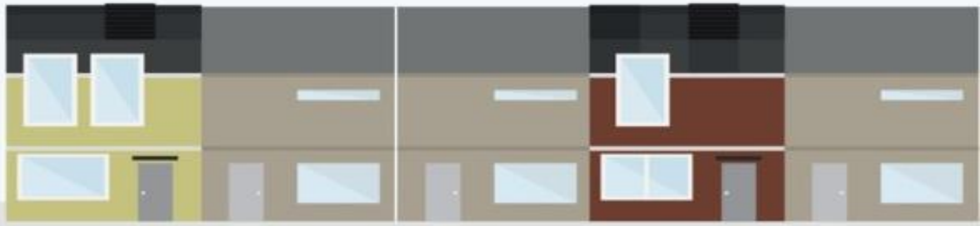
Thermal bridging of insulation:

- Steel frame not insulated
- Heat travels from inside to out through the frame
- Lack of continuity of insulation leads to thermal bridging which could lead to dampness and mould growth

- Lack of continuity of insulation can also result in significant increases in overall heat loss



4. THERMAL PERFORMANCE



Subject overview: The case for Portugal

Building Thermal Legislation

1990 Decree-Law 40/90 - Regulation of thermal performance characteristics of buildings (RCCTE)

1998 Decree-Law 119/98 - Regulation of HVAC systems in buildings (RSECE)

2002 **Directive 2002/91/EC - Energy Performance of Buildings Directive (EPBD)**

Decree-Law 78/2006 - Buildings Energy Certification System and Indoor Air Quality (SCE and QAI)

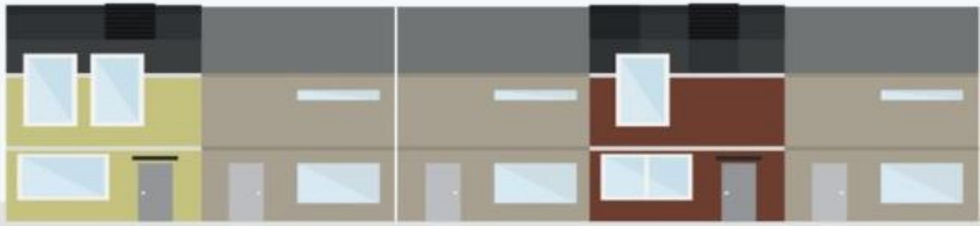
2006 Decree-Law 79/2006 - Regulation of HVAC systems in buildings (RSECE)

Decree-Law 80/2006 - Regulation of thermal performance characteristics of buildings (RCCTE)

2010 **Directive 2010/31/EU - Energy Performance of Buildings Directive (EPBD-recast)**

2013 **Decree-Law 118/2013** → **Updated by Decree-Law 68-A/2015 and by Decree-Law 194/2015**

- Buildings Energy Certification System (SCE)
- Energy Performance of Residential Buildings (Housing) (REH)
- Energy Performance of Commercial and Office Buildings (RECS)



Subject overview: The case for Portugal

Building Thermal Legislation

Decree-Law 118/2013 & related Ordinances and Mandamus → Portuguese thermal legislation

Transposes into national law the EPBD-recast & review the national thermal legislation.

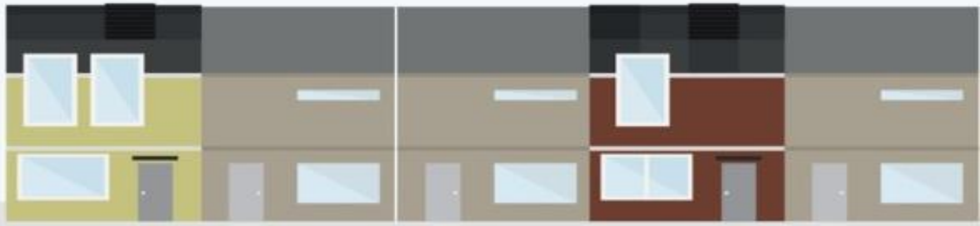
Includes in one document:

- Buildings Energy Certification System (SCE)
- Energy Performance of Residential Buildings (Housing) (REH)
- Energy Performance of Commercial and Office Buildings (RECS)

Sets the values for:

- thermal transmittance (U-values) of the building exterior envelope (walls, floors and roofs, thermal bridges)
- maximum Solar Factor, or Solar Heat Gain Coefficient (g or SHGC)

The values are defined accordingly to the building typology (residential and non-residential) and with the climate zone (defined for winter and summer depending on the climate severity).



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Article 3º - For buildings under the scope of the Energy Certification System

Point 1

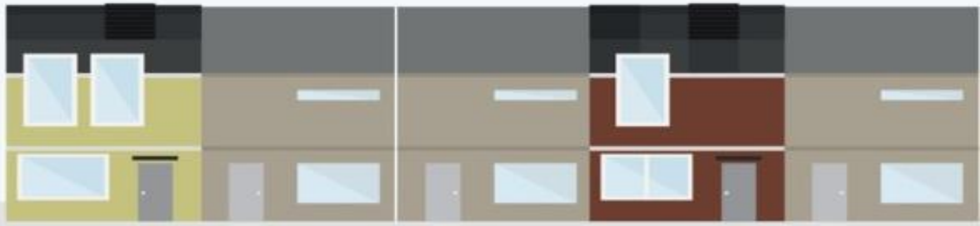
- New buildings → construction license/authorization
- Buildings undergoing major renovation works (renovation cost over 25% of the value of the building, excluding the value of the land upon which the building is situated) → construction license/authorization

Point 3

- Office and commercial buildings → more than 1000 m^2 interior area (500 m^2 in case of commercial areas like supermarkets or interior swimming pools)
- Public buildings → Buildings belonging or occupied by a public authority and open to public access with more than 500 m^2 (250 m^2 from 2015 onwards)

Point 4

- All buildings (except classified/listed buildings, tumble-down buildings, garages) → Whenever for sale or rent



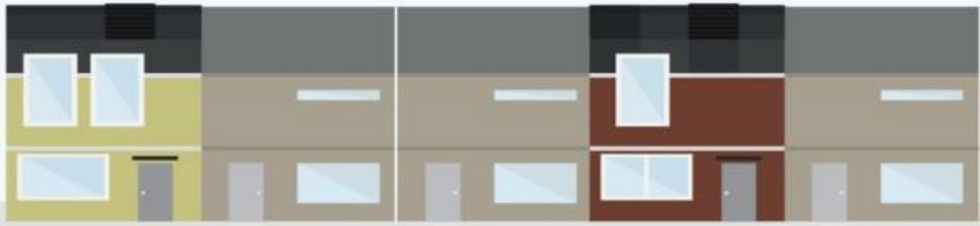
Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Energy Performance of Residential Buildings (REH)

Specific requirements

	Systems efficiency	Thermal behaviour
New buildings	✓	✓
Buildings undergoing major renovation works	✓	✓
Existing buildings		



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

REH (residential buildings) Thermal behaviour requirements of new buildings

Energy requirements

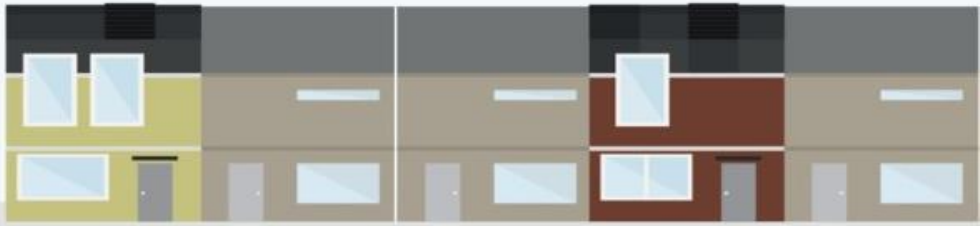
- Limits for heating energy demand
- Limits for cooling energy demand

Envelope quality requirements

- Thermal performance of opaque envelope → *Minimizing the occurrence of pathologies*
- Solar Heat Gain Coefficient (SHGC) → *Minimizing overheating of spaces*

Ventilation requirements

- Air tightness, air changes per hour



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

REH (residential buildings) Systems efficiency requirements

Technical systems requirements

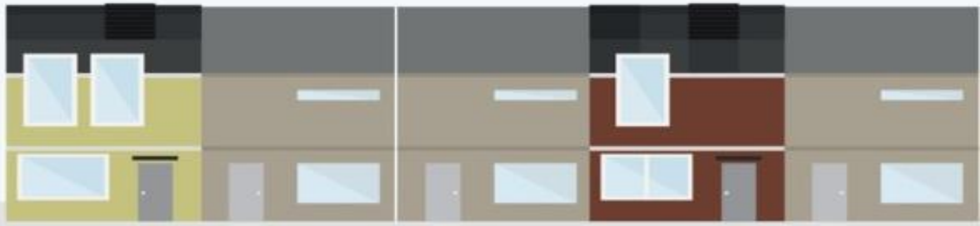
- General requirements → *Project design, control, maintenance*
- Efficiency requirements

Solar system requirements

- Mandatory installation for Domestic Hot Water (DHW) production → Design criteria revised - Standard collector
- Possibility replacement by other systems → Assuming a production equivalent to DHW

Energy consumption requirements

- Limits of primary energy demands



Subject overview: The case for Portugal

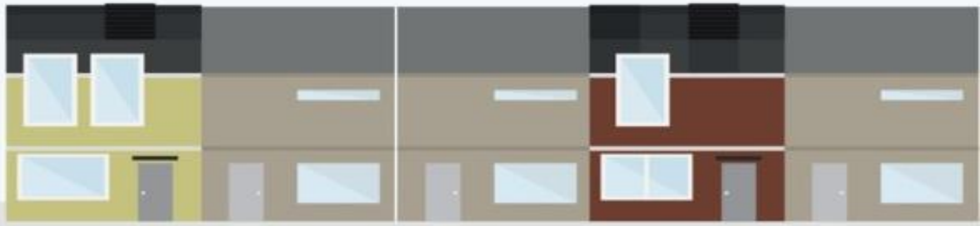
Building Thermal Legislation - Decree-Law 118/2013

Energy Performance of office and Commercial Buildings (RECS)

Specific requirements

	Systems efficiency	Thermal behaviour	Air quality	Installation Control Maintenance
New buildings	✓	✓	✓	✓
Buildings undergoing major renovation works	✓	✓	✓	✓
Existing buildings			✓	✓

4. THERMAL PERFORMANCE



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Energy Performance of office and Commercial Buildings (RECS)

New and subjected to major retrofit works

Envelope quality requirements

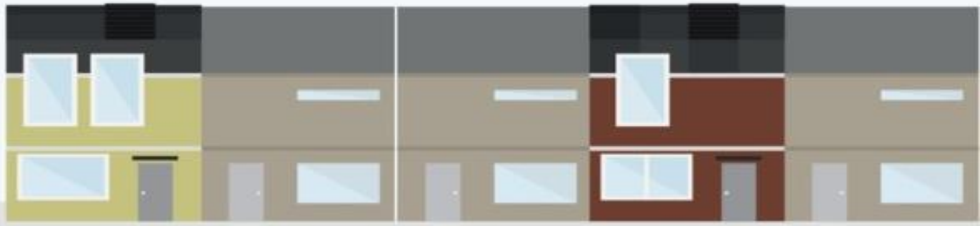
- Thermal performance of opaque envelope → *Minimizing the occurrence of pathologies*
- Solar Heat Gain Coefficient (SHGC) → *Minimizing overheating of spaces*

Technical systems requirements

- General requirements → *Project design, control, maintenance*
- Efficiency requirements

Air quality

- Minimum ventilation flow rates each air space of the building
- Natural or mechanical ventilation of spaces or a combination of both
- Pollutants concentration



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Energy Performance of office and Commercial Buildings (RECS)

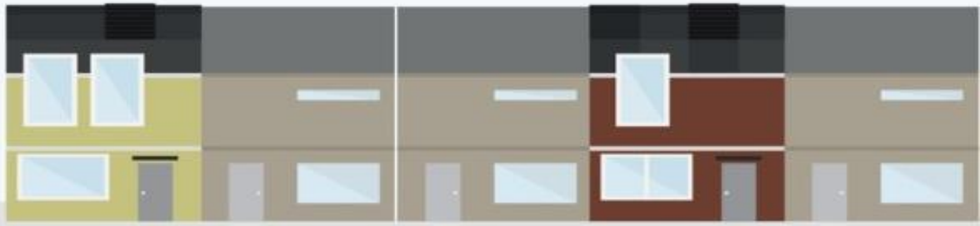
Existing, new and subjected to major retrofit works

Installation, Control & Maintenance

- Installation of HVAC systems - made by a team that includes a Technician of Installation and Maintenance (TIM);
- Maintenance of buildings - through a TIM to ensure the proper maintenance of the building and of their technical systems, monitor activities within this framework, and management and update all relevant technical information;
- Maintenance plan - technical systems (> 250 kW)

4. THERMAL PERFORMANCE

MORE—CONNECT



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Climatic data

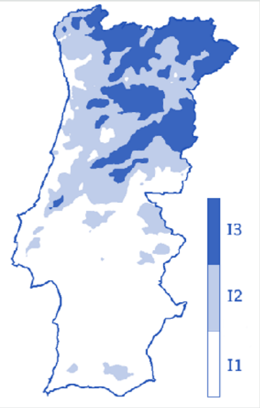
Winter

Heating Degree-days	**GD ≤ 1300**	**1300 < GD ≤ 1800**	**GD > 1800**
Zone	I1	I2	I3

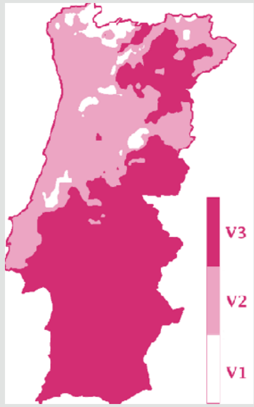
Summer

Outdoors average temperature in summer	**$\theta_{ext,v} \leq 20$ ºC**	**20ºC < $\theta_{ext,v} \leq 22$ ºC**	**$\theta_{ext,v} > 22$ ºC**
Zone	V1	V2	V3

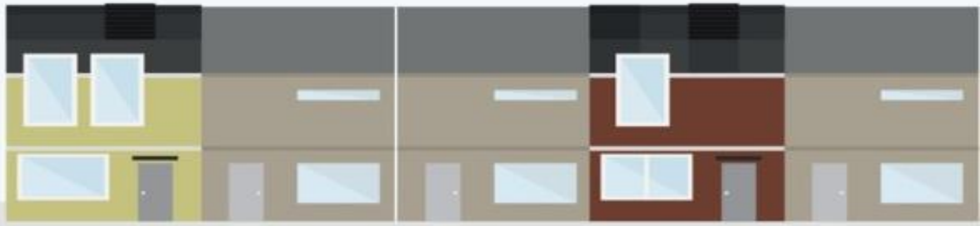
climate zone:



winter



summer



Subject overview: The case for Portugal

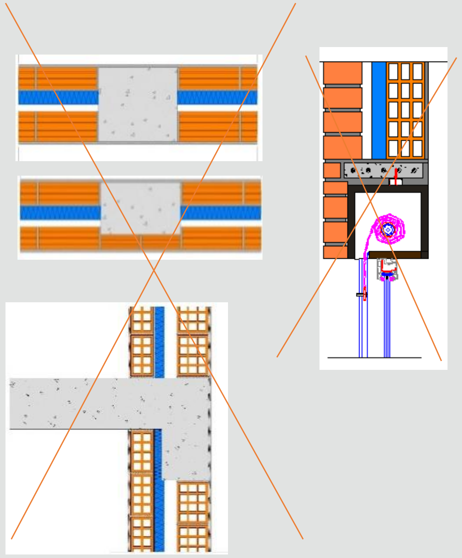
Building Thermal Legislation - Decree-Law 118/2013

Requisites

Thermal performance of opaque envelope $\Rightarrow U_{element} \leq U_{max}$

Thermal performance of plane thermal bridges (PTB):

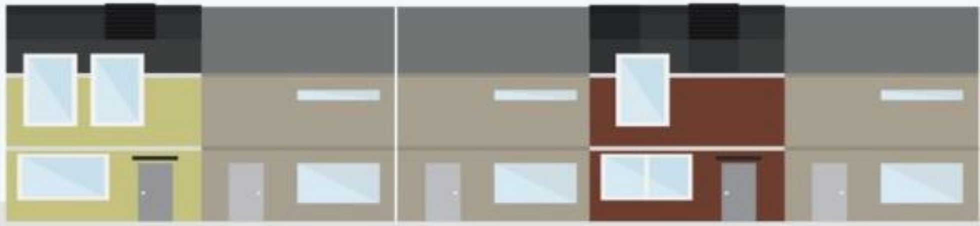
$\mathbf{U_{PTB} \leq}$ 0.9 W/m².ºC



$U_{máx}$ [W/m².ºC]		Climatic zone		
		I1	I2	I3
Envelope elements and elements separating useful and non useful areas (elevator shafts, common circulation areas) with $b_{tr} > 0.7$ (thermal conditions similar to outdoors)	Vertical elements	0.50	0.40	0.35
	Horizontal elements	0.40	0.35	0.30
Construction elements between buildings and non useful areas (elevator shafts, common circulation areas) with $b_{tr} \leq 0.7$ (thermal conditions similar to indoors)	Vertical elements	0.80	0.70	0.60
	Horizontal elements	0.60	0.60	0.50

4. THERMAL PERFORMANCE

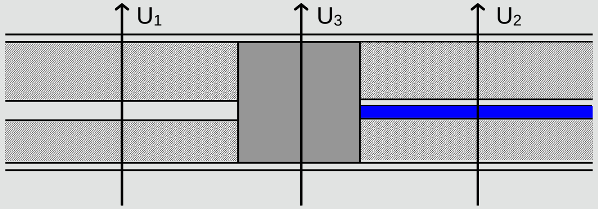
MORE — CONNECT

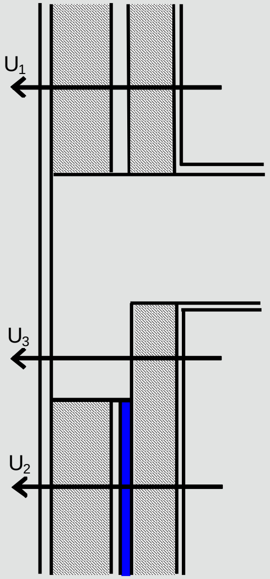


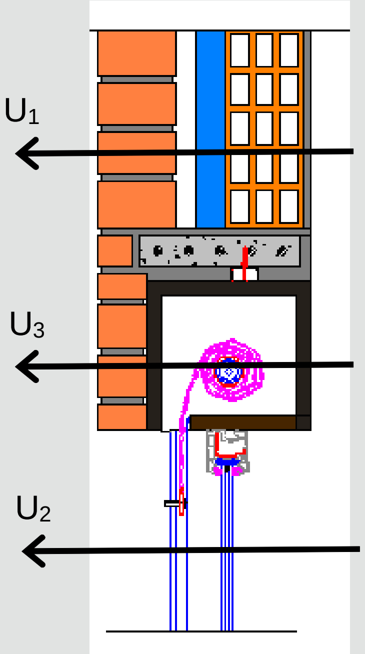
Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

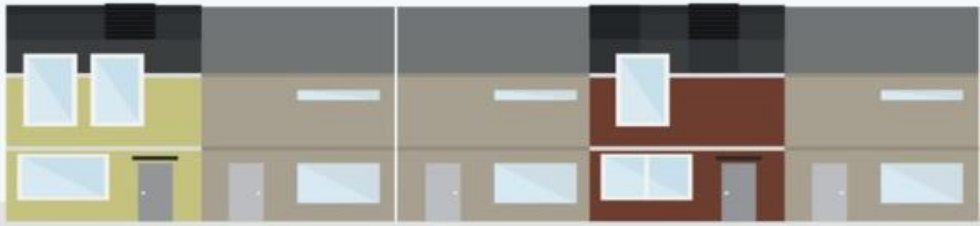
Requisites







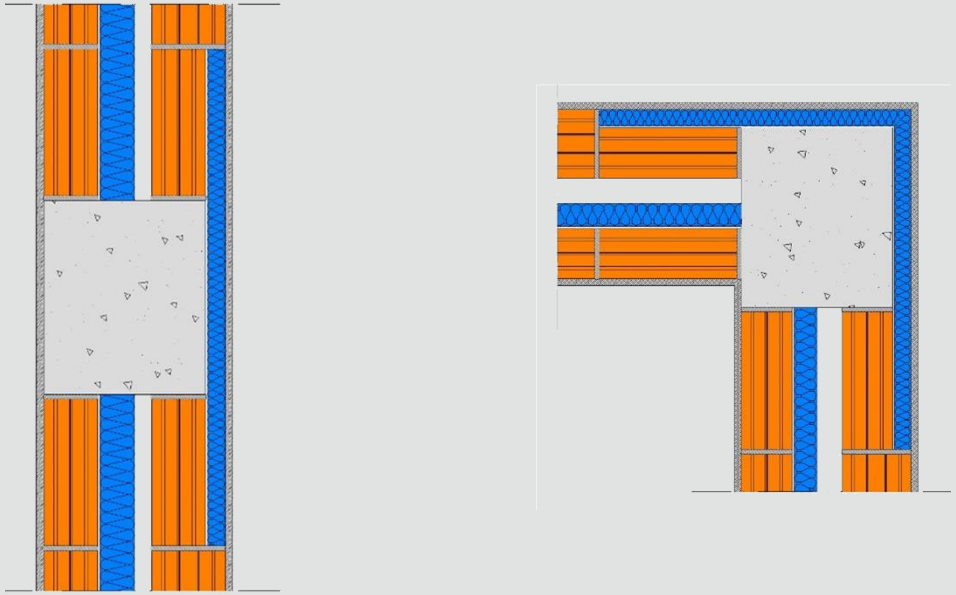
Requisites: $U_3 \leq 0.9$ W/m²ºC



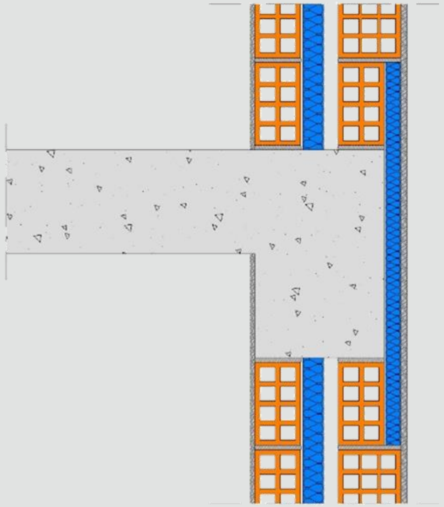
Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

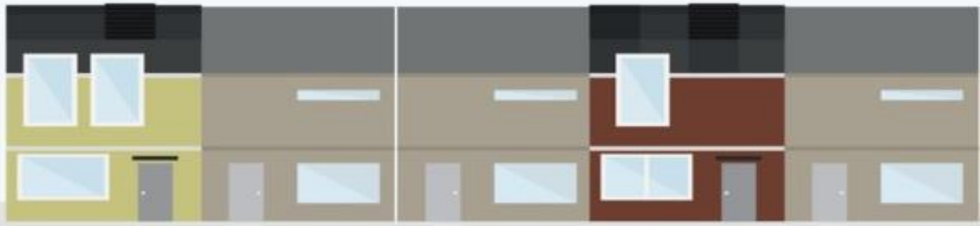
Thermal Bridges Treatment



Pillars



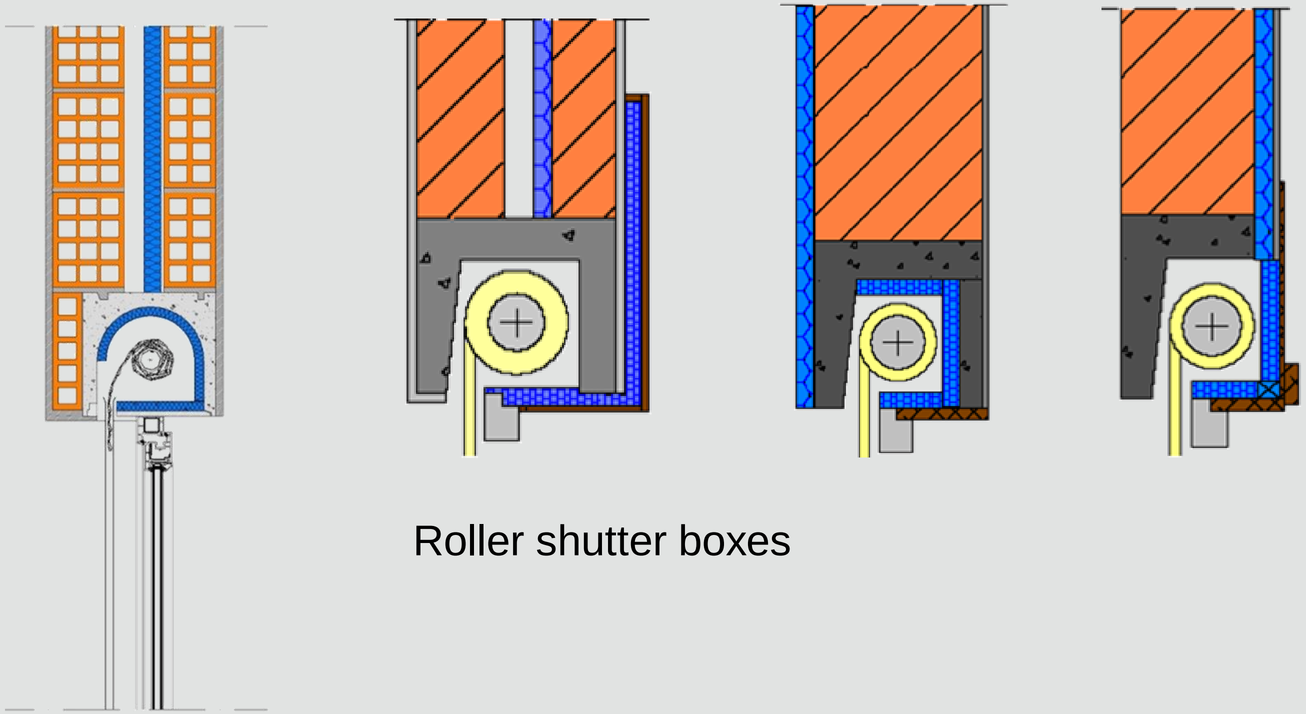
Beams and top of the slabs



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

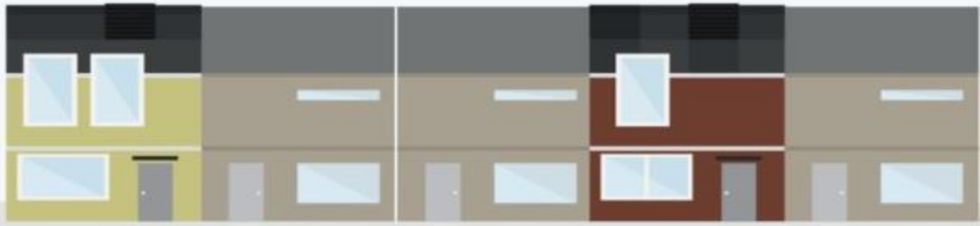
Thermal Bridges Treatment



Roller shutter boxes

4. THERMAL PERFORMANCE

MORE—CONNECT



Subject overview: The case for Portugal

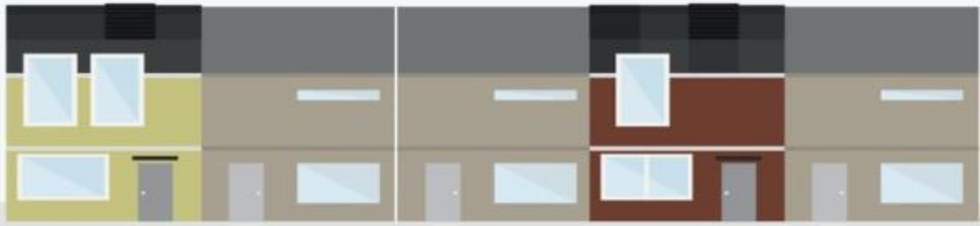
Building Thermal Legislation - Decree-Law 118/2013

Reference U-values, U_{ref}, Mainland Portugal [W/(m^2.°C)]

Envelope, U_{ref} [W/(m^2.°C)]		RCCTE			REH			After January 1st 2016		
		I1	I2	I3	**I1**	I2	I3	**I1**	I2	I3
Envelope elements and elements separating useful and non useful areas (elevator shafts, common circulation areas) with $b_{tr} > 0.7$ (thermal conditions similar to outdoors)	Opaque vertical elements	0.70	0.60	0.50	0.50	0.40	0.35	0.50	0.40	0.35
	Opaque horizontal elements	0.50	0.45	0.40	0.40	0.35	0.30	0.40	0.35	0.30
Construction elements between buildings and non useful areas (elevator shafts, common circulation areas) with $b_{tr} \leq 0.7$ (thermal conditions similar to indoors)	Opaque vertical elements	1.40	1.20	1.00	1.00	0.80	0.70	0.80	0.70	0.60
	Opaque horizontal elements	1.00	0.90	0.80	0.80	0.70	0.60	0.60	0.60	0.50
Windows (U_w) (doors and windows)		4.30	3.30	3.30	2.90	2.60	2.40	2.80	2.40	2.20
Elements in contact with the ground		-			0.5			0.5		

Note: These values might be updated until 2020 to take into account cost-optimal studies and nZEB requisites.

Portaria n.º 349-B/2013
Portaria n.º 379-A/2015 –1ª Alteração da Portaria n.º 349-B/2013

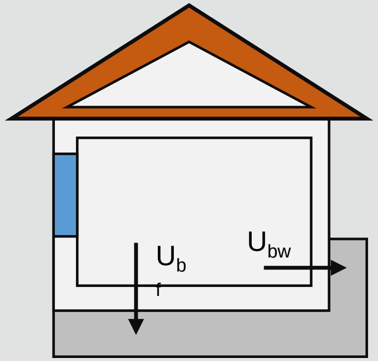


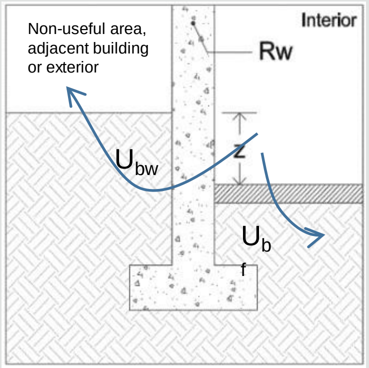
Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

U-value for floors and basements in contact with the ground.

Despacho n.º 15793-K





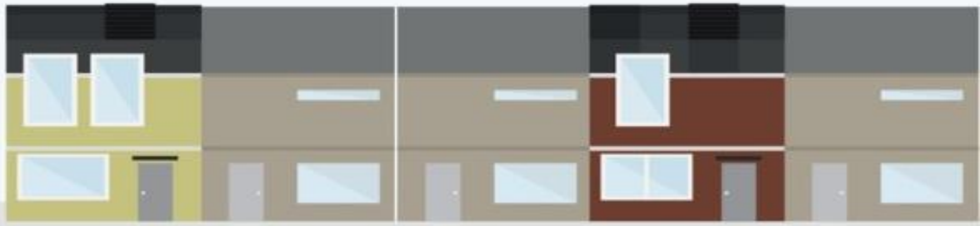
U_{bf} – U-value of the ground floor
U_{bw} - U-value of the wall in contact with the ground

U-value for floors and basements in contact with the ground.

Types of floors in contact with the ground:

- Slab-on-ground floor.
- Suspended floor.
- Heated basement.
- Unheated basement.
- Partly heated basement.

In accordance with EN ISO 13370:2007 - Thermal performance of buildings - Heat transfer via the ground - Calculation methods



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

U-value for floors and basements in contact with the ground

Despacho n.º 15793-K

Characteristic dimension of the floor: $B' = \dfrac{A_p}{0{,}5.\,P}$

A_p - Area of the heated floor in contact with the ground (m^2);

P - Perimeter of the floor which is exposed to the external environment, and/or unheated spaces attached to the dwelling such as attached garages of storage areas. (m);

R_f - Resistance of the floor (m^2.ºC)/W);

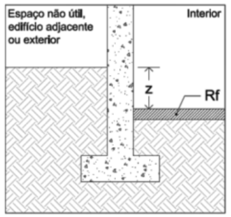
D - Insulation thickness (m);

U_{bf} - U-value of the ground floor.

U-value for floors in contact with the ground with continuous thermal insulation or without thermal insulation, U_{bf} [W/m².ºC]

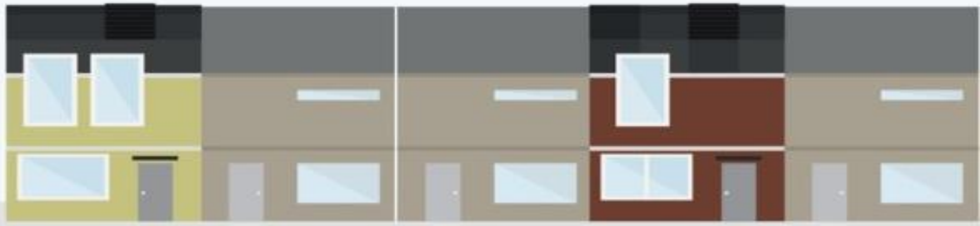
B'	z ≤ 0,5 m				0,5 m< z ≤ 1,0 m				1,0 m< z ≤ 2,0 m			
	R_f [(m².ºC)/W]				R_f [(m².ºC)/W]				R_f [(m².ºC)/W]			
	0,5	1	2	≥3	0,5	1	2	≥3	0,5	1	2	≥3
3	0,65	0,57	0,32	0,24	0,57	0,44	0,30	0,23	0,51	0,41	0,29	0,22
4	0,57	0,52	0,3	0,23	0,52	0,41	0,28	0,22	0,47	0,37	0,27	0,21
6	0,47	0,43	0,27	0,21	0,43	0,35	0,25	0,2	0,40	0,33	0,24	0,19
10	0,35	0,32	0,22	0,18	0,32	0,28	0,21	0,17	0,30	0,26	0,20	0,17
15	0,27	0,25	0,18	0,15	0,25	0,22	0,18	0,15	0,24	0,21	0,17	0,14
≥20	0,22	0,21	0,16	0,13	0,21	0,18	0,15	0,13	0,20	0,18	0,15	0,13

B'	2,0 m< z ≤ 3,0 m				z > 3 m			
	R_f [(m².ºC)/W]				R_f [(m².ºC)/W]			
	0,5	1	2	≥3	0,5	1	2	≥3
3	0,45	0,37	0,27	0,21	0,39	0,32	0,24	0,20
4	0,42	0,34	0,25	0,20	0,36	0,30	0,23	0,19
6	0,36	0,30	0,23	0,18	0,31	0,27	0,21	0,17
10	0,28	0,24	0,19	0,16	0,25	0,22	0,18	0,15
15	0,22	0,20	0,16	0,14	0,20	0,18	0,15	0,13
≥20	0,19	0,17	0,14	0,12	0,17	0,16	0,13	0,12



Note 1: If $z \leq 0{,}5$ m & thermal resistance < 0,5 m².ºC/W
$U_{bf} = 1{,}15 \times U_{(Rf=0{,}5)}$ [(W/(m².ºC)].

Note 2: If $z > 0{,}5$ m & thermal resistance < 0,5 m².ºC/W
$U_{bf} = 1{,}10 \times U_{(Rf=0{,}5)}$ [(W/(m².ºC)].



Subject overview: The case for Portugal

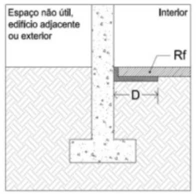
Building Thermal Legislation - Decree-Law 118/2013

U-value for floors and basements in contact with the ground

Despacho n.º 15793-K

U-value for floors in contact with the ground with horizontal perimeter thermal insulation, U_{bf} [W/m^2.ºC]

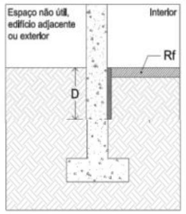
	D = 0,5 m					D = 1,0 m					D = 1,5 m				
	R_f [(m².ºC)/W]					R_f [(m².ºC)/W]					R_f [(m².ºC)/W]				
B'	0	0,5	1	2	≥3	0	0,5	1	2	≥3	0	0,5	1	2	≥3
3	0,86	0,60	0,46	0,29	0,21	0,79	0,57	0,44	0,29	0,20	0,75	0,55	0,42	0,28	0,20
4	0,74	0,54	0,42	0,29	0,21	0,69	0,52	0,41	0,28	0,21	0,66	0,50	0,40	0,28	0,20
6	0,59	0,45	0,36	0,26	0,20	0,55	0,43	0,36	0,26	0,20	0,53	0,42	0,35	0,26	0,20
10	0,42	0,34	0,28	0,22	0,18	0,40	0,33	0,28	0,22	0,18	0,38	0,32	0,27	0,21	0,18
15	0,32	0,26	0,23	0,18	0,15	0,30	0,25	0,22	0,18	0,15	0,29	0,25	0,22	0,18	0,15
20	0,26	0,21	0,19	0,15	0,13	0,24	0,21	0,19	0,15	0,13	0,24	0,21	0,18	0,15	0,13

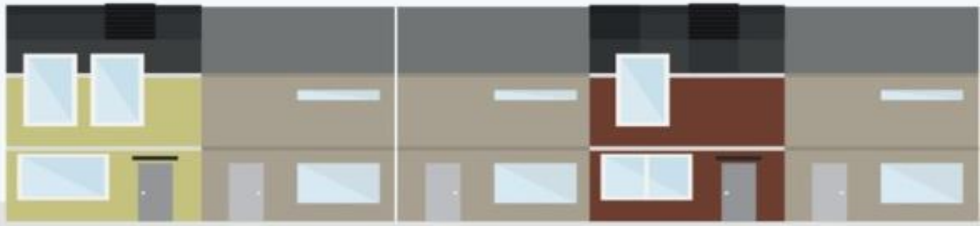


Note: Minimum thermal insulation thickness: 30mm.

U-value for floors in contact with the ground with vertical perimeter thermal insulation, U_{bf} [W/m^2.ºC]

	D = 0,5 m					D = 1,0 m					D = 1,5 m				
	R_f (m².ºC)/W					R_f (m².ºC)/W					R_f (m².ºC)/W				
B'	0	0,5	1	2	≥3	0	0,5	1	2	≥3	0	0,5	1	2	≥3
3	0,79	0,57	0,44	0,29	0,20	0,72	0,53	0,41	0,27	0,20	0,68	0,50	0,39	0,26	0,19
4	0,69	0,52	0,41	0,28	0,21	0,63	0,49	0,39	0,27	0,20	0,60	0,47	0,38	0,26	0,20
6	0,55	0,43	0,36	0,26	0,20	0,51	0,41	0,34	0,25	0,20	0,49	0,40	0,33	0,25	0,19
10	0,40	0,33	0,28	0,22	0,18	0,38	0,31	0,27	0,21	0,17	0,36	0,31	0,27	0,21	0,17
15	0,30	0,25	0,22	0,18	0,15	0,29	0,25	0,22	0,18	0,15	0,28	0,24	0,21	0,17	0,15
20	0,24	0,21	0,19	0,15	0,13	0,23	0,20	0,18	0,15	0,13	0,23	0,20	0,18	0,15	0,13





Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

U-value for floors and basements in contact with the ground

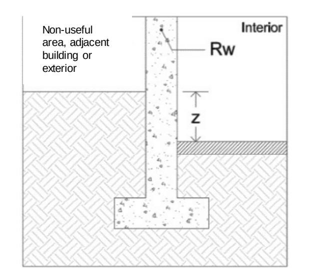
The U-value of the walls in contact with the ground, U_{bw}, depend on the:

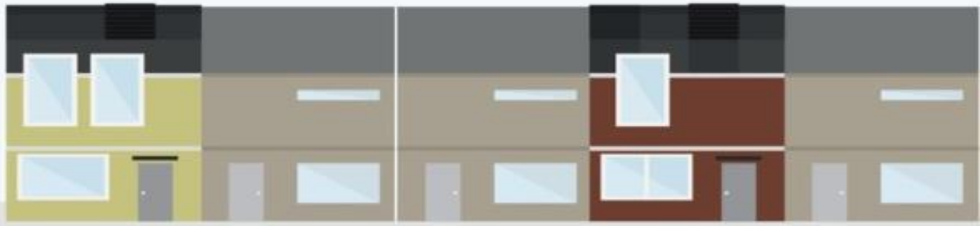
- R_w – Thermal resistance of the wall (m².ºC)/W);
- Z – Depth of the wall in contact with the ground.

Despacho n.º 15793-K

U-value for walls in contact with the ground, U_{bw} [W/m².ºC]

Z [m]	R_w (m².ºC)/W					
	0	0,5	1	1,5	2	≥3
0	5,62	1,43	0,82	0,57	0,44	0,30
0,5	2,77	1,10	0,70	0,51	0,40	0,28
1	1,97	0,91	0,61	0,46	0,36	0,26
2	1,32	0,70	0,50	0,38	0,31	0,23
4	0,84	0,50	0,38	0,30	0,25	0,19
≥ 6	0,64	0,39	0,31	0,25	0,21	0,17





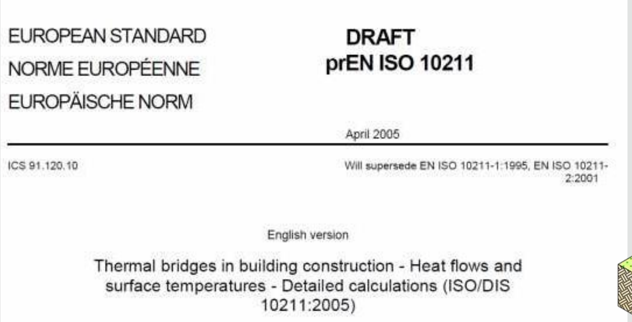
Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Linear thermal transmittance, ψ

Linear thermal bridges calculation methods:

- EN ISO 10211:2007 standard;
- Linear thermal bridges catalogues for different geometries and typical construction solutions (http://www.itecons.uc.pt/catalogoptl);
- Values listed in the Portuguese thermal regulation (Tabela 07, Despacho 15793-K/2013)



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

DRAFT
prEN ISO 10211

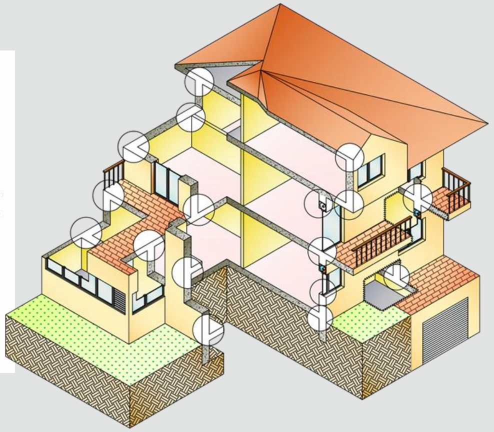
April 2005

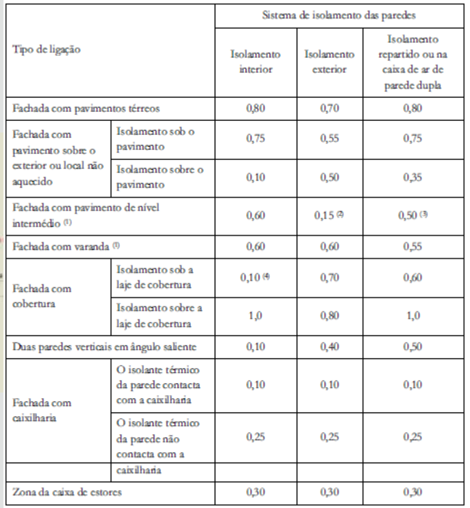
ICS 91.120.10

Will supersede EN ISO 10211-1:1995, EN ISO 10211-2:2001

English version

Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations (ISO/DIS 10211:2005)





Tipo de ligação		Sistema de isolamento das paredes		
		Isolamento interior	Isolamento exterior	Isolamento repartido ou na caixa de ar de parede dupla
Fachada com pavimentos térreos		0,80	0,70	0,80
Fachada com pavimento sobre o exterior ou local não aquecido	Isolamento sob o pavimento	0,75	0,55	0,75
	Isolamento sobre o pavimento	0,10	0,50	0,35
Fachada com pavimento de nível intermédio (1)		0,60	0,15 (2)	0,50 (3)
Fachada com varanda (1)		0,60	0,60	0,55
Fachada com cobertura	Isolamento sob a laje de cobertura	0,10 (4)	0,70	0,60
	Isolamento sobre a laje de cobertura	1,0	0,80	1,0
Duas paredes verticais em ângulo saliente		0,10	0,40	0,50
Fachada com caixilharia	O isolante térmico da parede contacta com a caixilharia	0,10	0,10	0,10
	O isolante térmico da parede não contacta com a caixilharia	0,25	0,25	0,25
Zona da caixa de estores		0,30	0,30	0,30

4. THERMAL PERFORMANCE

MORE—CONNECT

Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

Linear thermal transmittance, ψ

Linear thermal bridges

Default values for several connections types listed in the Portuguese thermal regulation (Despacho 15793-K/2013):

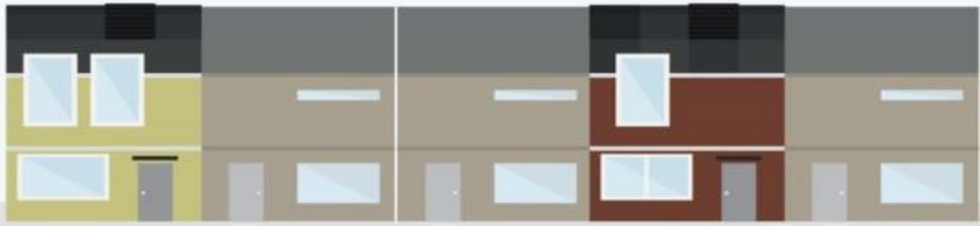
- Façade with ground floors
- Façade with pavements over the exterior or a non-heated room
- Façade with a intermediate floor
- Façade with balcony
- Façade with roofs
- Two vertical walls (sharp angle)
- Façade with window frame
- Roller shutter box

Default values for the linear thermal transmittance, ψ [W/(m.ºC)]

Tipo de ligação		Sistema de isolamento das paredes		
		Isolamento interior	Isolamento exterior	Isolamento repartido ou na caixa de ar de parede dupla
Fachada com pavimentos térreos		0,80	0,70	0,80
Fachada com pavimento sobre o exterior ou local não aquecido	Isolamento sob o pavimento	0,75	0,55	0,75
	Isolamento sobre o pavimento	0,10	0,50	0,35
Fachada com pavimento de nível intermédio (1)		0,60	0,15 (2)	0,50 (3)
Fachada com varanda (1)		0,60	0,60	0,55
Fachada com cobertura	Isolamento sob a laje de cobertura	0,10 (4)	0,70	0,60
	Isolamento sobre a laje de cobertura	1,0	0,80	1,0
Duas paredes verticais em ângulo saliente		0,10	0,40	0,50
Fachada com caixilharia	O isolante térmico da parede contacta com a caixilharia	0,10	0,10	0,10
	O isolante térmico da parede não contacta com a caixilharia	0,25	0,25	0,25
Zona da caixa de estores		0,30	0,30	0,30

(1) The values listed correspond to half of the losses due to the connection.

(2) (3) (4) Increase when the floor has a suspended ceiling in: (2) 25%; (3) 50%; (4) 70%



Subject overview: The case for Portugal

Building Thermal Legislation - Decree-Law 118/2013

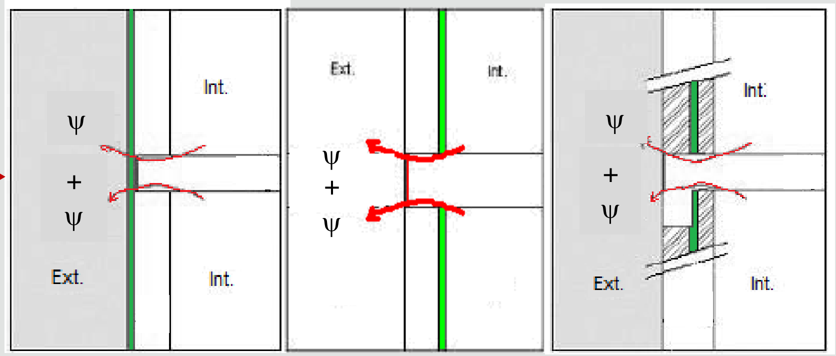
Linear Thermal Bridges

Linear thermal transmittance, ψ

ψ [W/(m.°C)]

Default values

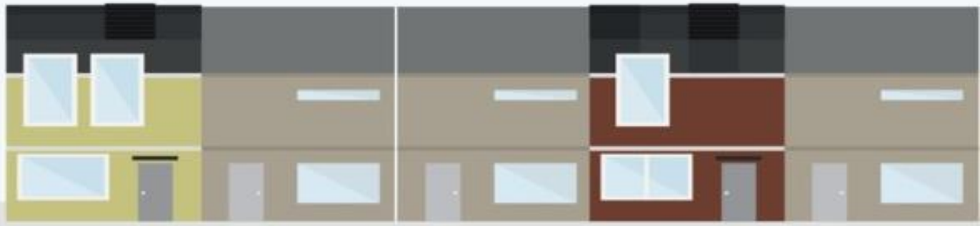
Half of the thermal losses in the connection



Connection	Exterior insulation	Interior insulation	Insulation on the air gap
Façade with a intermediate floor	**1.25 x** 0.15	0.60	**1.50 x** 0.50
Façade with balcony	0.60	0.60	0.55

4. THERMAL PERFORMANCE

MORE—CONNECT



Subject overview: The case for Portugal

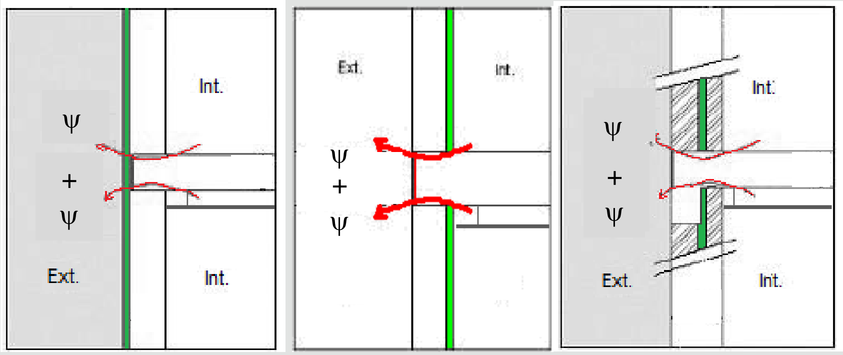
Building Thermal Legislation - Decree-Law 118/2013

Linear Thermal Bridges

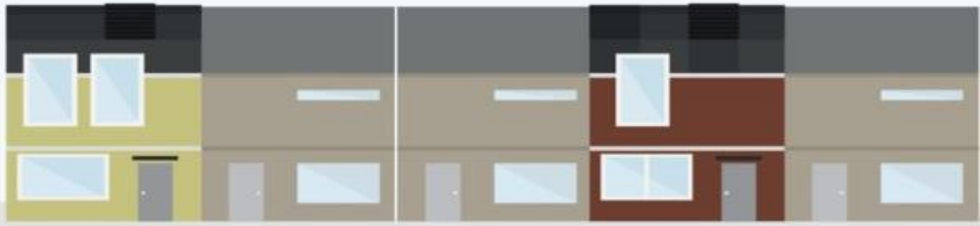
Linear thermal transmittance, ψ

ψ [W/(m.°C)]

Default values



Connection	With a suspended ceiling	**Exterior insulation**	**Interior insulation**	**Insulation on the air gap**
Façade with roofs	**Insulation under the floor**	0.10 **x 1.7**	0.10	0.60
	Insulation over the floor	0.80	1.00	1.00
Two vertical walls (sharp angle)		0.40	0.10	0.50



Subject overview: The case for Portugal

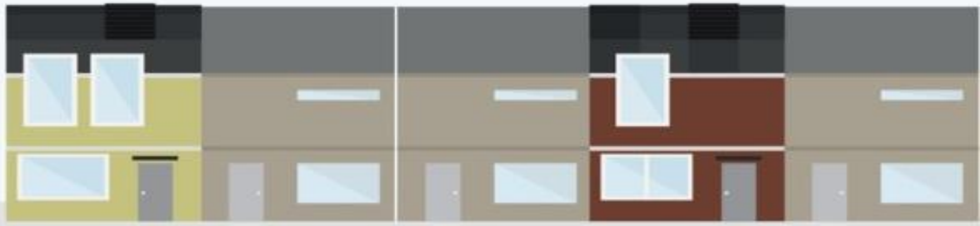
Building Thermal Legislation - Decree-Law 118/2013

Linear thermal transmittance, ψ

Reference values for the linear thermal transmittance, $\psi_{j,ref}$ **[W/(m.°C)]**

Connection Type	$\psi_{j,ref}$ **[W/(m.°C)]**
Facade with ground floors Facade with pavements over the exterior or a non-heated room Facade with roofs Facade with a intermediate floor Facade with balcony	0.50
Two vertical walls (sharp angle)	0.40
Facade with window frame Roller shutter box	0.20

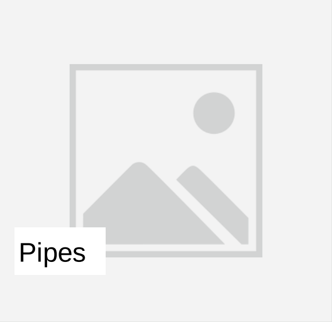
Note: These values might be updated until 2020 to take into account cost-optimal studies and nZEB requisites.



Subject overview: The case for Portugal

Thermal Bridges

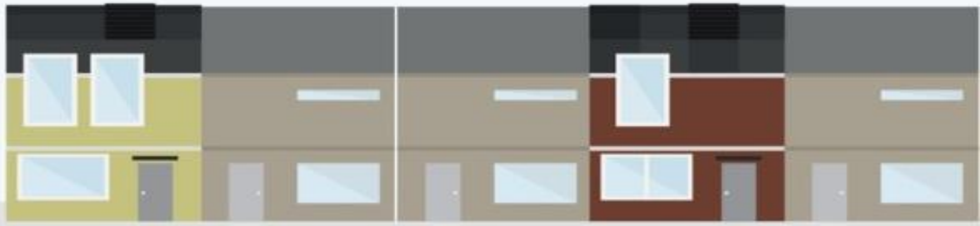
Most common



Pipes

4. THERMAL PERFORMANCE

MORE—CONNECT



Subject overview: The case for Portugal

Thermal Bridges

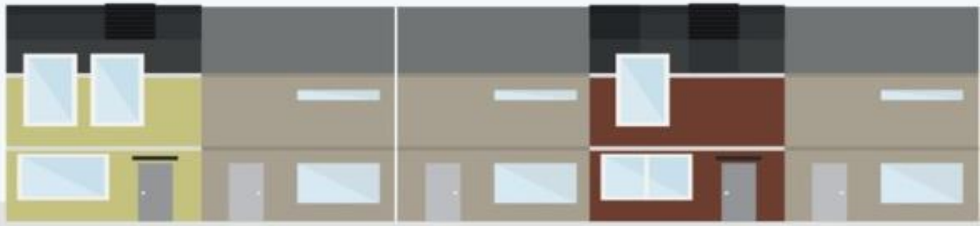
The problems

Some possible treatments

Thermal insulation (with high density)

4. THERMAL PERFORMANCE

MORE—CONNECT

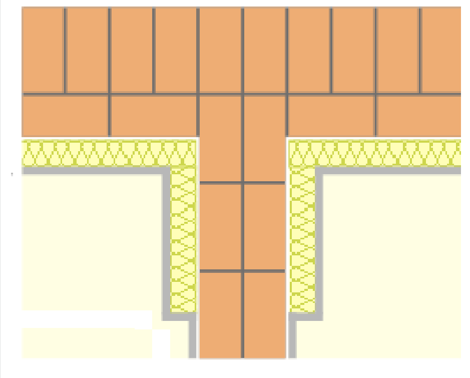


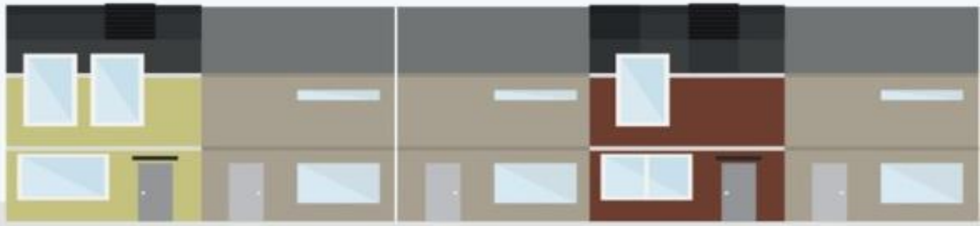
Subject overview: The case for Portugal

Thermal Bridges

The problems

Some possible treatments

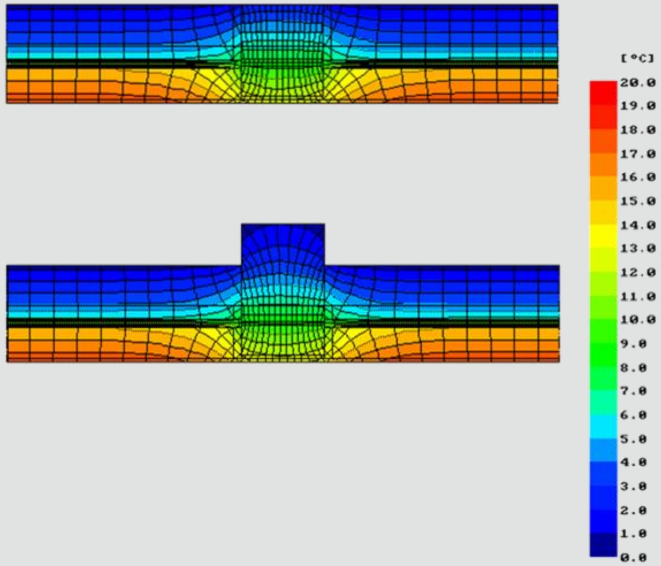


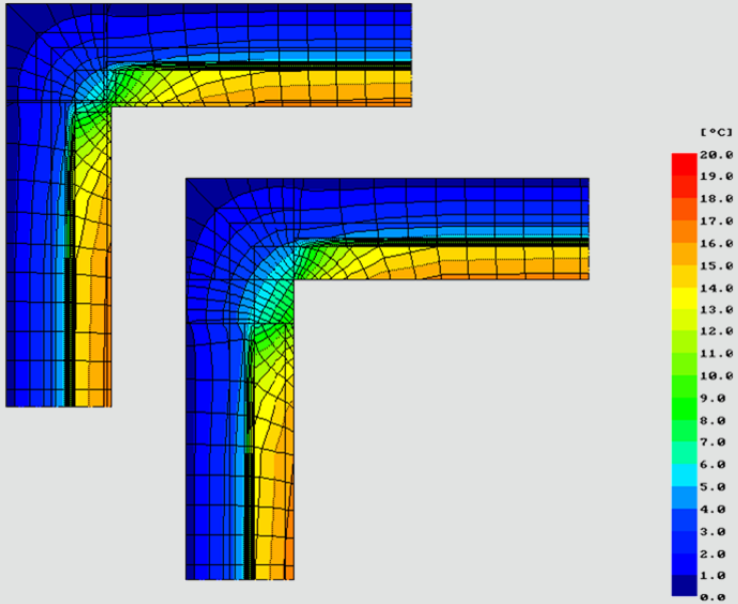


Subject overview: The case for Portugal

Thermal Bridges

The analysis

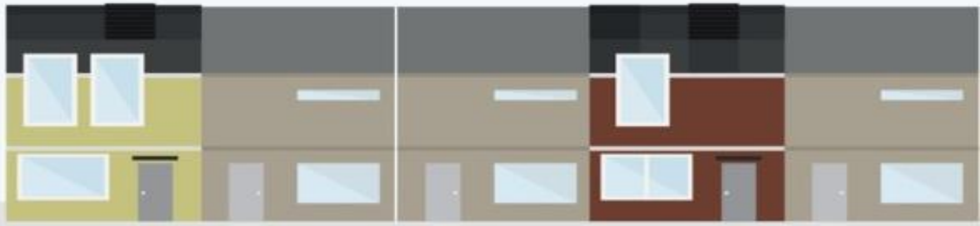




Source: Kobra

4. THERMAL PERFORMANCE

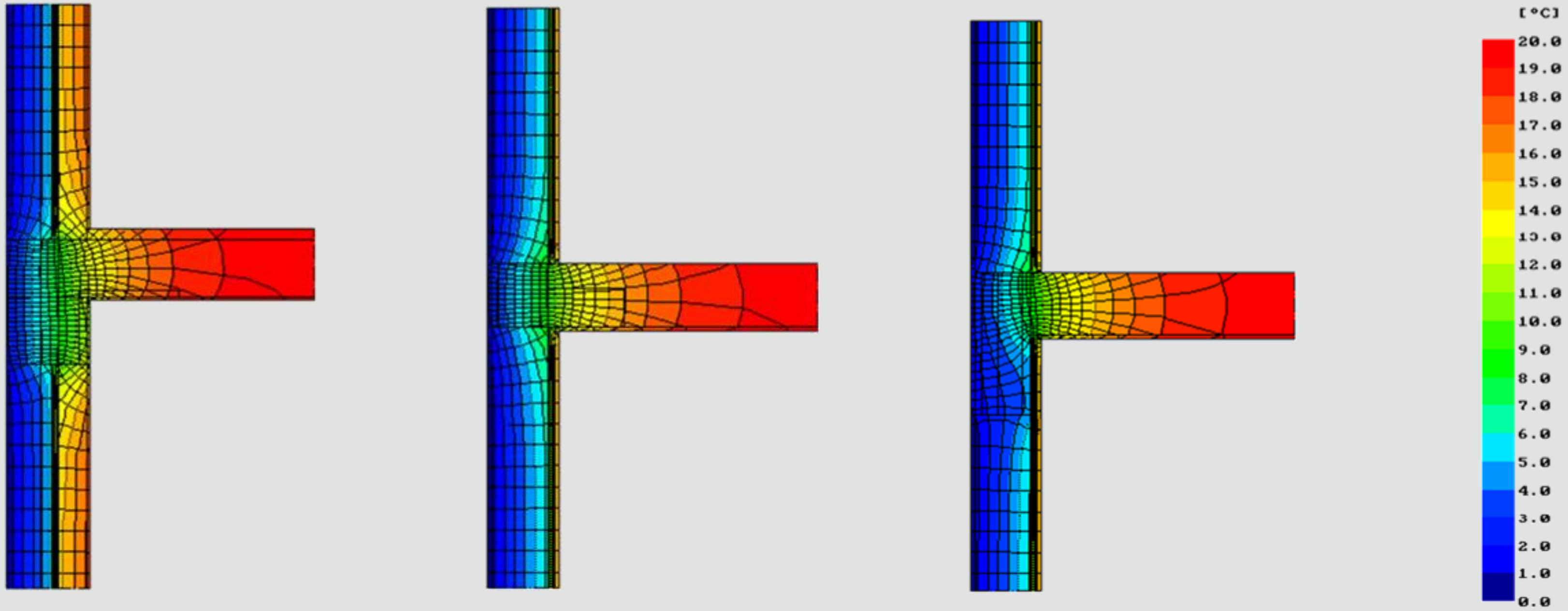
MORE—CONNECT



Subject overview: The case for Portugal

Thermal Bridges

The analysis



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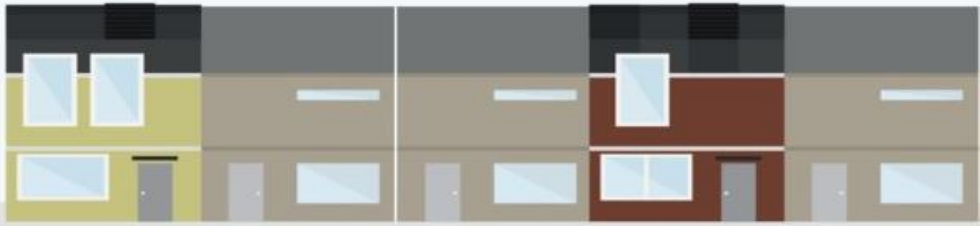
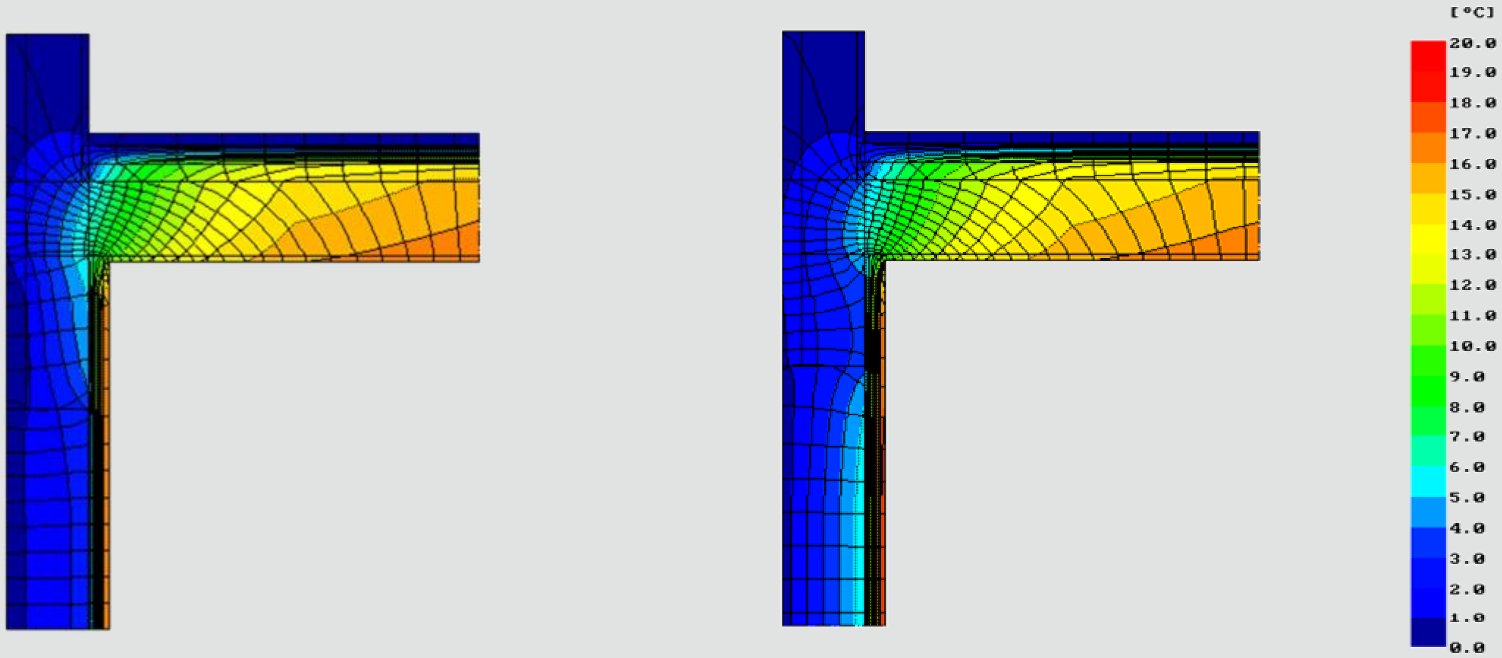


Subject overview: The case for Portugal

Thermal Bridges

The analysis



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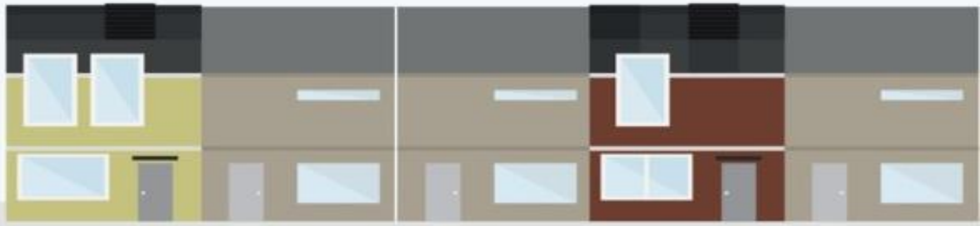
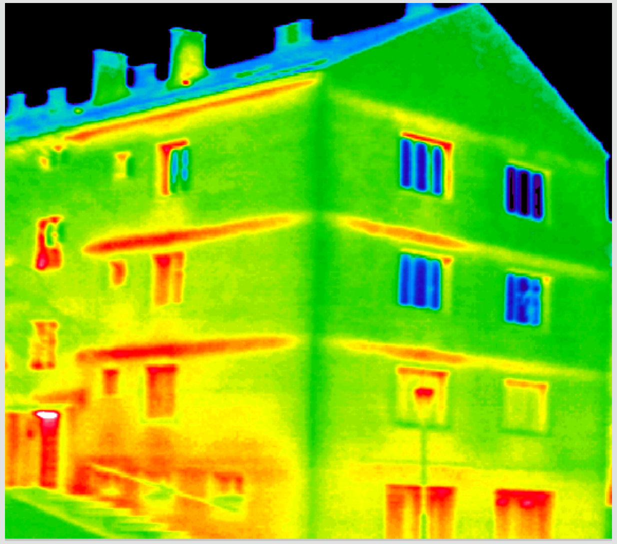


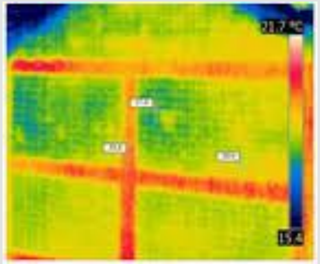
Subject overview: The case for Portugal

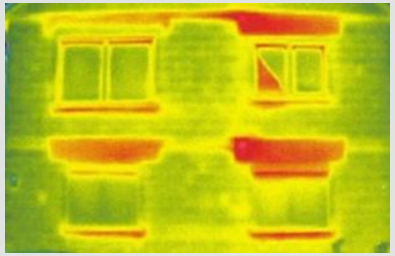
Thermal Bridges

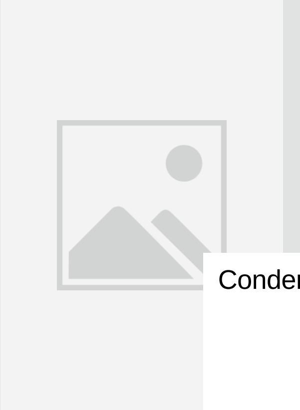
The current situation

The most common problem are the thermal bridges due to pillars, beams and roller shutter boxes.

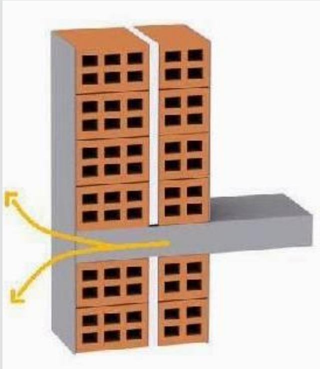


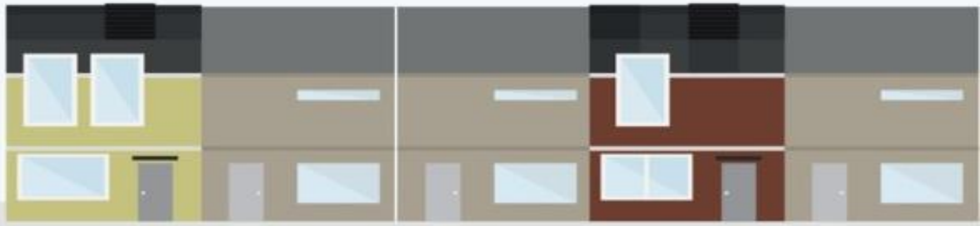






Condensation





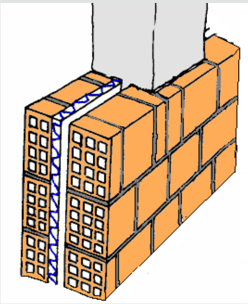
Subject overview: The case for Portugal

Thermal Bridges

The causes

Until 1990 (1st Portuguese thermal regulation) the thermal bridges were not treated.

From 1990 to 2007 the thermal bridges were treated with a 3cm ceramic brick.

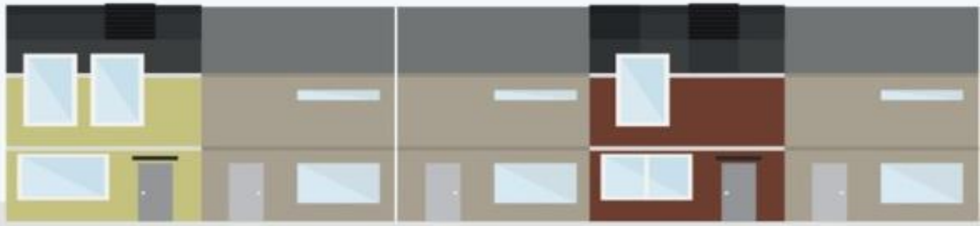


besides not being sufficient to avoid condensation the bricks splintered

Before 1990

1990 - 2007

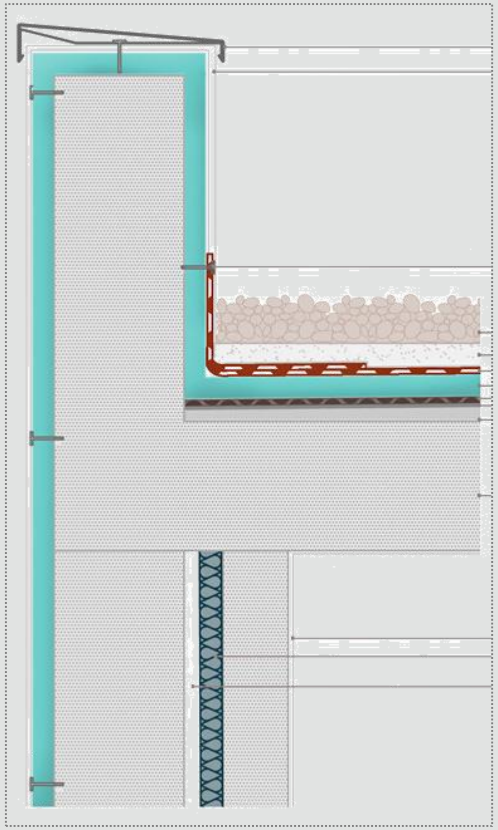
After 2007

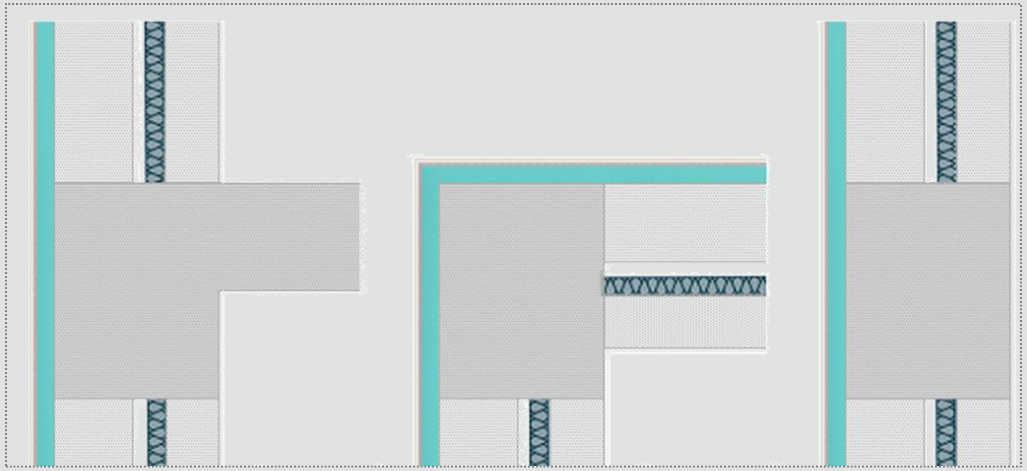


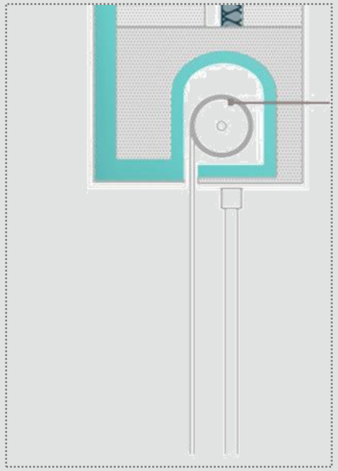
Subject overview: The case for Portugal

Thermal Bridges

The solution - retrofit

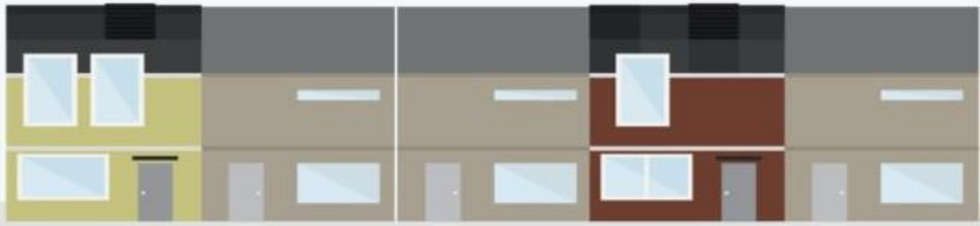






4. THERMAL PERFORMANCE

MORE—CONNECT



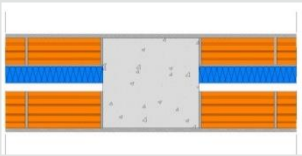
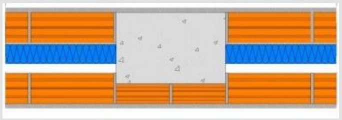
Subject overview: The case for Portugal

Building Thermal Legislation - Decreto-Lei 118/2013

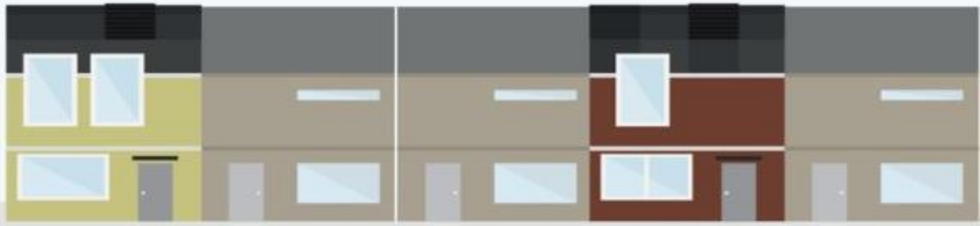
Thermal Bridges treatment (maximum thermal bridge U-value)

Wall U_{ref} ($I_1 \rightarrow 0{,}70$ $I_2 \rightarrow 0{,}60$ $I_3 \rightarrow 0{,}50$) [W/m²ºC]

U_{max} ($I_1 \rightarrow 1{,}80$ $I_2 \rightarrow 1{,}60$ $I_3 \rightarrow 1{,}45$) [W/m²ºC]

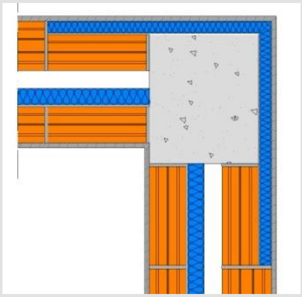
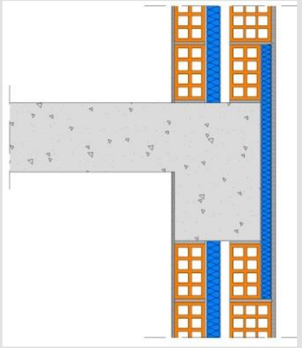
Geometry		Wall	Thermal bridge				
Without treatment	With a 3 cm ceramic brick (minimal thermal bridge treatment defined in the 1st Portuguese thermal regulation, from 1990)		Without treatment	With ceramic brick with: 3 cm 7 cm	With 2 cm of thermal insulation λ=0.04 W/mºC	With 3 cm of thermal insulation λ=0.04 W/mºC	With 4 cm of thermal insulation λ=0.04 W/mºC
		0,49	2,85	2,38 1.85	1,18	0,91	0,74

$U_{PTB} > 0.9$

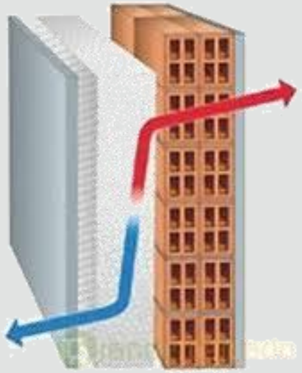


Subject overview: The case for Portugal

Building Thermal Legislation - Decreto-Lei 118/2013

Geometry		U_{max} ($I_1 \rightarrow$1,8 $I_2 \rightarrow$ 1,6 $I_3 \rightarrow$ 1,45 [W/m²ºC]			
With a 3 cm ceramic brick	Wall	3 cm ceramic brick	2 cm of thermal insulation (λ = 0.04 W/mºC)	3 cm of thermal insulation (λ = 0.04 W/mºC)	4 cm of thermal insulation (λ = 0.04 W/mºC)
	0,49	2,38	1,18	0,91	0,74
	0,49	2,38	1,18	0,91	0,74

U_{PTB} > 0.9



Subject overview: The case for Portugal

Thermal Bridges

The future

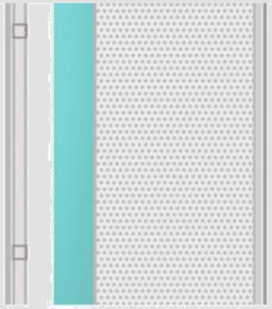
Improved envelope

Reduce heat transfer through envelope

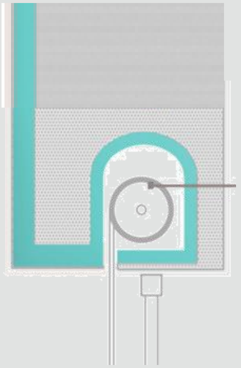
Increased thermal comfort conditions

Treat thermal bridges – continuous thermal insulation

Avoid condensation (and mould) → better Indoor Air Quality

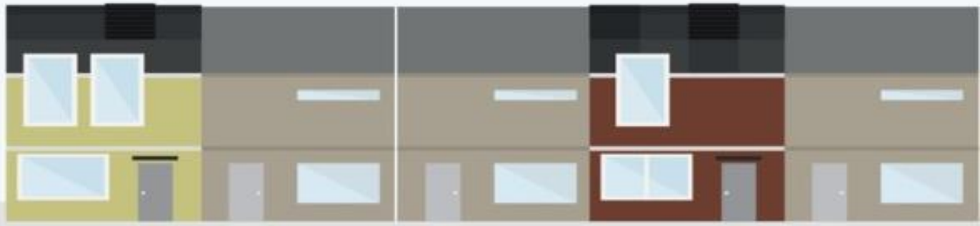


Ventilated facade



ETICS

4. THERMAL PERFORMANCE



BRE Certified Thermal Details and Products Scheme

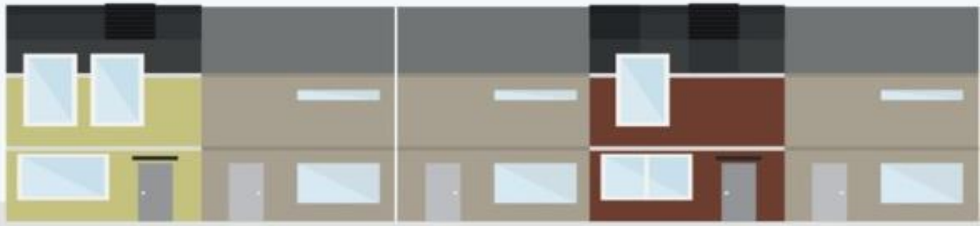
The need for such a scheme:

- **No recognised certification scheme** for the calculated thermal performance of junction details
- Industry allows only for **'self-certification'** of the thermal performance of junction details
- Potential **inaccuracies** in the declared thermal performance values
- **Potential for incorrect values to be utilised in National Calculation Tools:**
  - SAP (Standard Assessment Procedure)
  - SBEM (Simplified Building Energy Model)

All of the above can contribute to the variability of the performance gap between design and construction

4. THERMAL PERFORMANCE

MORE—CONNECT



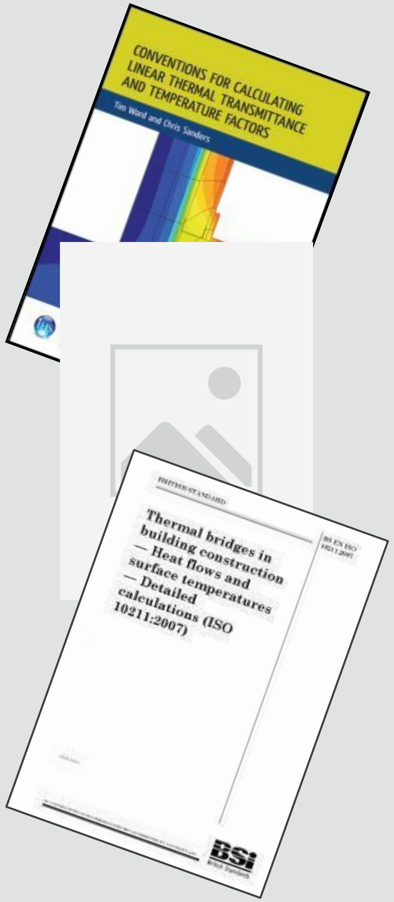
BRE Certified Thermal Details and Products Scheme

BRE Expertise: Standards and conventions

- **BRE BR 497:** Conventions for calculating linear thermal transmittance and temperature factors

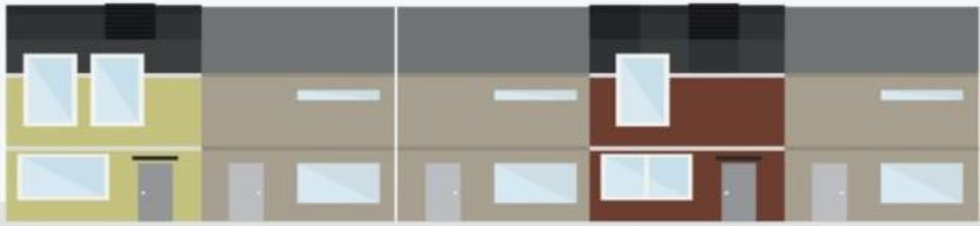
- **BRE BR 443:** Conventions for U-value calculations

- **EN ISO 10211:** Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations



4. THERMAL PERFORMANCE

MORE—CONNECT



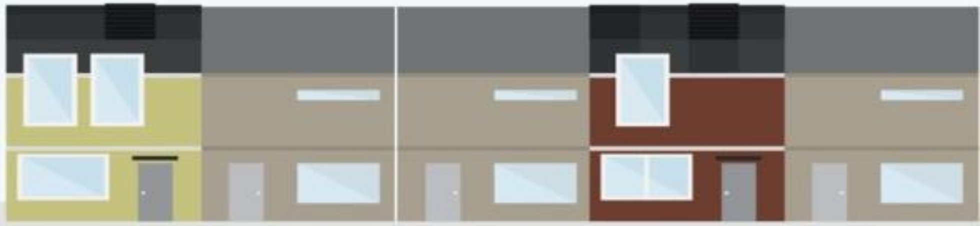
BRE Certified Thermal Details and Products Scheme

BRE Expertise: Research and Guidance

- **BRE FB 61:** Reducing thermal bridging at junctions when designing and installing solid wall insulation
- **BRE BR 262:** Thermal insulation, avoiding risks
- **BRE IP 4/13:** Advanced thermal insulation technologies in the built environment

4. THERMAL PERFORMANCE

MORE—CONNECT



BRE Certified Thermal Details and Products Scheme

BRE Expertise: Building Regulations / Standards

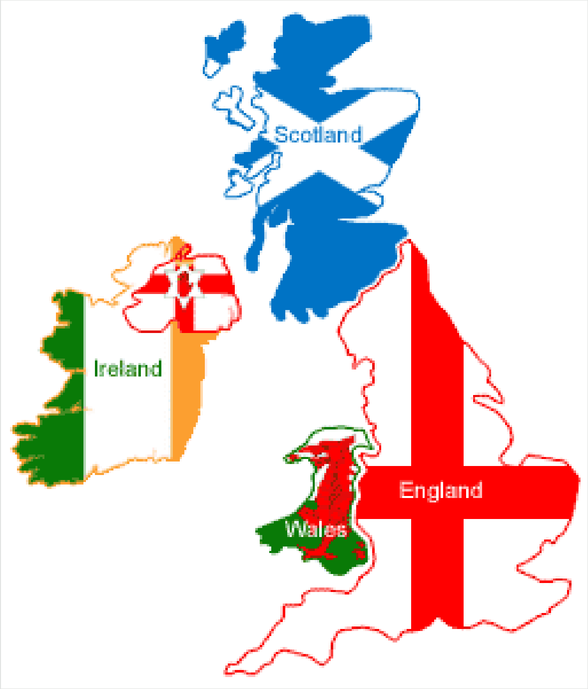
BR 497conventions referenced within range of standards, inlcluding

- **Approved Document L1A and L2A**
- **Scottish Technical Standards**

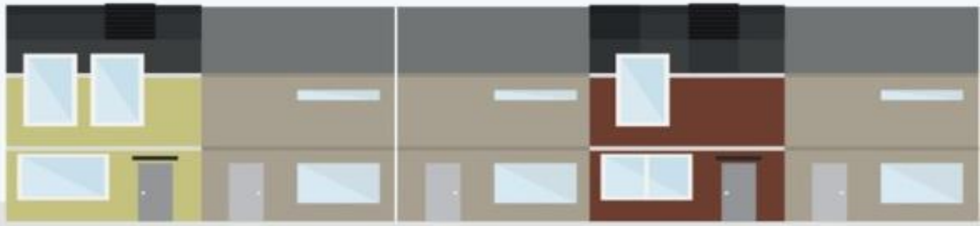
BRE developed and assessed both:

- **Scottish Building Standards Accredited Construction Details**

  and
- **Irish Building Standards Acceptable Construction Details**



4. THERMAL PERFORMANCE



BRE Certified Thermal Details and Products Scheme

BRE Expertise: Building Regulations / Standards

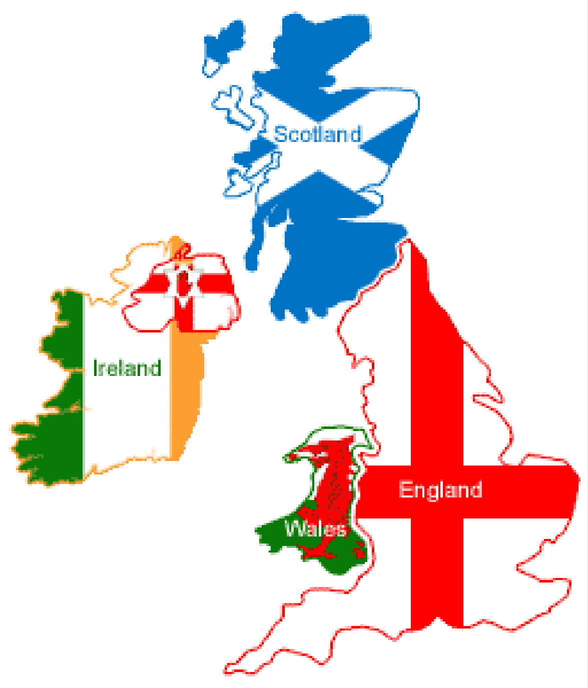
BRE is in discussion with both:

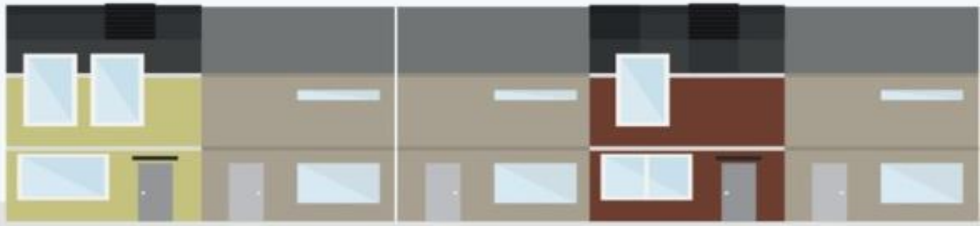
- **DCLG**

  and

- **Welsh Assembly**

to develop revised (DCLG) and new (Welsh Assembly) details databases – proposals imminent





BRE Certified Thermal Details and Products Scheme

Consultation

Communities and Local Government

The Scottish Government
Riaghaltas na h-Alba

Llywodraeth Cymru
Welsh Government

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

NorDan

BUILDING TRUST Sika

sita
Für gutes Wetter im Bau.

CCG

Xtratherm
More than insulation

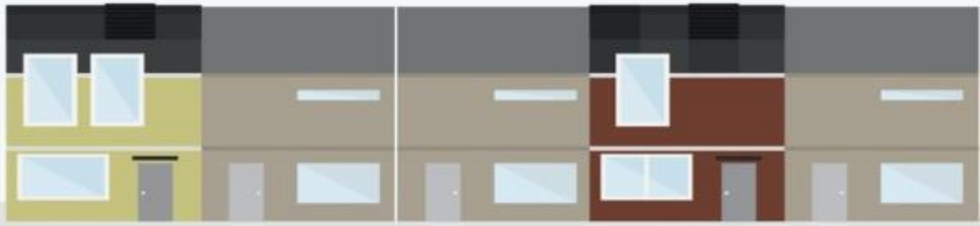
thermohouse
the low energy building system

SAP

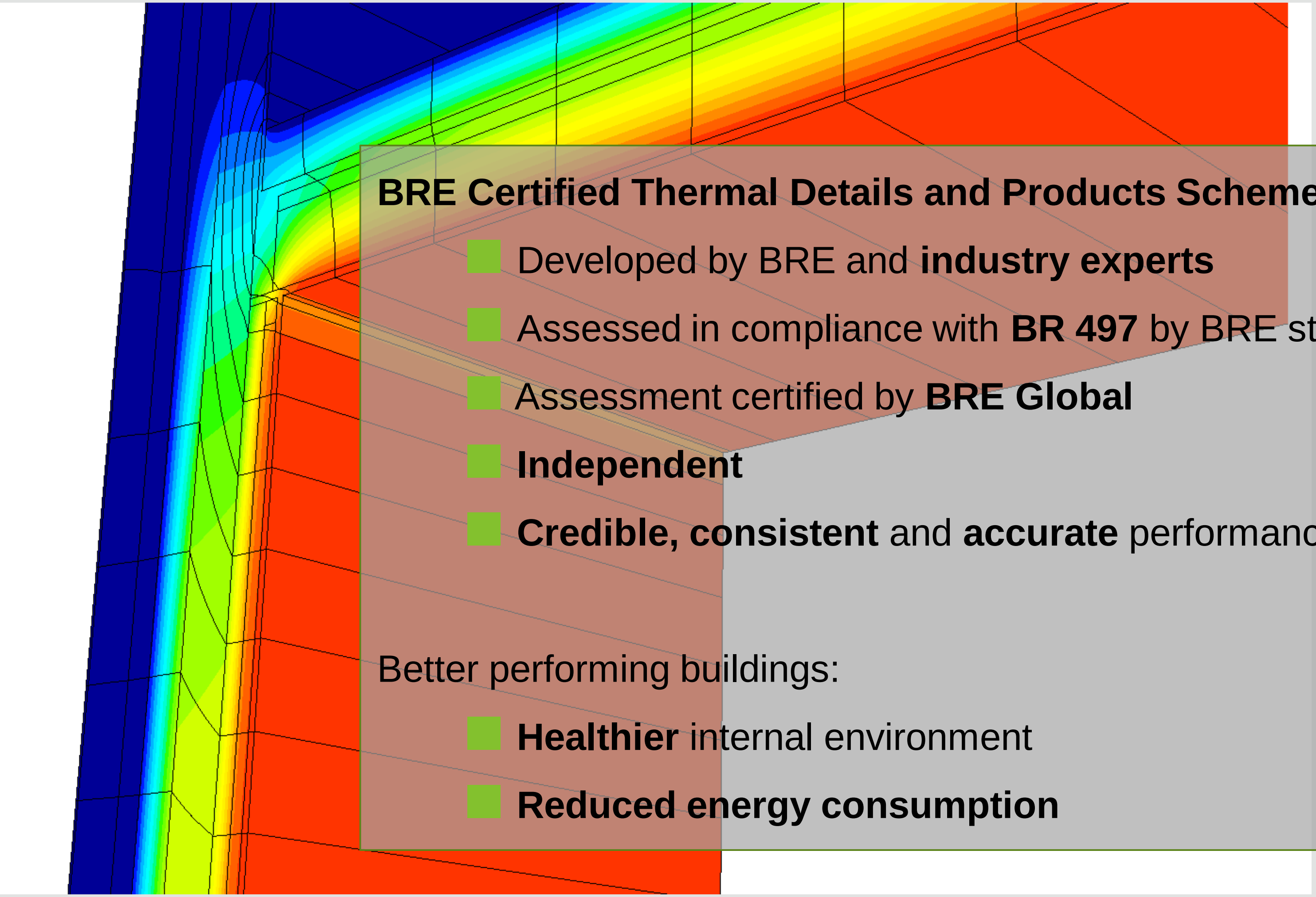
HOME QUALITY MARK

4. THERMAL PERFORMANCE

MORE—CONNECT



BRE Certified Thermal Details and Products Scheme



BRE Certified Thermal Details and Products Scheme:

- Developed by BRE and **industry experts**
- Assessed in compliance with **BR 497** by BRE staff
- Assessment certified by **BRE Global**
- **Independent**
- **Credible, consistent** and **accurate** performance values

Better performing buildings:

- **Healthier** internal environment
- **Reduced energy consumption**

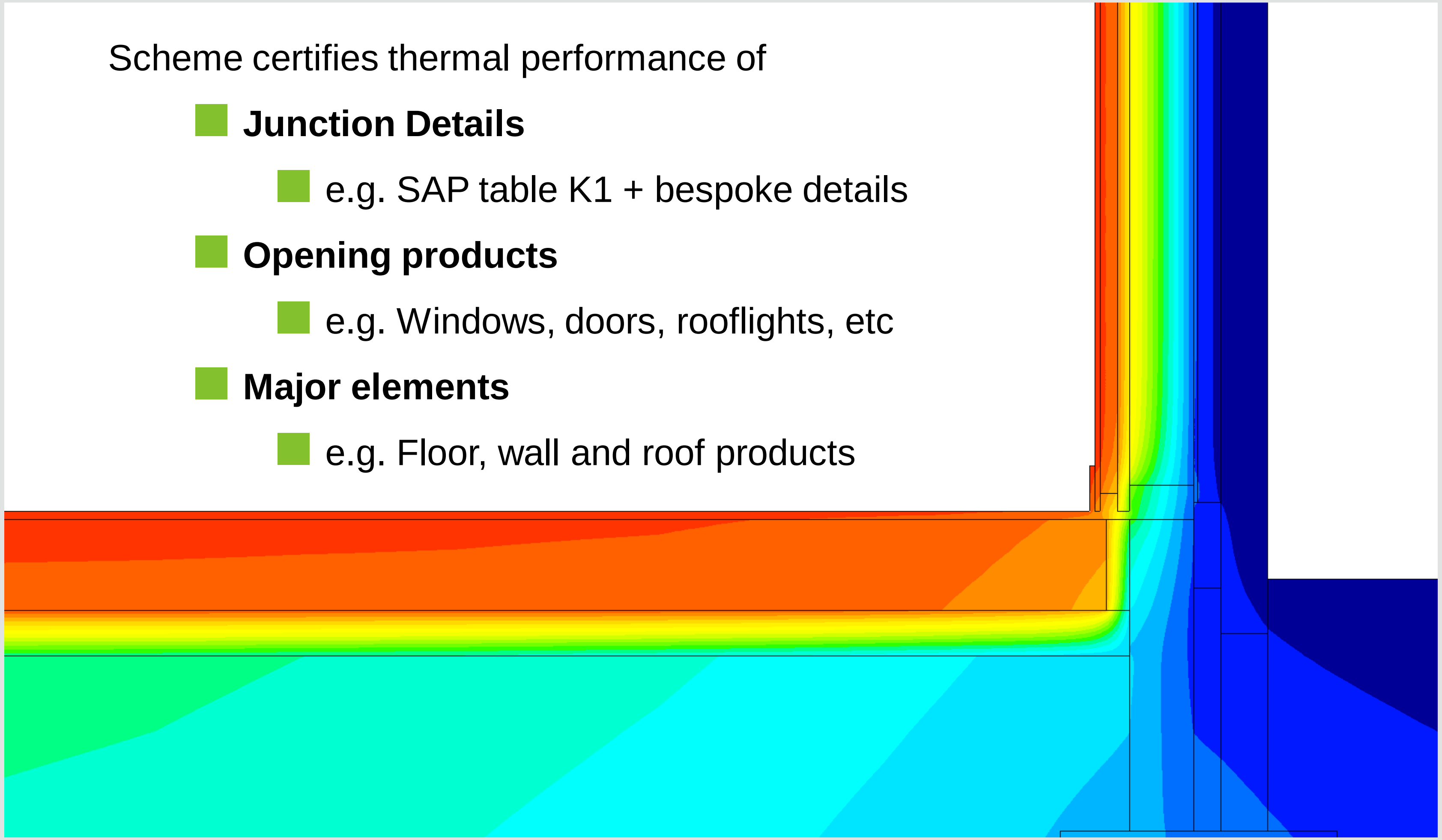
4. THERMAL PERFORMANCE

MORE—CONNECT

BRE Certified Thermal Details and Products Scheme

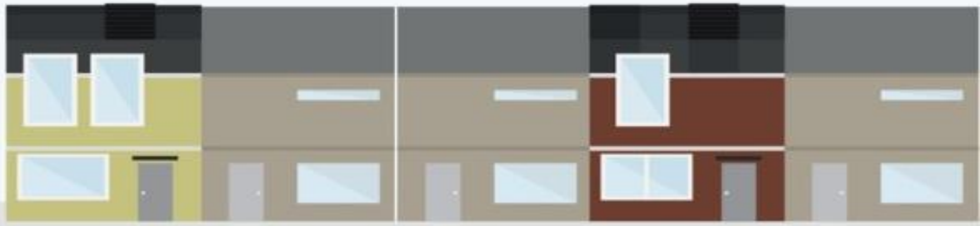
Scheme certifies thermal performance of

- **Junction Details**
  - e.g. SAP table K1 + bespoke details
- **Opening products**
  - e.g. Windows, doors, rooflights, etc
- **Major elements**
  - e.g. Floor, wall and roof products



4. THERMAL PERFORMANCE

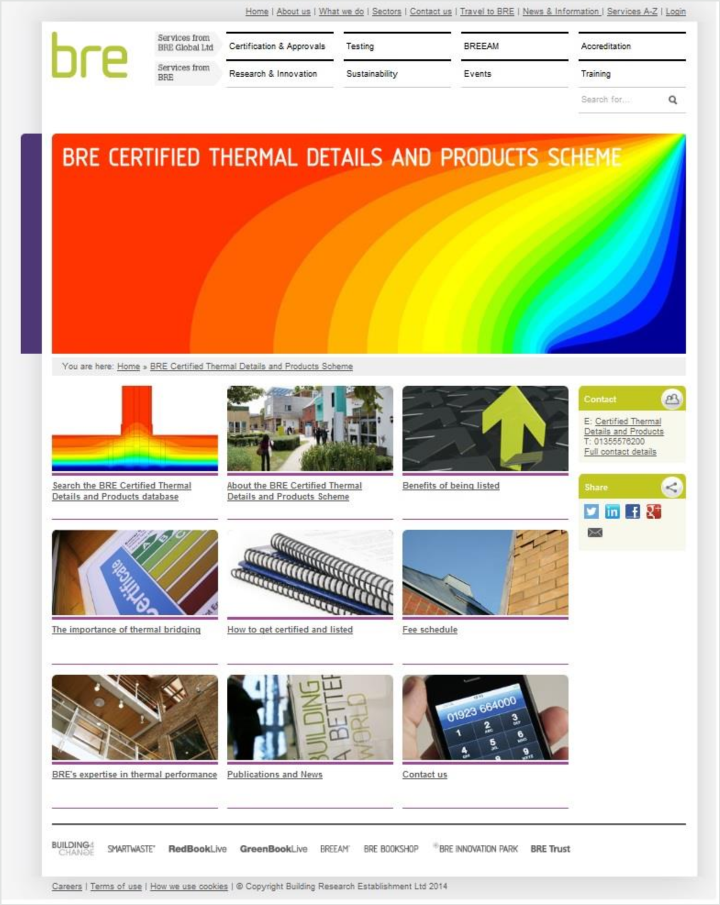
MORE—CONNECT



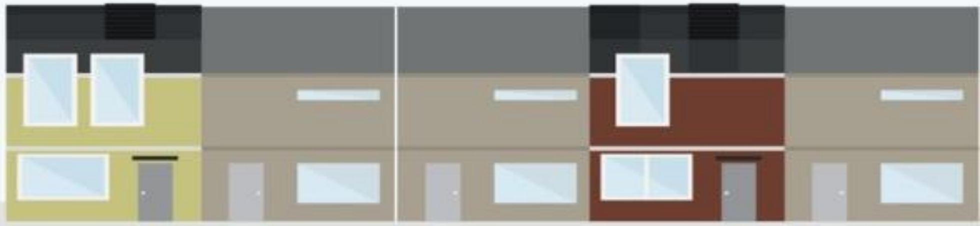
BRE Certified Thermal Details and Products Scheme

Online and Digital

- Online and fully searchable database
- Includes a range of industry products and details
- Also includes Government Accredited Details
- Single, online and accessible resource for designers, developers and clients



4. THERMAL PERFORMANCE



BRE Certified Thermal Details and Products Scheme

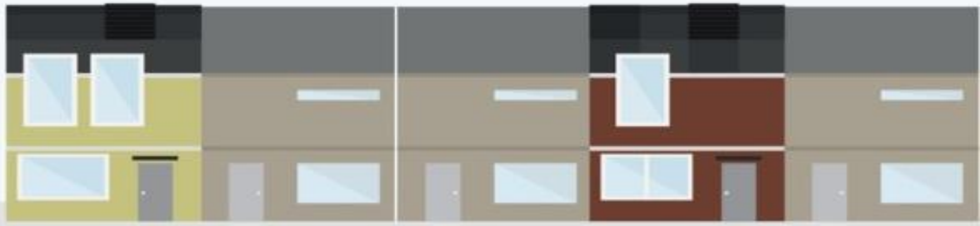
Why become certified?

Thermal performance of your product will be:

- **Accurate**
- **Consistent**
- **Credible**
- **Independent**

Access to the database is free and enables:

- Specification of details that meet appropriate standards
- Avoidance of increased risk and error
- Confirdence in performance
- Expansion of products into new markets

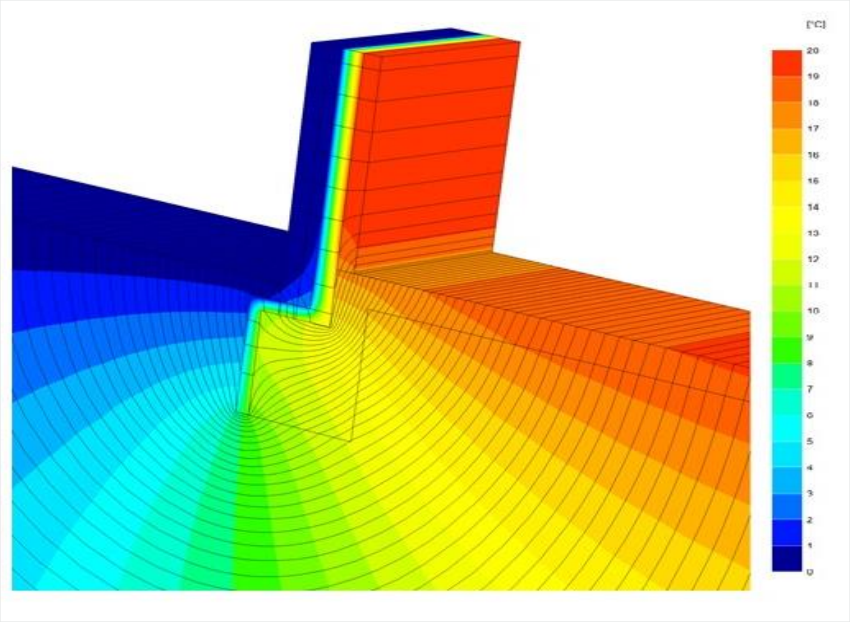


BRE Certified Thermal Details and Products Scheme

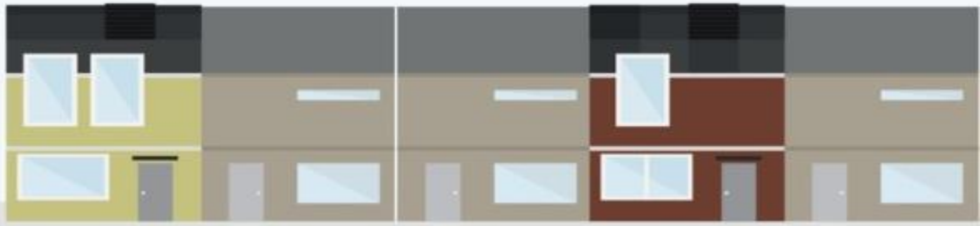
How to gain certification?

To apply for product certification and listing write to the **BRE Certified Thermal Details and Products Scheme** technical manager, with details of your product or complete and return the below application form and a quotation will be prepared.

CertifiedThermalProducts@BRE.co.uk



4. THERMAL PERFORMANCE

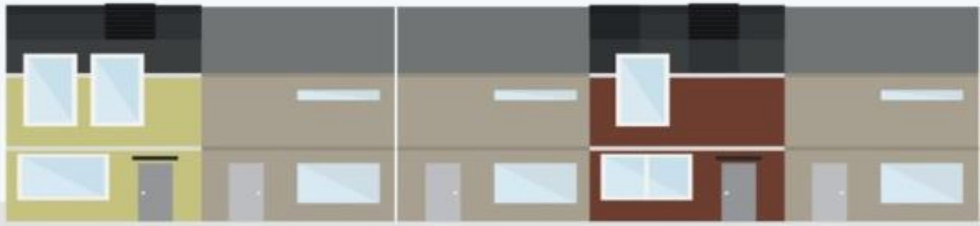


Fabric Performance and ZEBs

Contribution to Near ZEBs, EPBD and Global Greenhouse Gas Targets

The Energy Performance of Buildings Directive (EPBD) defines a nearly zero-energy building as *“a building that has a very high energy performance, as determined in accrodance with Annex I [of the Directive]. The nearly zero or very low amount of energy required should , to a very significant extent, be energy from renewable sources, included energy from renewable sources produced on-site or nearby.”*

- All new buildings to be nearly zero-energy by 2020 (2018 for public buildings)
- EPCs included in all advertisements for sale/rental of buildings
- EU countries must establish inspection schemes for heating / air conditioning systems or put in place measures with equivalent effect
- EU countries to set minimum performance requirements for new buildings, major renovation and replacement/retrofit of building elements
- EU countries to draw up lists of national financial measures to improve energy efficiency of buildings



Fabric Performance and ZEBs

Current UK New-build Regulations – U-values

Type of element	Max. U-value (W/m^2K)
Roof	0.2
Wall	0.3
Floor	0.25
Party Wall	0.2
Swimming pool basin	0.25
Windows, roof windows, roof-lights, curtain walling and pedestrian doors	2

Domestic Buildings

Type of element	Max. U-value (W/m^2K)
Roof	0.25
Wall	0.35
Floor	0.25
Swimming pool basin	0.25
Windows, roof windows, roof-lights, curtain walling and pedestrian doors	2.2
Vehicle access and similar large doors	1.5
High-usage entrance doors	3.5
Roof ventilators (inc. smoke vents)	3.5

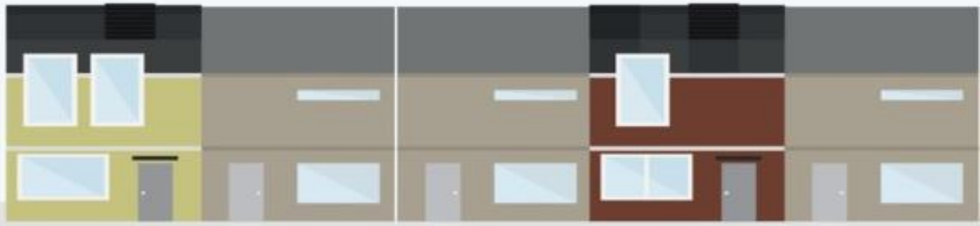
Non-domestic Buildings

Thermal Bridging:

- Separate assessment of non-repeating thermal bridging carried out for new buildings subject to standard 6.1
- Value for non-repeating thermal bridging input to SAP.
- Determined by default, ACD or y-value from numerical modelling

Air Tightness:

- No backstop value set for uncontrolled air infiltration
- Recommended that buildings are design to achieve a value of 10 $m^3/m^2.h$ @ 50 Pa to allow a balanced approach to managing building heat loss.

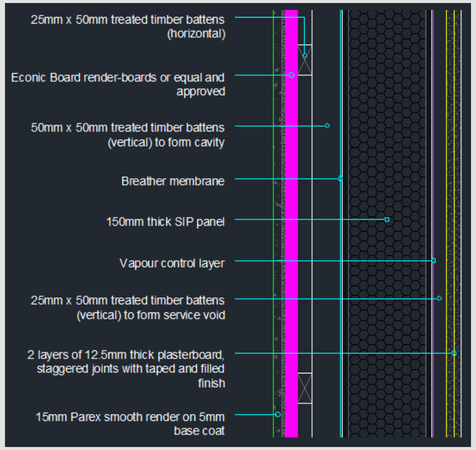


4. THERMAL PERFORMANCE

MORE — CONNECT

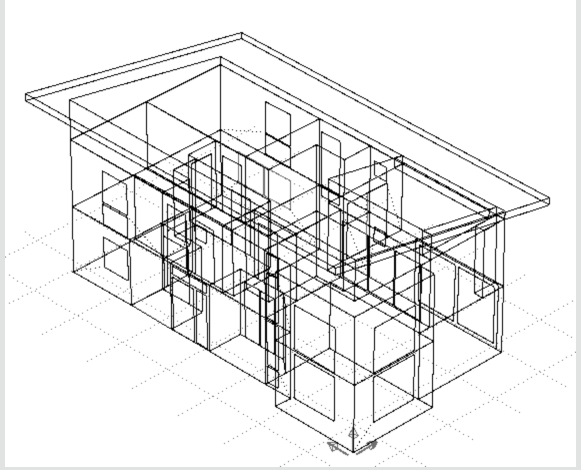
Fabric Performance and ZEBs

Inclusion in Building Simulation / Energy Performance Prediction Tools



	Layer	Thick (mm)	Description of material
i	1	20.00	Render External 20 mm
j	2	20.00	particle board underlay
k	3	75.00	gap 0.17 0.17 0.17
l	4	10.00	OSB3
m	5	65.00	Polyurethane foam bd
n	6	65.00	Polyurethane foam bd
o	7	10.00	OSB3
p	8	25.00	gap 0.10 0.10 0.10
q	9	12.50	Plasterboard (wallboard)
r	10	12.50	Plasterboard (wallboard)

ISO 6946 U hor/up/down 0.160 0.161 0.159

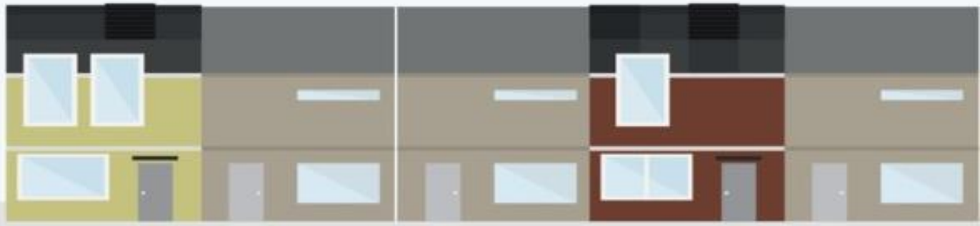


Outputs:

- Energy Consumption and Carbon Emissions:
  - Space heating
  - Domestic Hot Water
  - Lighting & Small Power
- Internal Environment:
  - Temperatures and Relative humidity
  - Thermal comfort
  - IAQ (CO_2 levels)

4. THERMAL PERFORMANCE

MORE—CONNECT



Fabric Performance and ZEBs

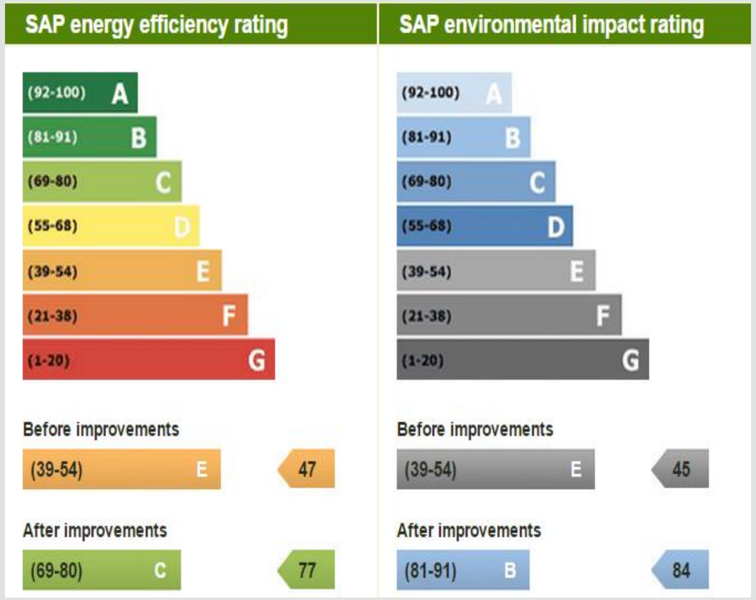
SAP / SBEM Process and Impact

SAP (domestic) and SBEM (non-domestic) are methodologies used by government to assess/compare the energy and environmental performance of buildings.

Supporting the NCM, EPBD and the Green Deal, the outputs from SAP and SBEM include:

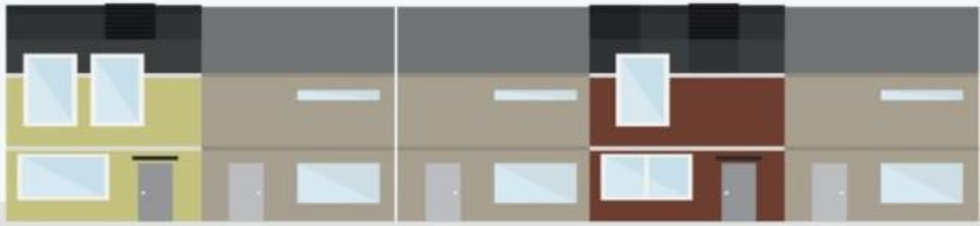
- Energy consumption
- Cost rating
- CO_2 emissions
- Dwelling Emission Rate (DER)
- Target Fabric Energy Efficiency (TFEE)

All of the above are based on a number of factors including **constuction materials** and **thermal insulation** of the building fabric and **air leakage**.



SAP Ratings

5. THE ROLE OF COMMISSIONING

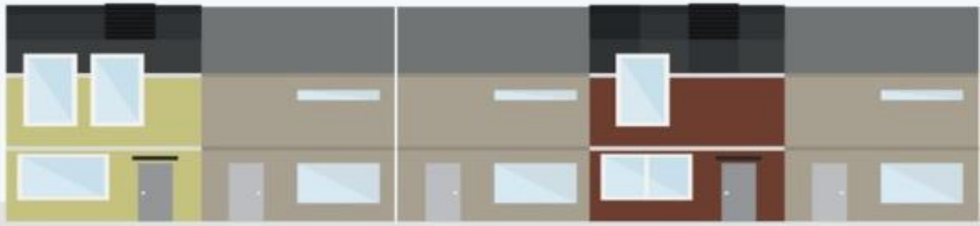


Construction management

Roles & Responsibilities (1/2)

- Construction Manager / General Contractor
  - ✓ Process management
  - ✓ Direct the participation of sub-contractors
  - ✓ Site Inspection
- Sub-Contractors
  - ✓ Demonstrate correct system installation during functional testing
  - ✓ Mock up testing
- Manufacturers and Vendors
  - ✓ Provide documentation

5. THE ROLE OF COMMISSIONING

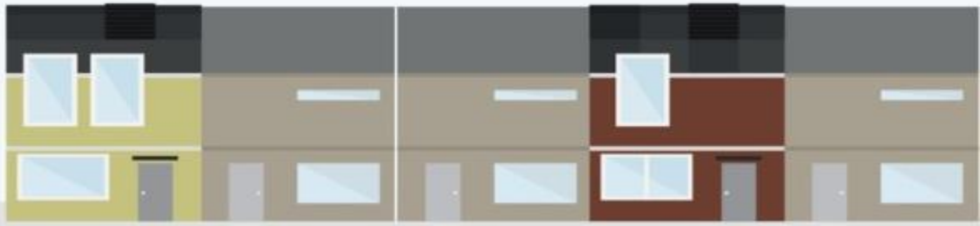


Construction management

Roles & Responsibilities (2/2)

- Commissioning Agent
  - ✓ Write testing plans
  - ✓ Direct and document testing
- Architect, Engineer Design Team
  - ✓ Incorporate requirements into specs
  - ✓ May attend testing
- Owner Project Managers
  - ✓ Witness functional testing
  - ✓ Final approval of Commissioning work products

5. THE ROLE OF COMMISSIONING



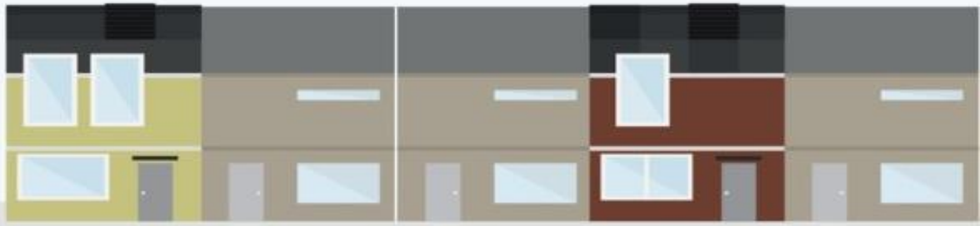
Construction management

Roles & Responsibilities – Construction Manager

- Aims at meeting the client’s requirements
- Control the financial aspects of the construction ➔ viability
- Setting and monitoring the schedule ➔ flow of the materials and delivery of equipment on site
- Setting and monitoring the schedule:
- Implementation of the system
- Finance of the project

Source: Snell (2002)

5. THE ROLE OF COMMISSIONING



MORE—CONNECT

Construction management

Phases

I. Procurement

II. Products Receipt & Acceptance

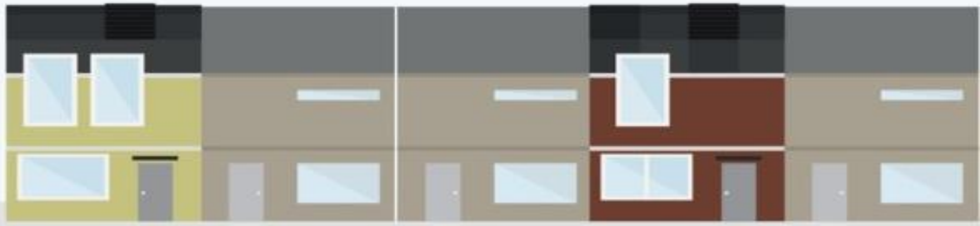
III. Construction Supervision & monitoring

IV. Pre-commissioning

V. Commissioning

5. THE ROLE OF COMMISSIONING

MORE—CONNECT



Construction management

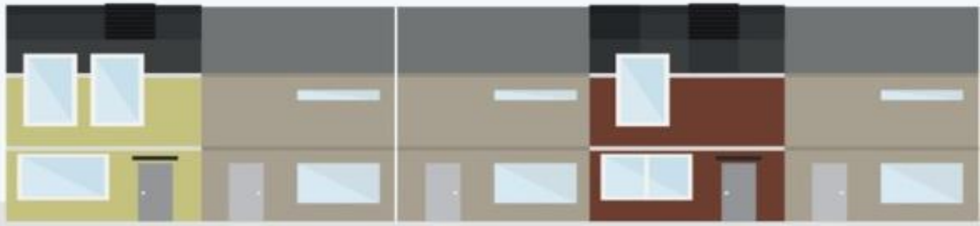
Procurement Phase – Bidding Process

1. Preparation of Bidding Document:
    a) Budget
    b) Quality requirements
    c) Time of delivery
2. Contract Details
    a) Warranty
    b) Liabilities requirements

Procurement Phase – Purchase of Material

1. Identification of installation site:
    a) To see if any special requirements are required
2. Specifying standards and technical requirements
    a) EN standards to be met
    b) Technology to be applied
    c) Compatibility requirements

5. THE ROLE OF COMMISSIONING



MORE — CONNECT

Construction management

Products Receipt and Acceptance Phase – Onsite Delivery

The field supervisor is responsible to handle material delivery

Steps to perform:

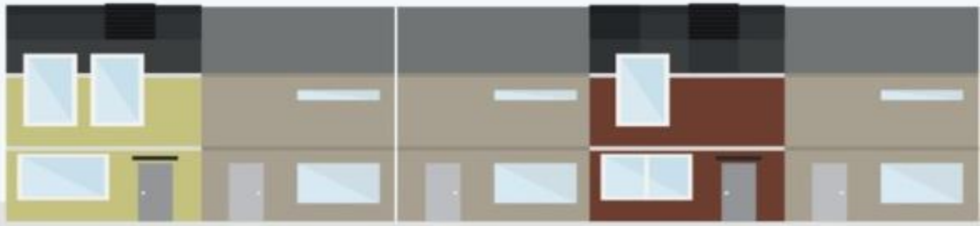
- Confirm specifications
- Confirm quantity
- Confirm compliance with design requirements

Products Receipt and Acceptance Phase – Alterations

- Alterations are to be communicated to the construction manager
- Construction manager takes corrective actions to deal with this issue
- The impact and consequences of alterations are to be identified and studied before making any decision

5. THE ROLE OF COMMISSIONING

MORE—CONNECT

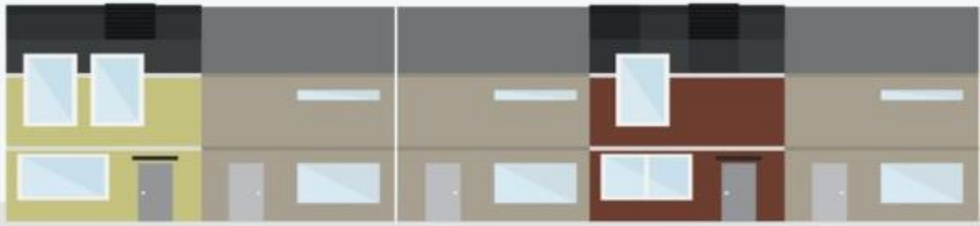


Construction management

Construction Supervision & Monitoring Phase – Scheduling & Work plan

- Construction manager should set the project schedule and distribute the work among the workforce
- Field supervisor should:
    - Monitor quality
    - Ensure proper implementation of schedule
    - Resolve issues appearing on site
    - Inform construction manager of work progress and any delays taking place

5. THE ROLE OF COMMISSIONING



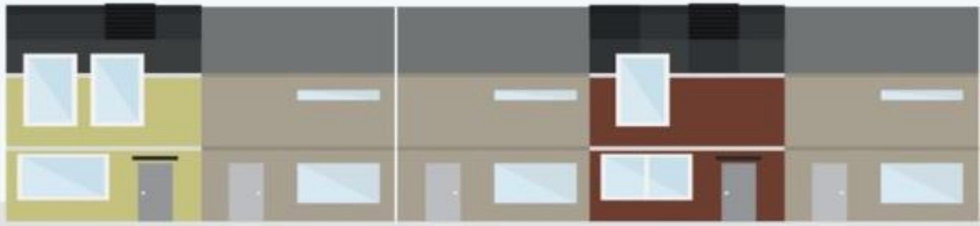
MORE—CONNECT

Construction management

Construction Supervision & Monitoring Phase – Safety Measures

- Field supervisor should:
    - Make sure all safety measures are implemented
        - For example when working with thermal insulation proper precautions must be considered. Some material are toxic and other should be avoided.

5. THE ROLE OF COMMISSIONING



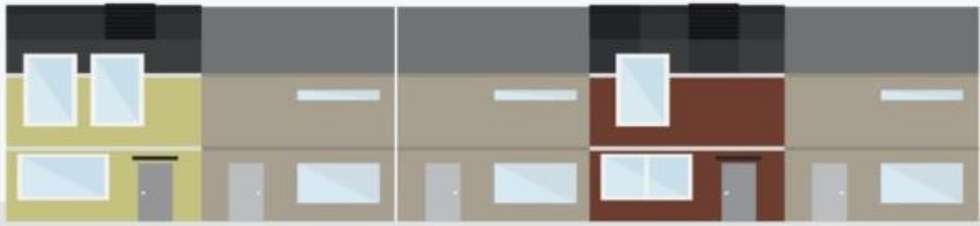
MORE — CONNECT

Construction management

Pre- Commissioning Phase – Maintenance Reports

- A maintenance of test reports should be prepared including:
  - Test type
  - Date and time
  - Equipment tested
  - Test data
  - Test results
- Faulty or incomplete items should be reported to the construction manager to follow up with concerned parties

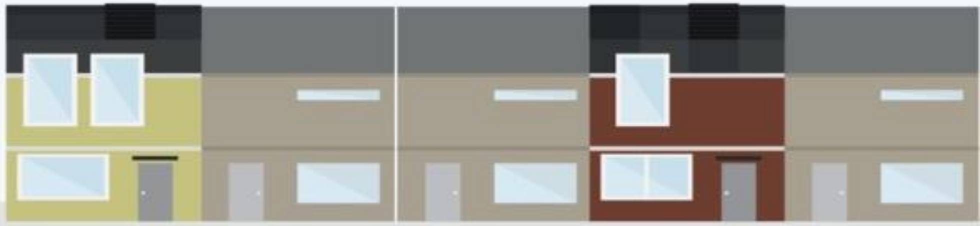
5. THE ROLE OF COMMISSIONING



Construction management

Commissioning Phase – Commissioning Process

- Organization and Preparation
    - Commissioning Specs
    - Design Reviews & Scrub Specs
- Installation Inspections
    - Review Submittals , RFI’s, Change Orders, etc.
    - Equipment Start-Up
- Performance Verification
    - Performance Testing
    - Building Simulation
    - Correction of Deficiencies
    - Re-Test of Systems



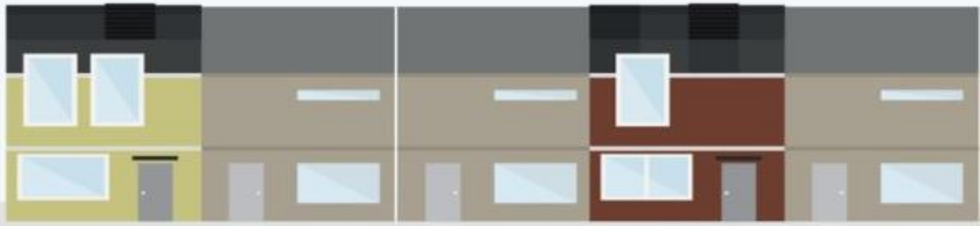
Construction management

Commissioning Phase – Commissioning Process Outputs (1/7)

Owner Project Requirements

- Owner's Vision & Directives
- Project Budget & Schedule
- Occupant Requirements
- System Performance & Integration
- Restrictions & Limitations
- Training & Warranty Requirements
- Quality of System, Materials & Construction
- Operations & Maintenance
- Benchmarking & Project Documentation

5. THE ROLE OF COMMISSIONING

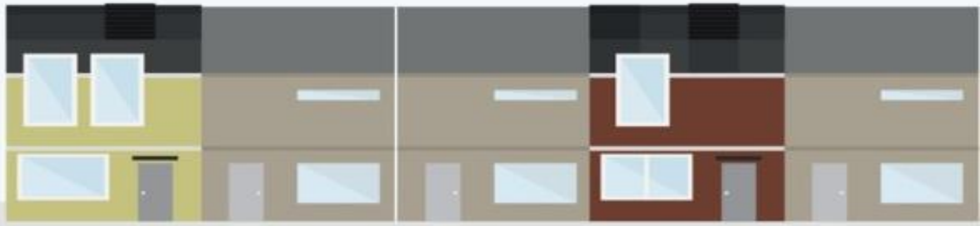


Construction management

Commissioning Phase – Commissioning Process Outputs (2/7)

Basis of Design Document

- Description of each system option considered:
  - Exterior Enclosure, Sub-systems, Materials and Components
- Interaction of Building Exterior Enclosure with:
  - Heating, Cooling, Mechanical and Natural Ventilation, Lighting, Interior
- Operational Assumptions
- Calculations



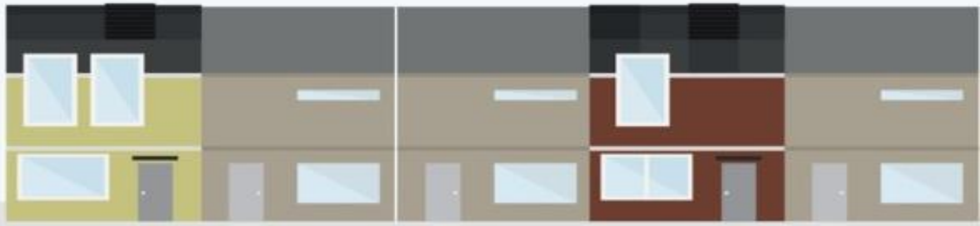
Construction management

Commissioning Phase – Commissioning Process Outputs (3/7)

System Manual Structure

- A systems manual is developed for each major building exterior enclosure:
    - Roof, Skylights, Atria, Exterior Walls, Windows, Doors, Sealants & Expansion Joints, Control Joints, Flashings, Shading Devices, Curtain Walls, Plaza Decks, Planters, Below-Grade, Balconies, Floors, …

5. THE ROLE OF COMMISSIONING



Construction management

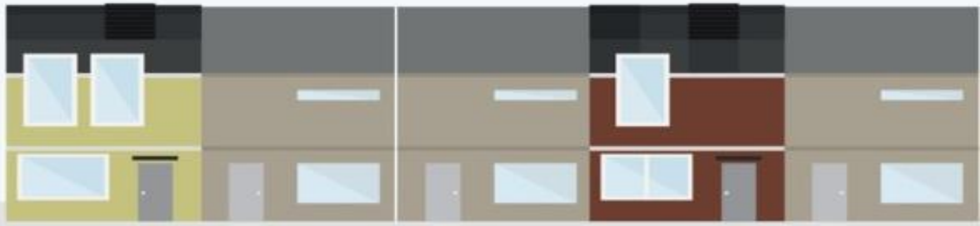
Commissioning Phase – Commissioning Process Outputs (4/7)

Commissioning Process Requirements for Construction

- Systems to be Documented and Tested
- Schedule of Building Exterior Enclosure for:
  - Witnessing Testing Activities
  - Systems and Equip. Accessibility for maintenance and commissioning
  - Completion of Construction Checklist
  - Activities relative to substantial completion/project closeout
- Include in Building Exterior Enclosure Spec:
  - Specific Component performance documentation requirements
  - Use of construction checklists
  - commissioning process activities

5. THE ROLE OF COMMISSIONING

MORE—CONNECT



Construction management

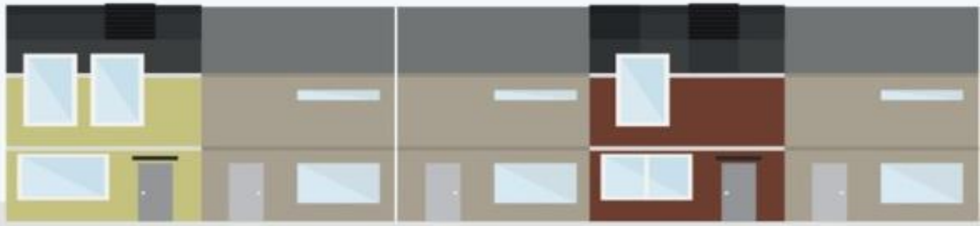
Commissioning Phase – Commissioning Process Outputs (5/7)

QA/QC Plan

- Verify QA/QC Requirements:
  - Field Testing
  - Manufacturing Performance Testing
  - Submittal & Shop Drawings
  - Laboratory testing for Custom Systems
  - Sample Construction
  - Formal Mock-up Testing Submittal
  - Inspection
  - Pre Construction/installation meeting
- Random Sampling

5. THE ROLE OF COMMISSIONING

MORE—CONNECT



Construction management

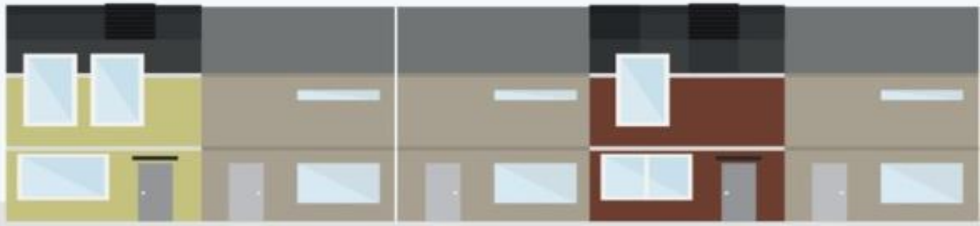
Commissioning Phase – Commissioning Process Outputs (6/7)

Pre-Construction Commissioning Process

- Special Issues relative to sequencing and early installation of equipment should be discussed
- Pre-Construction Conference (Pre-Bid Conference)

5. THE ROLE OF COMMISSIONING

MORE—CONNECT



Construction management

Commissioning Phase – Commissioning Process Outputs (7/7)

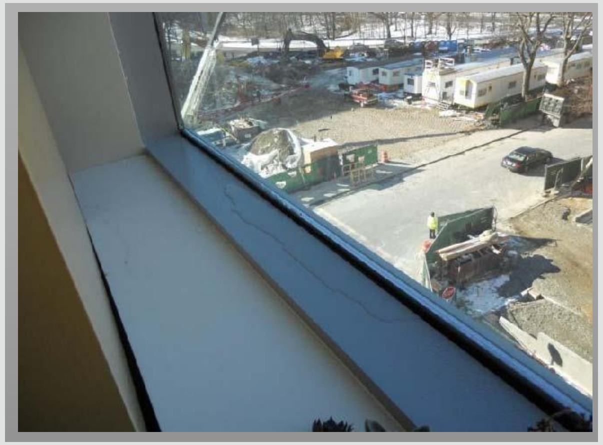
Training

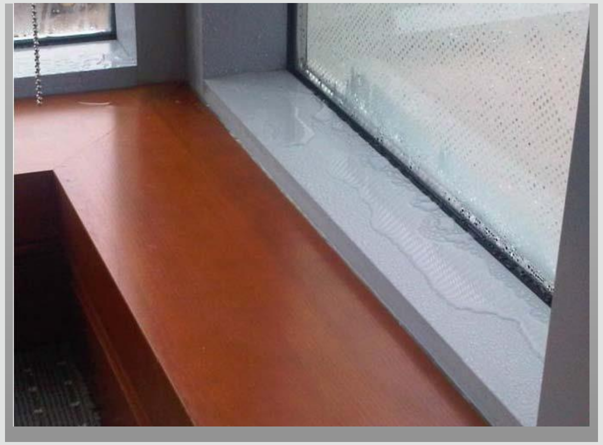
- **Seasonal Weather Cycles:** Responsibilities of each O&M position, Certification of training comprehension, Repair/modifications/decommissioning
- **Post-Occupancy Performance Verification:** O&M document directory, Emergency operating procedures, Operating manual meeting O.P.R., Operation changes, Maintenance manual, Warranty & verified equipment performance data, Changes in maintenance procedures, Performance verification log forms & repair docs, Test reports, Non-conformance logs, As-built, guides and schedules
- **Training during Occupancy & Operations Phase:** Roles & Responsibilities, Means of determining level of comprehension, Methods of cross-training & tracking, Short Narrative of essential exterior enclosure design characteristics.

Construction management

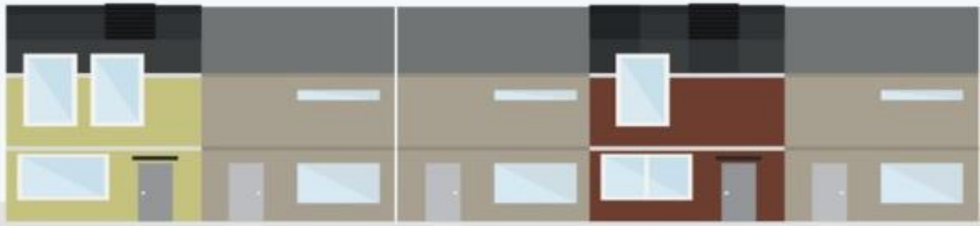
Commissioning Phase – Testing (1/2)

- Testing should be performed to avoid:
  - Issues with the envelope
  - Water leaks
  - Condensation on windows
  - Excessive infiltration
  - Visual damage
  - Snow and ice formation on windows
  - Air leakage in an air distribution system
  - Insufficient foam thickness
  - High moisture content of wood





5. THE ROLE OF COMMISSIONING



Construction management

Commissioning Phase – Testing (2/2)

- Testing Methods
    - Field Testing
    - Infrared testing
    - Water leakage testing
    - Visual inspection
    - Temperature variation measurements

5. THE ROLE OF COMMISSIONING

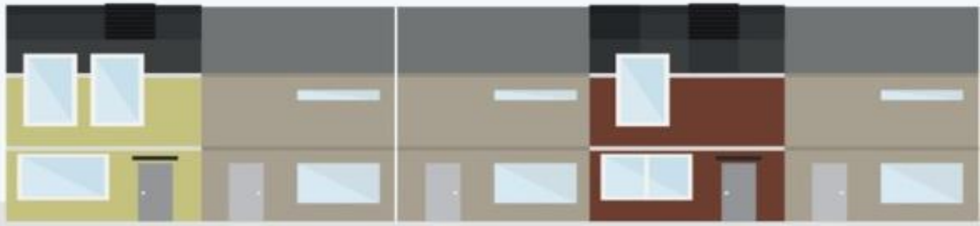
MORE—CONNECT

Construction management

Commissioning Phase – Façade Air & Water Test

- Air pressure differential - intended to simulate the effect of a positive wind pressure on the performance of the glazing system or assembly.
- Application of water - delivered to the exterior surface of the test specimen using a calibrated spray “rack”.

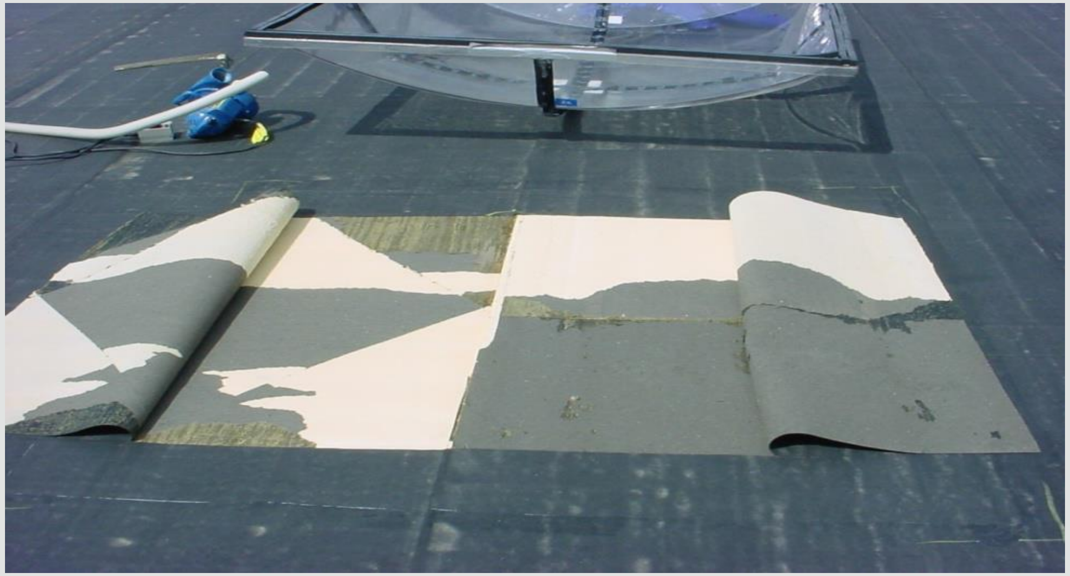
MORE — CONNECT



Construction management

Commissioning Phase – Roof Test

- Tests mainly focus on roof uplifting



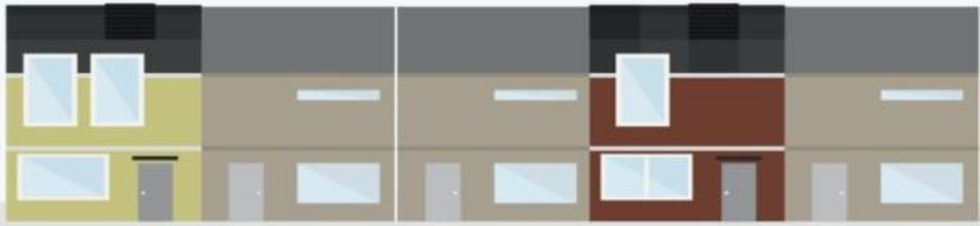
5. THE ROLE OF COMMISSIONING

Construction management

Commissioning Phase – Field Test

- This test method consists of mechanical pressurization or de- pressurization of a building and measurements of the resulting airflow rates at a given indoor- outdoor static pressure differences. From relationship between the airflow rates and pressure differences, the air leakage characteristics of a building envelope can be evaluated.

5. THE ROLE OF COMMISSIONING



MORE—CONNECT

Construction management

Commissioning Phase – Assessment Tools

Temp. & Humidity Logger

Heat Flux Meter

Infrared Thermometer

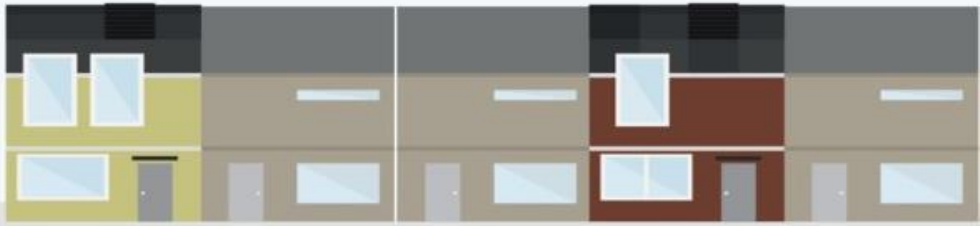
Blower Door

Thermal Imager

Pyranometer

5. THE ROLE OF COMMISSIONING

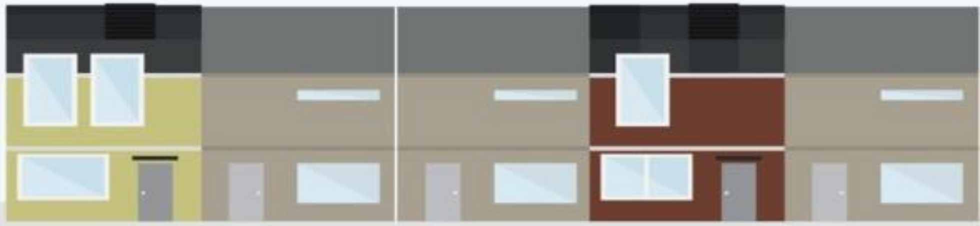
MORE—CONNECT



Construction management

Assessment Tools: Temperature & Humidity Logger

- Measures and records temperature and humidity over a desired period of time
- Features built-in sensors to measure ambient temperature and humidity in many settings

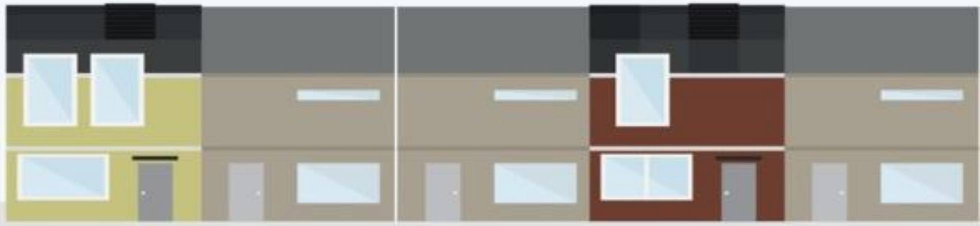


Construction management

Assessment Tools: Heat Flux Meter

- Measures and records heat flow, to find thermal resistance and heat flux in building envelopes
- Measures both radiative and conductive heat

5. THE ROLE OF COMMISSIONING



MORE—CONNECT

Construction management

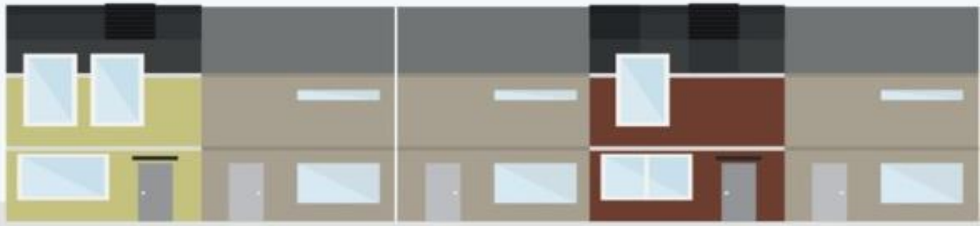
Assessment Tools: Infrared Thermometer

- Measures temperature from distance and records it along with the distance to object

Assessment Tools: Blower Door

- Measures air tightness in buildings
- Components:
  1. Calibrated variable-speed fan,
  2. Pressure measurement instrument (manometer)
  3. Mounting system

5. THE ROLE OF COMMISSIONING



Construction management

Assessment Tools: Thermal Imager

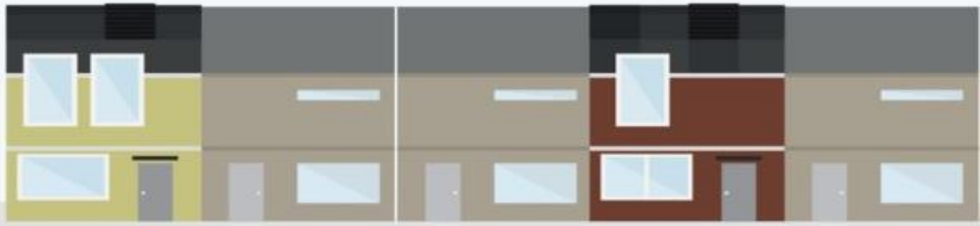
- Detects radiation in the infrared range of the electromagnetic spectrum
- Shows heat loss areas and air infiltration issues

Assessment Tools: Pyranometer

- Measures solar radiations on site
- Can be used to measure the performance of windows in the building

5. THE ROLE OF COMMISSIONING

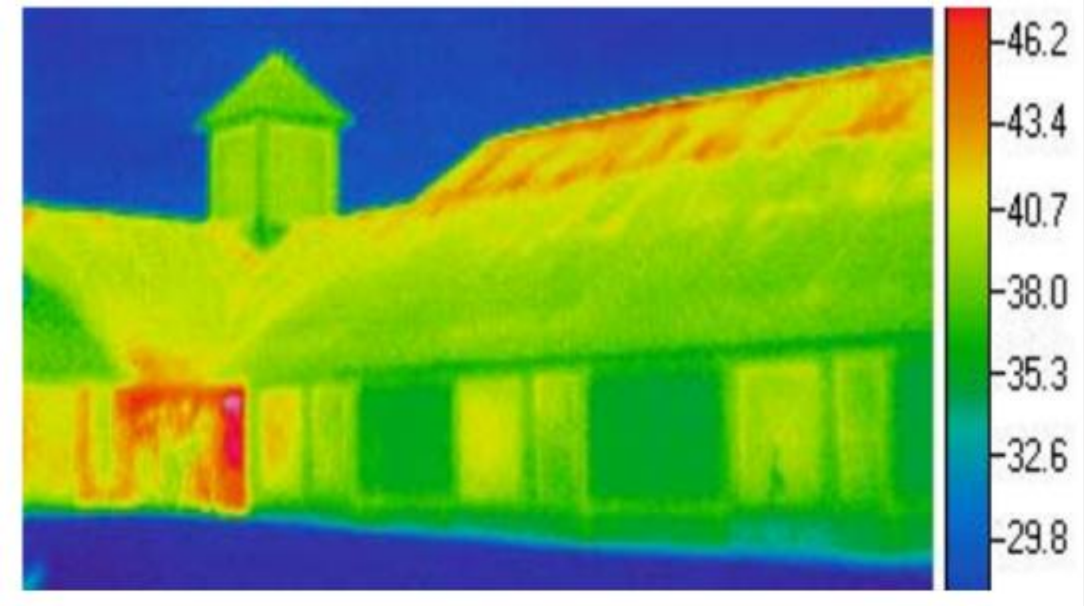
MORE—CONNECT



Construction management

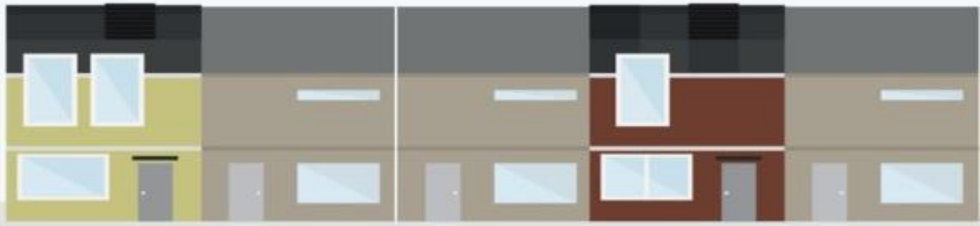
Assessment Tools – Use of Thermography (Thermal Imager)

Infrared thermography also known as thermal imaging can provide remarkable, nondestructive information about construction details and building performance.



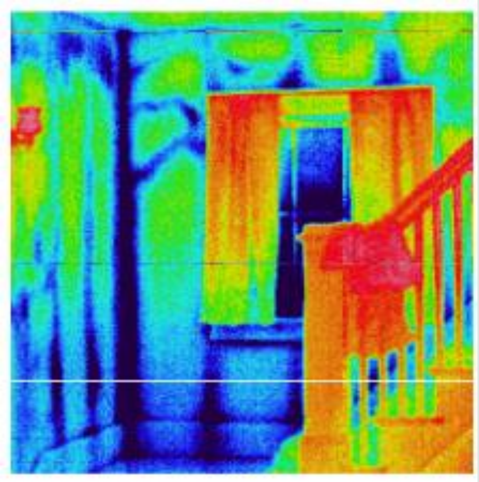
Source: Snell (2002)

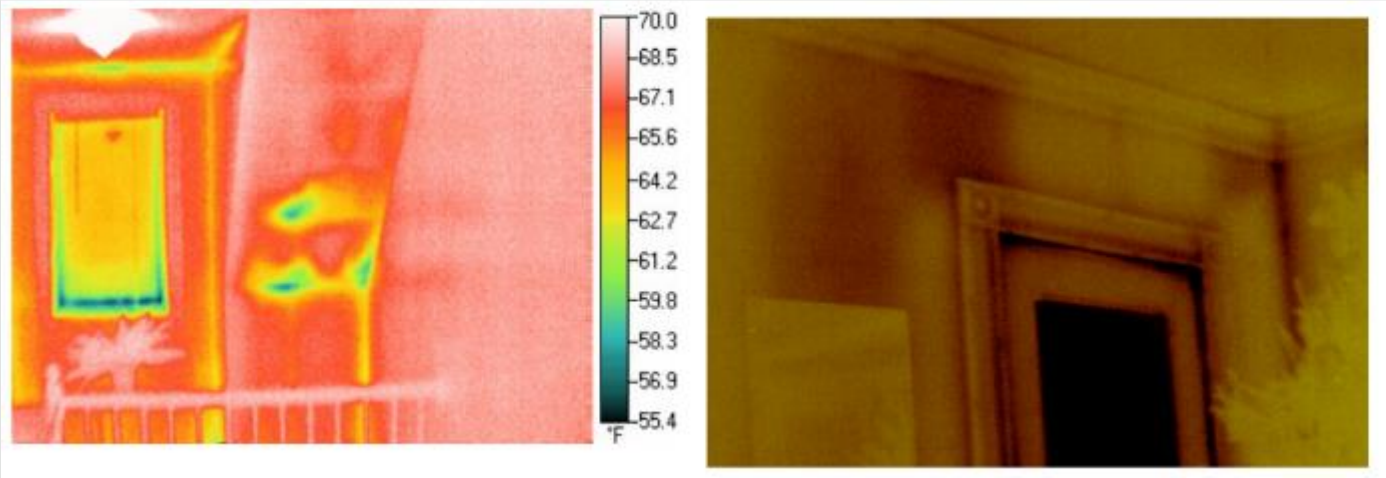
5. THE ROLE OF COMMISSIONING



Construction management

Assessment Tools – Use of Thermography: Insulation Check





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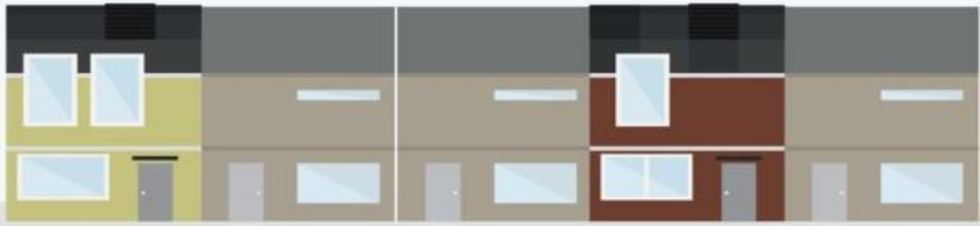
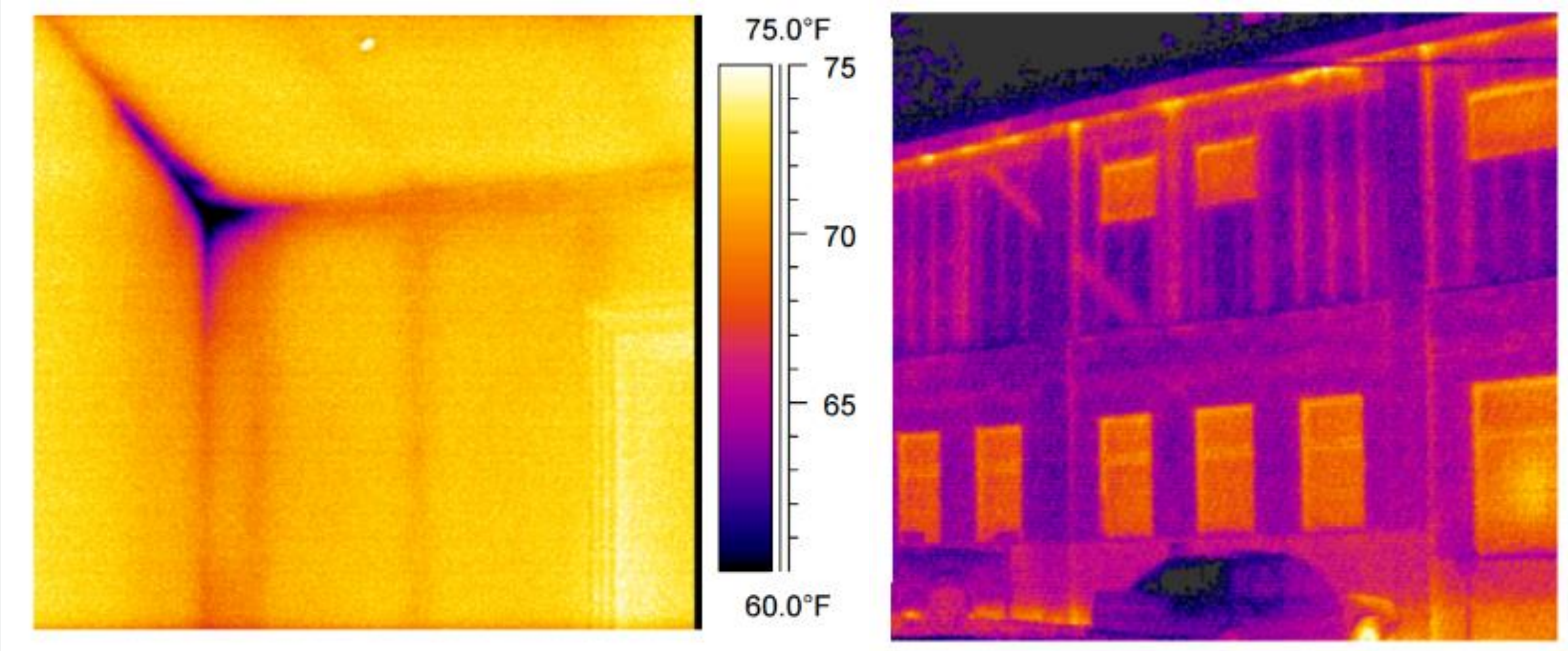


Construction management

Assessment Tools – Use of Thermography: Air Leakage



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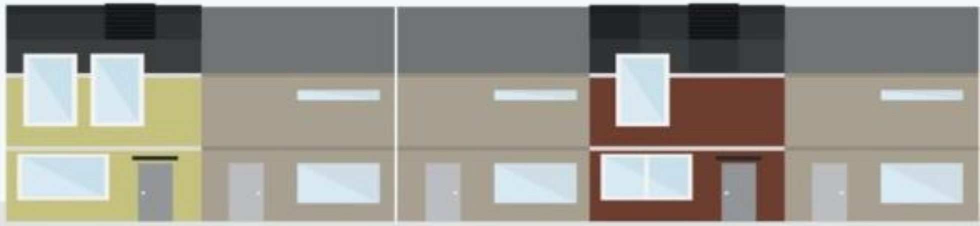
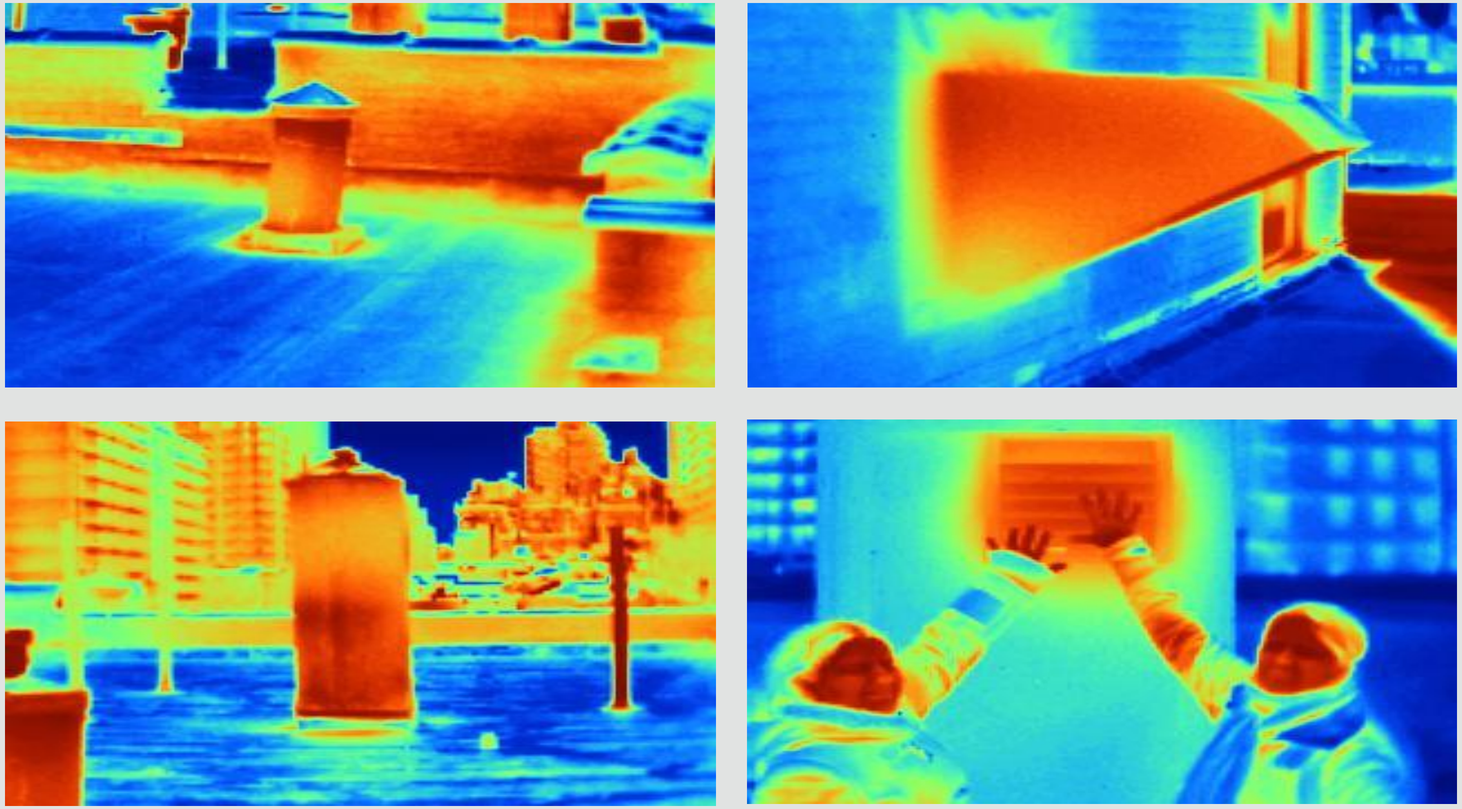


Construction management

Assessment Tools – Use of Thermography: Heat Loss



5. THE ROLE OF COMMISSIONING

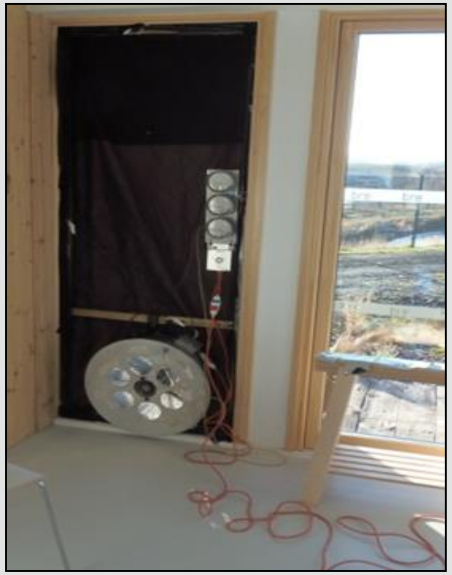
Building Fabric

Overview

Commissioning is a vitally important process for ensuring that new building fabric and systems perform as they should according to the design specification.

A number of testing methods can be used to determine whether building fabric meets, exceeds, or does not meet it’s design specification including:

- In-situ U-value measurement
- Airtightness testing
  - Smoke tests to determing high-leak areas
- Thermal imaging
  - Identify areas of missing insualtion and other significant thermal bridges

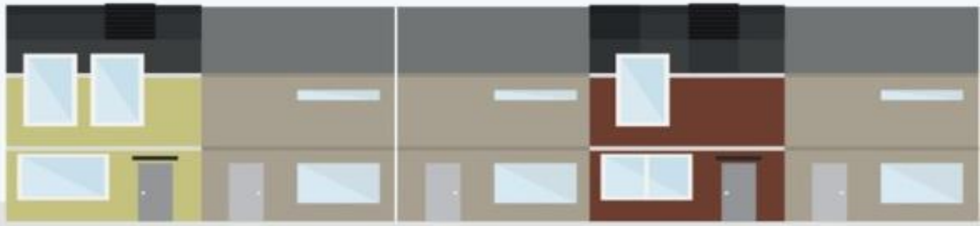


Airtightness test kit

Any issues raised undergo a process of remediation.

5. THE ROLE OF COMMISSIONING

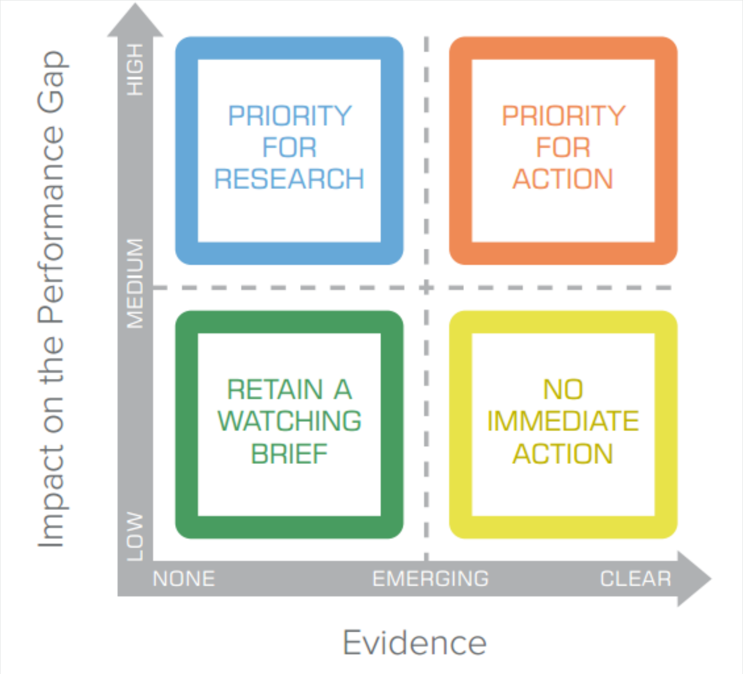
MORE—CONNECT

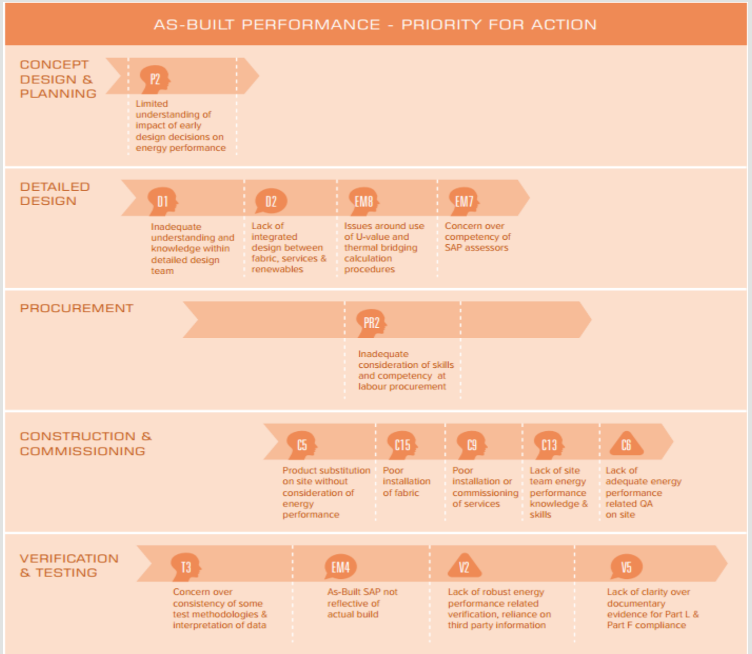


Building Fabric

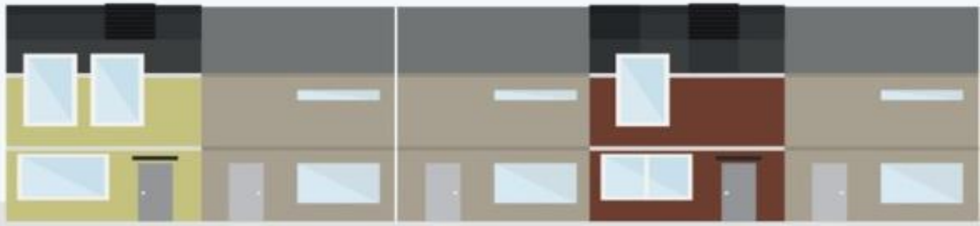
Design vs In Use

The Zero Carbon Hub's recommendation to Government in 2011: *"By 2020, at least 90 % of all new homes should meet, or perform better than, their designed energy/carbon performance.*





Zero Carbon Hub Framework for reducing the performance gap

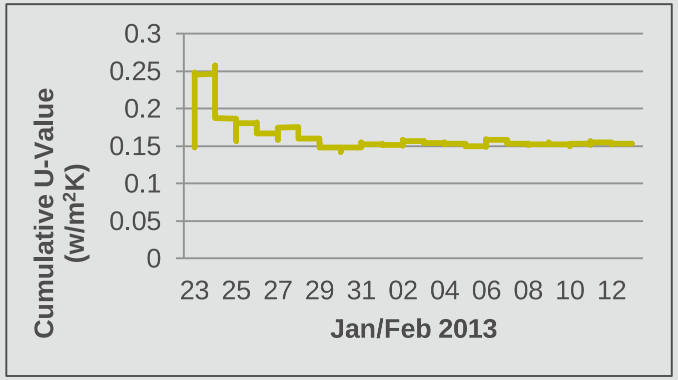


Building Fabric

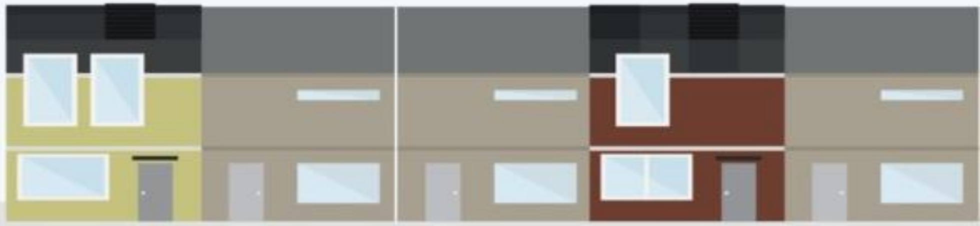
In-situ U-value measurement

In-situ U-value measurement can quantify the performance of the plane areas of the building fabric

- Case Study:
  - Walls – 0.15 W/m^{2}K
  - Roof / Floor – 0.1 W/m^{2}K
  - Windows – 0.9 W/m^{2}K



Performance as per the design specification ✓

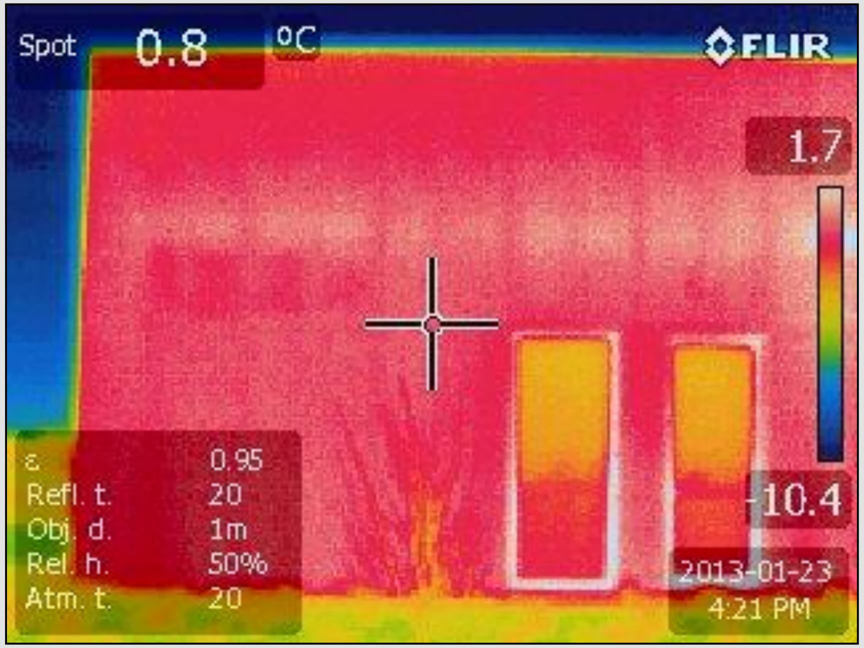


Building Fabric

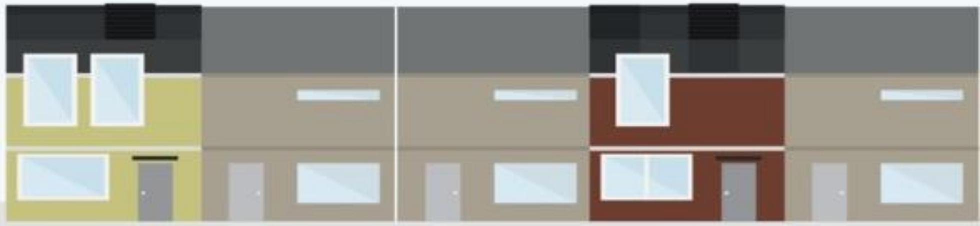
In-situ Testing – Thermography

This type of thermographic survey can be used to test for:

- Continuity of insulation
- Significant Thermal bridging
- Areas of different heat loss
- Areas affected by Damp
- Air leakage or ingress



No issues identified ✓



Thank you for your attention!

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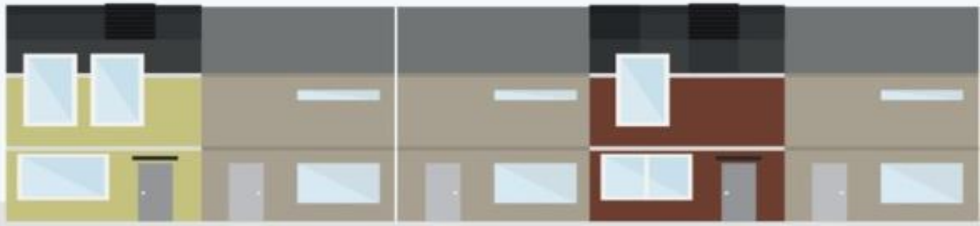

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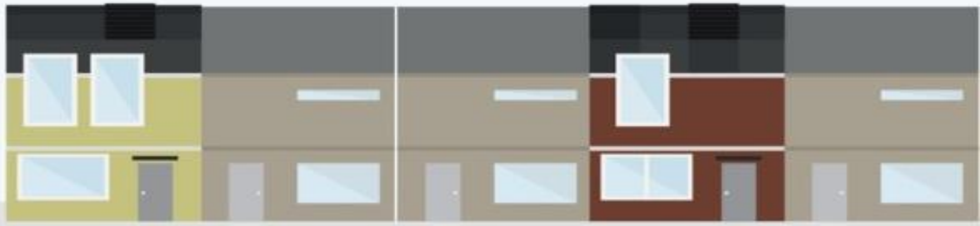

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