Module 3.1

Introduction to U-values

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Learning Outcomes

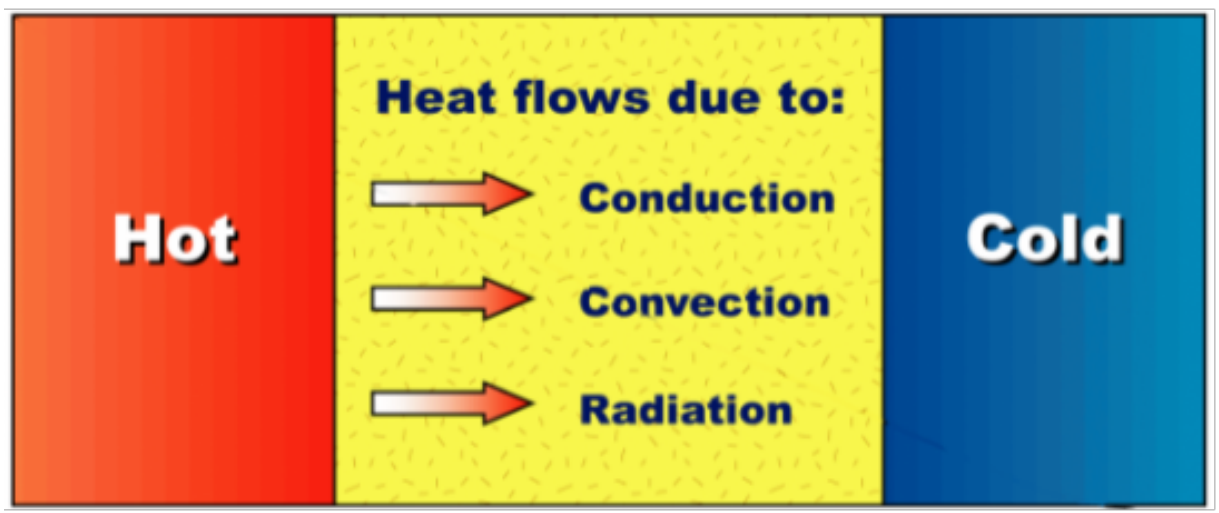
- On successful completion of this module learners will be able to

- Describe the concept of U-value.

- Describe the relevance of U-value to heat loss from buildings.

Heat loss from buildings.

- Heat flows naturally from a warmer to a cooler space.
- In winter, the heat moves directly from all heated living spaces to the outdoors and to adjacent unheated attics, garages, and basements - wherever there is a difference in temperature. Source: http://www.ornl.gov/sci/roofs+walls/insulation/ins_01.html



Introduction to U-values.

- U-value is the measure of the rate of heat loss through a material.
- U-value is the also know as thermal transmittance.
- The lower the U-value, the less heat that is transmitted through the material.
- The lower the U-value, the better the insulation value of the material.
- To reduce heat loss from buildings, designers, builders and owners should strive for the lowest

U-values possible on surfaces dividing hot and cold areas.

Units of U-value.

- U-values describe the amount of heat lost through

- one square meter of the material
- for every degree difference in temperature
- either side of the material.

- It is indicated in units of

- Watts per Meter Squared per Degree Kelvin
- or W/m^2K.

- Note that Kelvin is used as the scale of temperature difference, but this is numerically equal to ^oC.

Heat loss depends on U-value.

- Heat loss from any given surface is calculated using

Heat loss = U x A x dT

where U = U-value (W/m^2K)

A = Area of surface (m^2)

dT = Temperature difference inside to outside (K)

Units of Heat loss = Watts.

Units of Heat loss =	W	=	W	x	m^2	x	K
			$m^2 \times K$				

Calculations using U-value – 1m^2 area

Calculations using U-value – 9m^2 area

- continued.

- Heat loss = U x A x dT
- When designing buildings

The surface area (A) of floors, walls, roofs, windows, etc are set by the owners needs.

The temperature difference (dT) between inside and outside is set by the climate and internal temperature.

Only the U-value (U) can be changed by the designer of the building.

- To minimise heat loss – must minimise U-value.

Relationship of U-value to thermal resistance and thermal conductivity

- Units related to these parameters.

Symbol	Description	Units
U	thermal transmittance	W/m^2K
R_T	Total thermal resistance	m2K/W
R	thermal resistance	m^2K/W
λ (lambda)	thermal conductivity	W/m K
d	thickness (depth)	m

- continued.

- U-value (thermal transmittance) = $1 / R_T$

where R_T = total thermal resistance.

- Thermal resistance $R = d / \lambda$

where d = thickness (depth) of material layer

λ = thermal conductivity of the material

Significance of U-value, R and λ to building designers, builders and owners.

- To reduce heat loss from buildings, designers, builders and owners should strive for the lowest U-values possible on surfaces dividing hot and cold areas. Low U-value = low heat loss.
- Low U-values can be achieved if the value of R (thermal resistance) is large.
- High values of R can be achieved if

- λ (thermal conductivity) is low and/or if
- d thickness (depth) of material is large.

-continued.

- In non technical language

Low heat loss in buildings can be achieved by installing high thickness (depth) of good insulation material.

- Using the more technical terms just explained above

Low U-values in buildings can be achieved by installing high thickness (depth) of insulation material with a low thermal conductivity (λ) and so having a high thermal resistance (R).

Thermal conductivities of common building materials.

- Thermal conductivity (λ) (lambda) is the intrinsic property of a material which relates its ability to conduct heat. Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole .
- Typically dense materials have a high thermal conductivity.
- Typically lightweight materials have a low thermal conductivity.
- Insulation materials have a low thermal conductivity (λ) (lambda).

- continued.

Some examples of thermal conductivity (λ) for usual building materials.

NB examples only – use certified manufacturers values when performing calculations

Source: www.isover.co.uk

Still air 0,025

Units of λ = W / m K

Examples using U-value, R, λ and d.

Take equal thickness of two common building materials.

100mm timber (softwood)	100mm mineral wool
R = d / λ (from earlier equation)	R = d / λ (from earlier equation)
λ = 0.130 W/mK (CIBSE Guide A)	λ = 0.038 W/mK (CIBSE Guide A)
R = 0.100 / 0.13	R = 0.100 / 0.038
R = 0.769 m^2K / W	R = 2.632 m^2K / W
Then U = 1 / R (from earlier equation)	Then U = 1 / R (from earlier equation)
U = 1 / 0.769	U = 1 / 2.632
U = 1.30 W / m^2 K	U = 0.38 W / m^2 K
High λ = large U-value = large heat loss	Low λ = small U-value = small heat loss

Examples – continued.

For equal thickness of two common building materials.
From calculations above.

Sources of thermal conductivity (λ) of common building materials.

- International standards.
- ISO 10456 : 2007 Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values. Approximate cost € 65.

Sources of thermal conductivity (λ) of common building materials.

- National standards.
- CIBSE Guide A – Environmental Design – Section A3.
  Approximate cost € 125.
- Building Regulations (Part L Amendment) Regulations 2008. Technical Guidance Document L – Conservation of Fuel and Energy – Dwellings, Appendix A (Ireland)

Download:www.environ.
ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,19069,en.pdf.

- Other standards.
- Manufactures certified data.

Thermal conductivities (λ) some building materials.

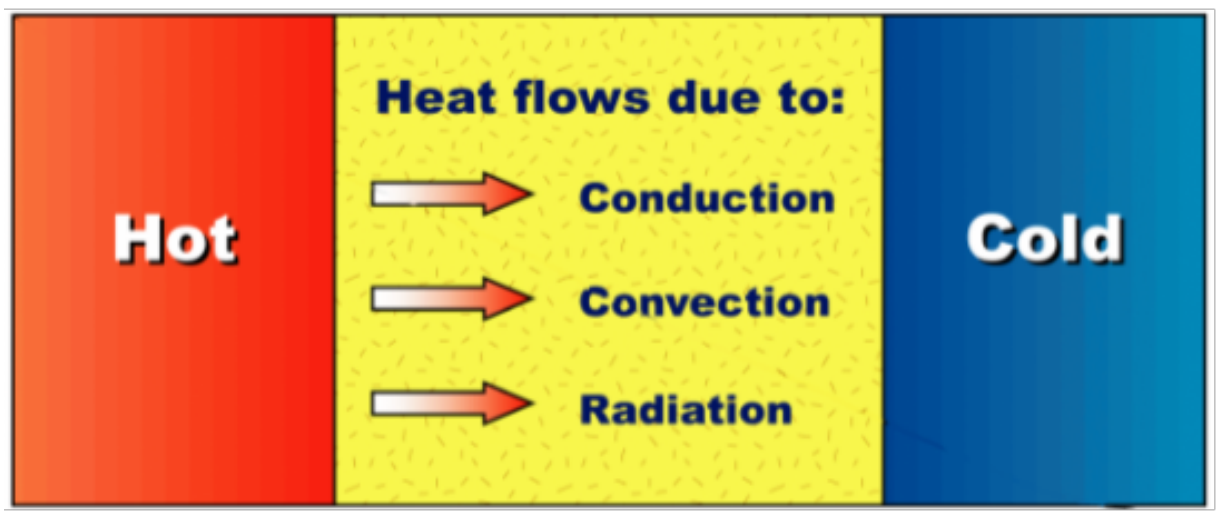
Technical Guidance Document L – Conservation of Fuel and Energy – Dwellings, Appendix A (Ireland)

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

Material	Density (kg/m3)	Thermal conductivity (W/mK)
Clay brickwork (outer leaf)	1700	0.77
Concrete block (heavyweight)	2000	1.33
Concrete block (autoclaved aerated)	600	0.18
Cast concrete, high density	2400	2.00
Reinforced concrete (2% steel)	2400	2.50
Plasterboard	900	0.25
Timber, softwood	500	0.13
Wood panels (plywood, etc)	500	0.13

How insulation works.

- Heat flows naturally from a warmer to a cooler space.
- In winter, the heat moves directly from all heated living spaces to the outdoors and to adjacent unheated attics, garages, and basements - wherever there is a difference in temperature. Source: http://www.ornl.gov/sci/roofs+walls/insulation/ins_01.html



How insulation works – continued.

- In summer, in warmer countries, heat moves from outdoors to the house interior.
- Most insulation materials work by reducing heat transfer due to conduction.
- Reflective insulation works by reducing the amount of energy that travels in the form of radiation.
- Insulation materials have a low thermal conductivity (λ).

Advantage of using insulation.

- To maintain comfort, the heat lost in winter must be replaced by your heating system.
- Also the heat gained in summer must be removed by an air conditioner.
- Insulating ceilings, walls, and floors decreases the energy needed for heating or cooling by providing an effective resistance to the flow of heat.
- This saves on running cost for the building and helps the environment by reducing dependence on fossil fuels.

Types of insulation.

- See the appendix attached to this module to see a description of different types of insulation.

Module summary

- U-value (U) is the measure of the rate of heat loss through a material.
- Tasks.

a) What are the units of U-value.

b) State the formula which use U-value to calculate the heat loss from any given surface.

Module summary – continued.

- U-value (U) can be related to thermal resistance (R) and thermal conductivity (λ) .
- Tasks.

a) State the formula which links U-value to the total thermal resistance.

b) State the formula which links thermal resistance to thermal conductivity.

Module summary – continued.

- Insulation materials reduce heat flow from warm areas to cold areas.
- Tasks.

a) How do blanket, blown, foam and rigid insulation materials reduce heat flow.

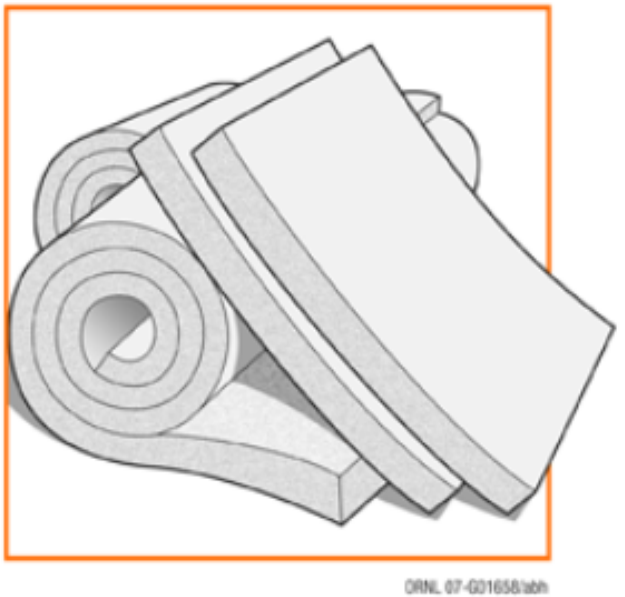
b) How do reflective insulations reduce heat flow.

c) Given equal thickness of material, which type of insulation typically offers the best reduction in heat flow, i.e. the lowest thermal conductivity (λ) (lambda).

Appendix - Types of insulation.

- There are many different types of insulation, not all are described here.
- All types of insulation are not compatible with every construction situation. Use manufacturers recommendations to selecting appropriate materials.
- All types of insulation should be installed following the manufacturers instructions.

Types of insulation. http://www.ornl.gov/sci/roofs+walls/insulation/ins_02.html



- Blankets insulation, in the form of batts, mats or rolls.

These are flexible products made from wood fibers, hemp, sheep wool, mineral fibers, fiberglass or rock wool.

They are available in widths suited to standard spacing of wall studs and attic or floor joists. They must be hand-cut and trimmed to fit wherever the joist spacing is non-standard . Typical thermal conductivity 0.035-0.044 W/mK

Types of insulation – continued

- Advantages of wood fiber insulation.

Thermal conductivity as low as 0.038 W/m.K.

Semi-rigid, easily cut, non irritating material.

Is a renewable / sustainable product.

Provides both thermal and acoustic insulation.

Has the ability to absorb and release moisture.

Types of insulation – continued

- Advantages of hemp insulation.

Semi-rigid, easily cut, non irritating material.

Is a renewable / sustainable product.

Has the ability to absorb and release moisture.

Not effected by mould growth or insect attack because the fiber does not contain proteins.

- Advantages of sheep's wool insulation.

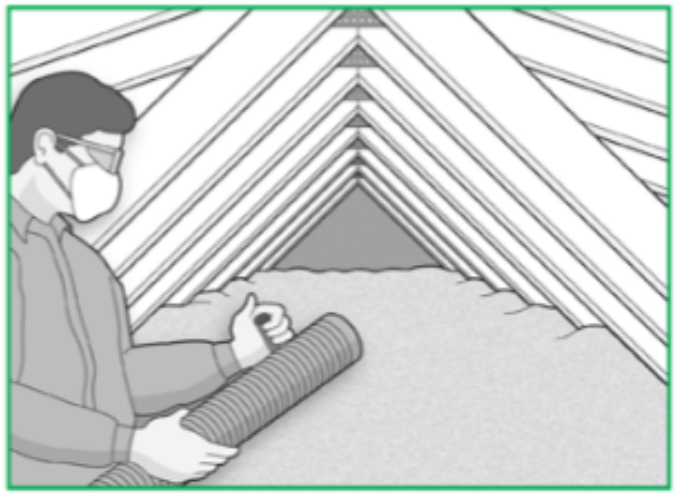
Semi-rigid, easily cut, non irritating material.

Is a renewable / sustainable product.

Has the ability to absorb and release moisture.

Types of insulation – continued

- Blown-in loose-fill insulation includes cellulose, fiberglass, or rock wool in the form of loose fibers or fiber pellets



These are blown into place using pneumatic equipment, usually by professional installers. This form of insulation can be used in wall cavities and for irregularly shaped areas. Typical thermal conductivity 0.037-0.040 W/mK

Types of insulation – continued

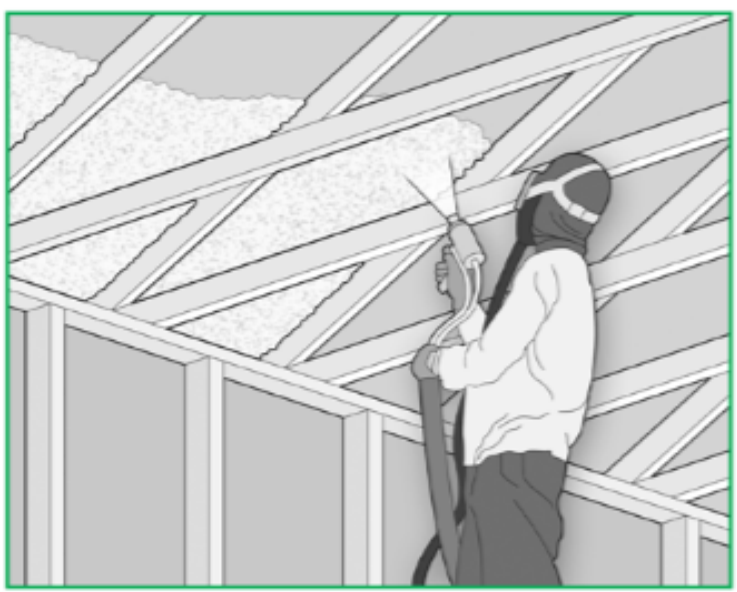
- Blown-in loose-fill

- continued

In the open wall cavities of a new house, cellulose and fiberglass fibers can also be sprayed after mixing the fibers with an adhesive or foam to make them resistant to settling.

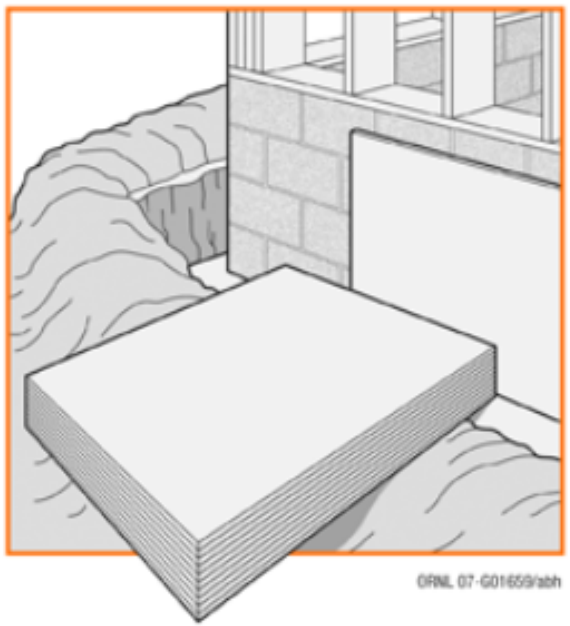
Types of insulation – continued

- Foam insulation can be applied by a professional using special equipment to meter, mix, and spray the foam into place.
- Typical thermal conductivity 0.025 W/mK



Types of insulation – continued

- Rigid insulation is made from fibrous materials or plastic foams and is produced in board-like forms and molded pipe coverings.



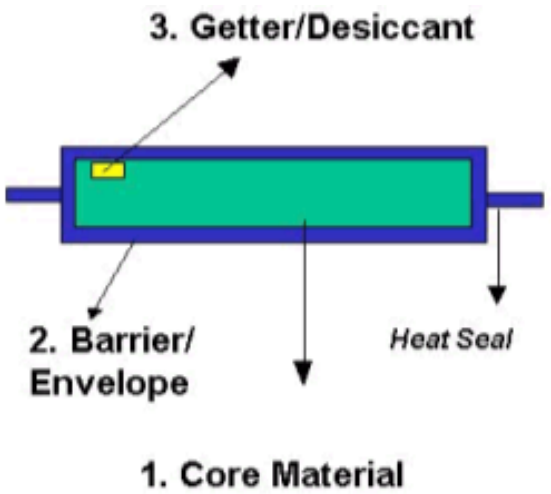
These provide full coverage with few heat loss paths and are often able to provide a a lower thermal conductivity (λ) than other insulation materials, typically 0.021-0.038 W/m.K.

Types of insulation – continued

- VIP – Vacuum insulated panels.

VIP consist of a gas-tight enclosure and a rigid core from which the air has been evacuated . By removing air from the fiber, powder, or foam core materials, VIP uses the insulating effects of a vacuum to produce much higher thermal resistance than conventional insulation.

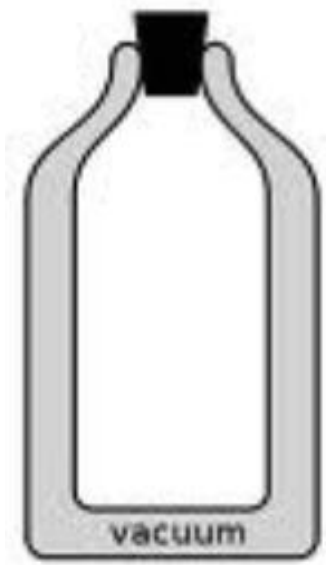
Image source www.igloothermal.com/4/6.gif



Types of insulation – continued

- The near-vacuum inside VIP's greatly reduces conduction and convection of heat.

This is similar to the way in which a vacuum flask works, but without the reflective metal coatings.



Types of insulation – continued

VIP is an insulation product that is five to ten times thinner than conventional insulation materials used in building (e.g. polystyrene, polyurethane, glass or mineral wool) for the same heat transfer coefficient (U-value).

Types of insulation – continued

- Vacuum insulated panels are typically used in refrigeration systems and in applications where space is limited.
- VIP's are not widely used as a building insulation, but this fact may change.
- VIP's must be made to size at the factory.
- They cannot be cut to size on site.
- They must be very carefully installed to avoid damage.
- VIP's cannot be drilled to allow services pass through.

Types of insulation – continued

- Reflective insulation systems are fabricated from aluminum foils with a variety of backings such as kraft paper, plastic film, polyethylene bubbles, or cardboard.
- Reflective systems are typically located between roof rafters, floor joists, or wall studs.
- If a single reflective surface is used alone and faces an open space, such as an attic, it is called a radiant barrier.

Thermal conductivities (λ) insulation materials.

Technical Guidance Document L – Conservation of Fuel and Energy – Dwellings, Appendix A (Ireland)

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

Material	Density (kg/m^3)	Thermal conductivity (W/m.K)
Mineral fibre / wool quilt	12	0.044
Mineral fibre / wool quilt	25	0.039
Expanded polystyrene slab (SD)	15	0.038
Expanded polystyrene slab (HD)	25	0.035
Extruded polystyrene	30	0.029
Phenolic foam	30	0.025
Ployurethane board (unfaced)	30	0.021

References:

- Building Regulations (Part L Amendment) Regulations 2008. Technical Guidance Document L – Conservation of Fuel and Energy – Dwellings. (Ireland)

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