

Module 2.3

Fabric and ventilation heat loss from buildings

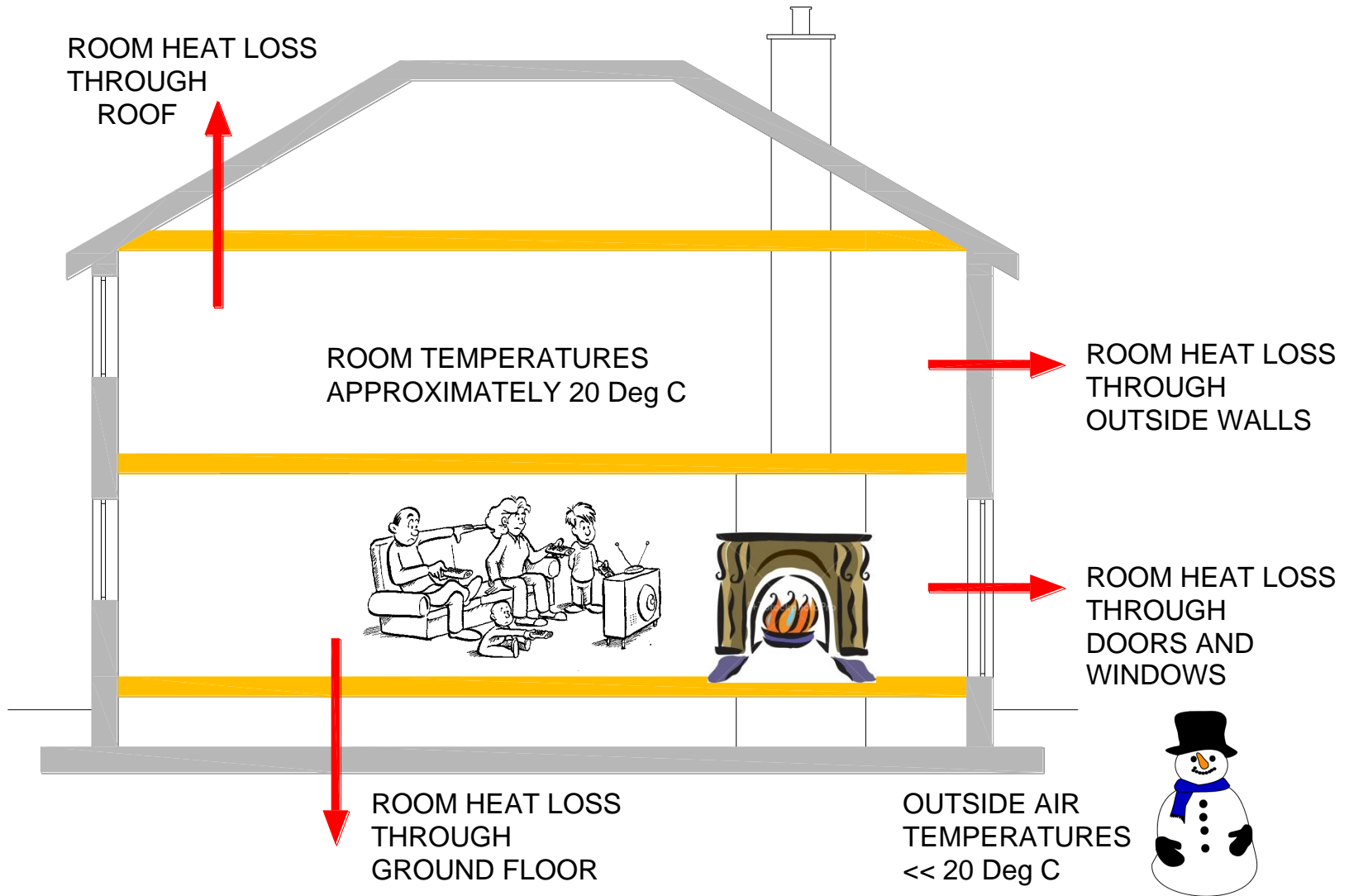
Learning Outcomes

- On successful completion of this module learners will be able to
 - Describe how heat is lost from of a building.
 - Describe the basic heat loss equation.

Heat loss through the fabric of a building.

- Heat flows from hot areas to cold areas. (Second law of thermodynamics)
- Most people like to live and work in room temperatures of approximately 20 °C.
- In many European countries, outside air temperatures in winter are well below 20 °C.
- Heat from warm areas flows out through the fabric of the buildings (floors, walls, roofs, windows and doors) to the colder areas.

- continued.



- continued.

- Simplified heat loss through any given surface is calculated using

$$\text{Heat loss} = U \times A \times dT$$

where U = U-value ($\text{W}/\text{m}^2\text{K}$) Thermal transmittance

A = Area of surface (m^2)

dT = Temperature difference
inside to outside (K)

Units of heat loss = Watts.

$$\text{Units of heat loss} = \frac{\text{W} \times \cancel{\text{m}^2} \times \cancel{\text{K}}}{\cancel{\text{m}^2} \times \cancel{\text{K}}}$$

- continued.

- The overall heat loss through the fabric of any building is calculated using

$$\text{Heat Loss} = \sum (U \times A \times dT)$$

where \sum = (sigma) sum of

i.e. sum of

- heat loss through all floors
- plus heat loss through all walls
- plus heat loss through all roofs
- plus heat loss through all windows
- plus heat loss through all doors.

- continued.

- Note:

The formula Heat Loss = $\sum (U \times A \times dT)$

- Does include for thermal bridging in the main fabric elements of floors, walls and roofs. This is included when calculating the U-value for each element.
- Does not include for thermal bridging around windows, doors etc. European countries have different methods of dealing with this heat loss.

- continued.

- Simple fabric heat loss = $U \times A \times dT$
- 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.

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

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

- continued.

- To maintain comfort, the heat lost in winter must be replaced by a 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.

- continued.
- 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.
- Obviously it is not physically or economically possible to achieve a near zero U-value for all parts of a building fabric.
- The table on the next page shows some recommended European U-values from 2007.

- continued.

Recommended U-values for building elements in some European countries at April 2007. (Windows 2005)

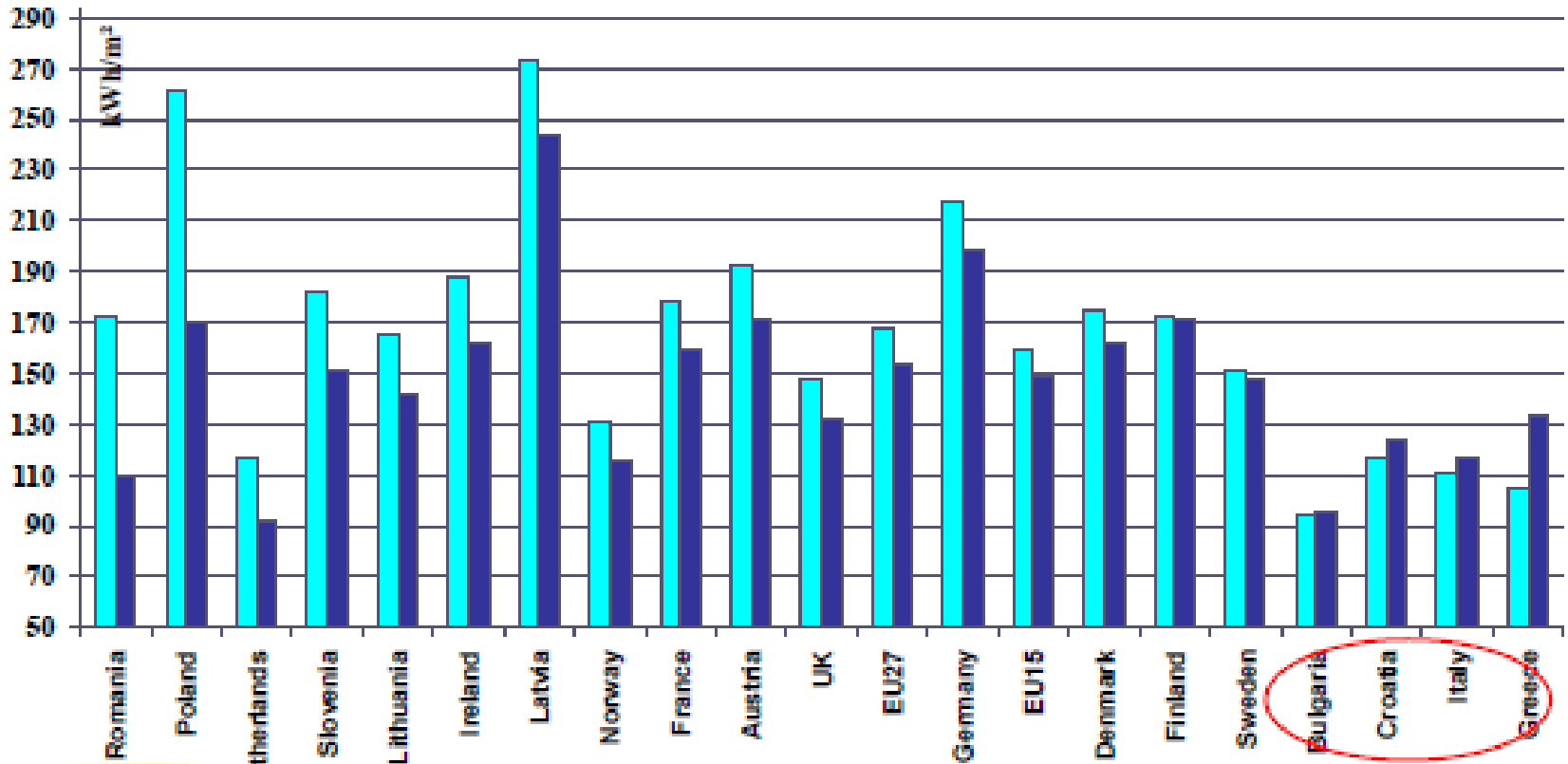
Units = $W / m^2 K$ Source: www.eurima.org/u-values-in-europe/

	Wall	Roof	Floor	Window
Denmark	0.20	0.15	0.12	1.8
France	0.36	0.20	0.27	2.2
Germany	0.30	0.20	0.40	- - -
Ireland	0.27	0.16	0.25	2.2
Poland	0.30	0.30	0.60	2.6
Spain	0.82	0.45	0.82	- - -
United Kingdom	0.25	0.13	0.20	2.2

- continued.

Annual Heating consumption in dwellings (kWh/m²/a)

1997 V's 2006 Image source: www.odyssee-indicators.org



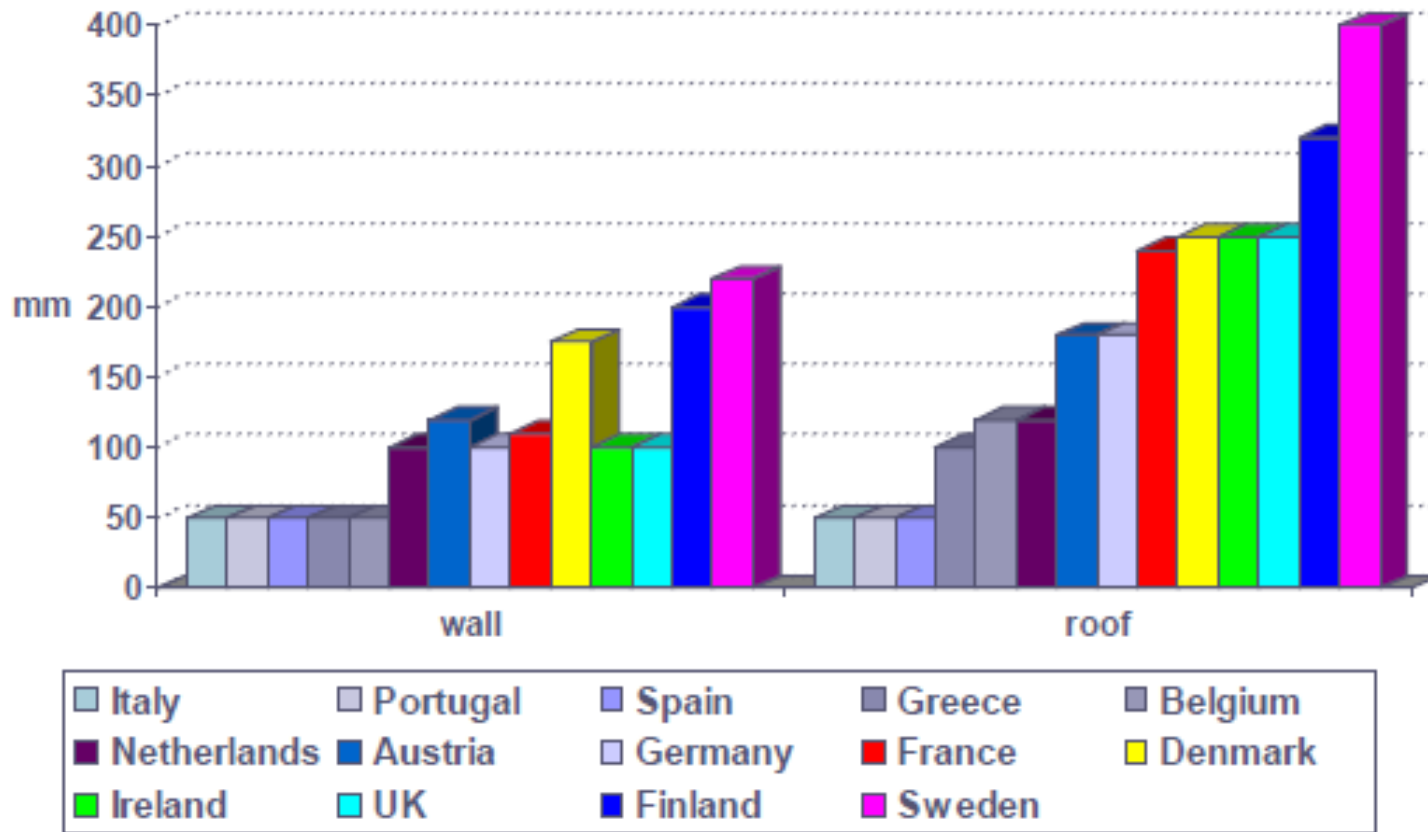
■ 1997 ■ 2006



- continued.

Use of insulation materials for new dwellings. (Date not given)

Image source: www.odyssee-indicators.org



Source : Eurima

- Future trends in heat loss from dwellings
 - Future dwellings will possibly be insulated to “passive house” standards.
 - Average U-value $< 0.15 \text{ W / m}^2 \text{ K}$.
 - Annual heating demand $< 15 \text{ kWh/m}^2/\text{a}$.
 - Annual cooling demand $< 15 \text{ kWh/m}^2/\text{a}$.
 - Total primary energy demand $< 120 \text{ kWh/m}^2/\text{a}$.
i.e. source energy for heating, hot water, electricity.
 - Air leakage ≤ 0.6 times the house volume per hour when tested at 50Pa pressure.

- Impact of passive house standards
 - In some European countries, dwellings built to passive house standards could use 75 – 85% less energy for space heating, compared to current building regulations.
 - Carbon emissions related to space heating could be reduced by up to 94%.
 - Insulation thickness on floors, walls, roofs of
 - > 150mm of rigid / foam insulation, or,
 - > 300mm of fibreglass / mineral wool insulation.

Heat loss due to ventilation of buildings.

- Definition – ventilation.

Ventilating is the deliberate process of replacing air in any space to provide high indoor air quality.

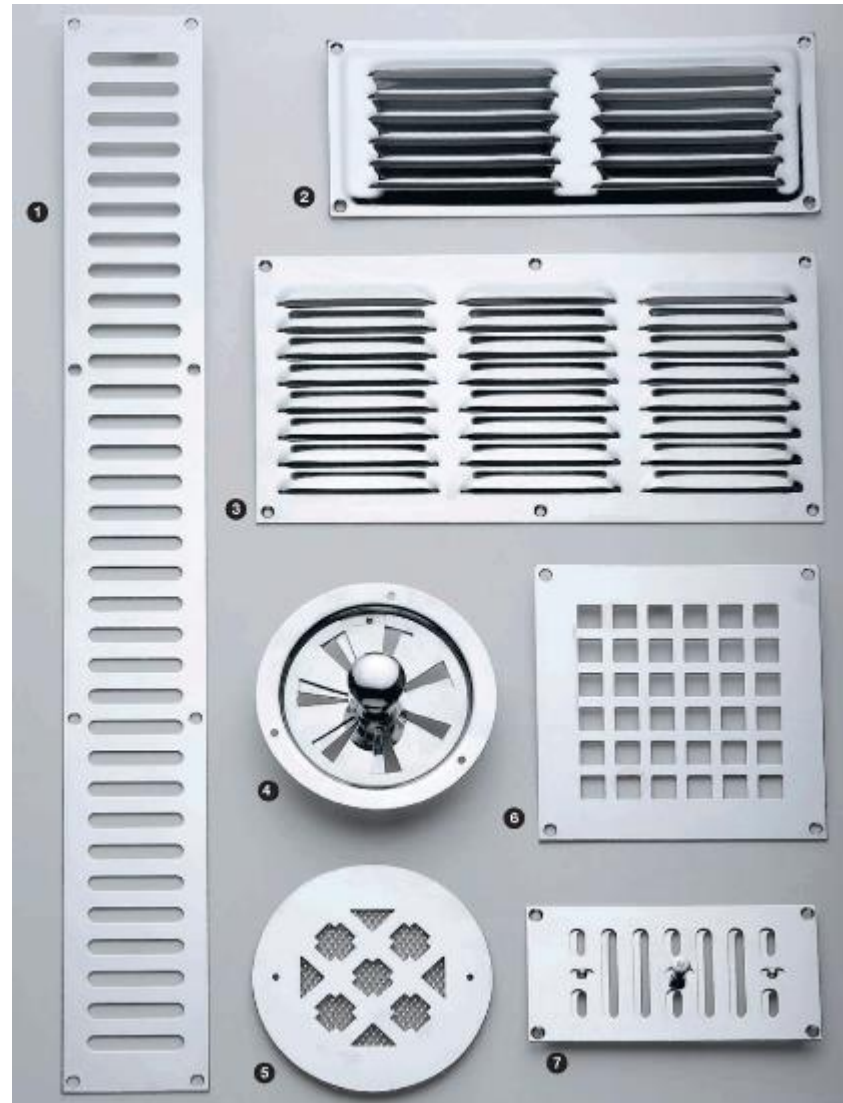
- Definition – infiltration.

Infiltration is the uncontrolled entry of fresh air into a dwelling through air leakage paths in the building.

Infiltration can contribute to ventilation but cannot be considered as reliable when it is not controlled.

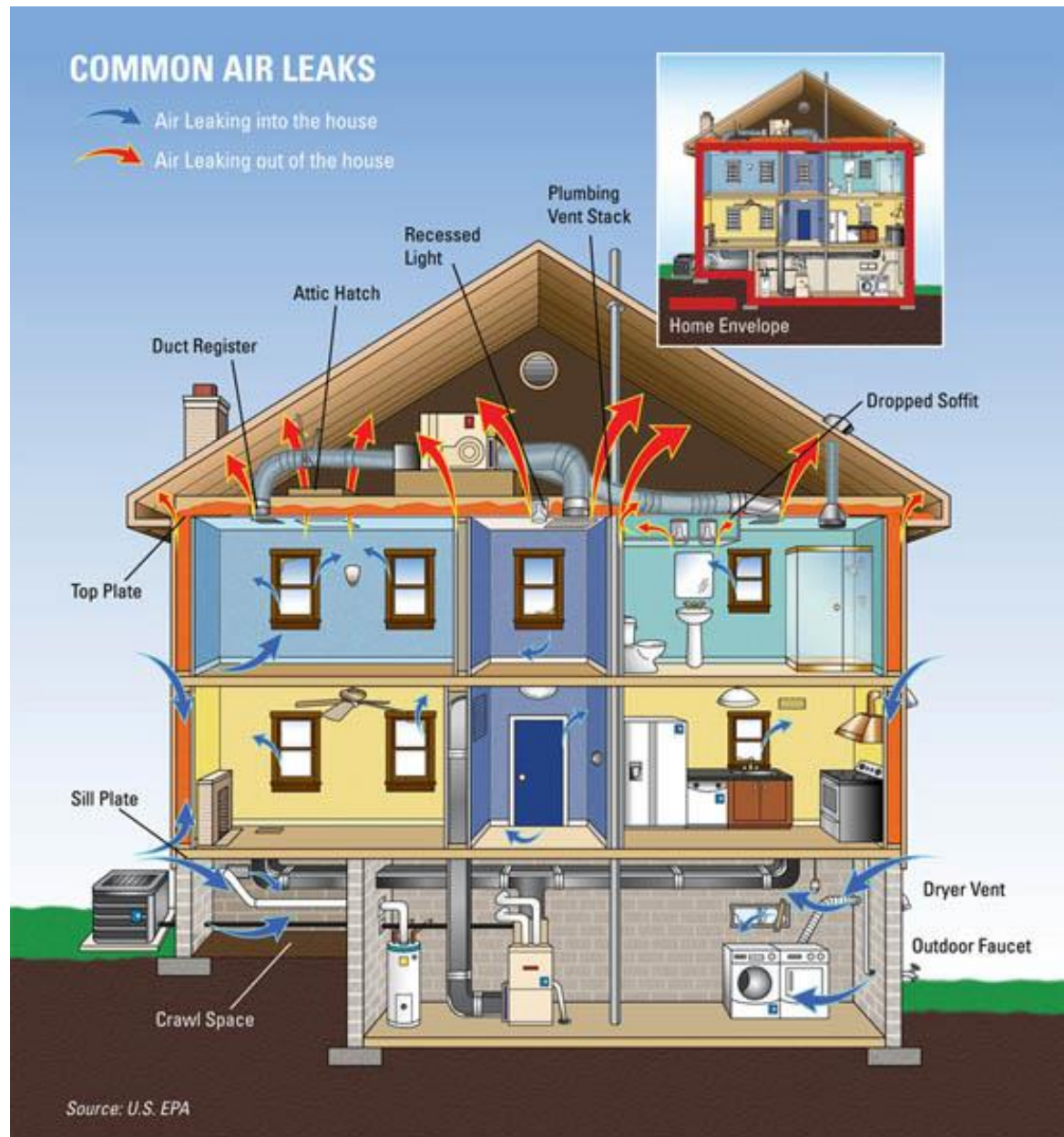
Ventilation – deliberate process.

Image source: www.aandhbrass.co.uk



Infiltration – air leakage

Image source: U.S EPA



Impact of ventilation and infiltration.

- Ventilation and infiltration both bring outside air into the building, forcing out the air that was inside the building.
- In winter time, the cold outside air replaces the warm inside air.
- To keep the temperature inside at about 20 Deg C, the heating system must raise the temperature of the outside air to 20 Deg C.
- This heating of ventilation and infiltration air will add to the heating costs of the building.

Heat loss due to ventilation and infiltration.

- Heat loss due to air change inside a building is calculated using

$$\text{Heat loss} = \rho \times V \times C \times dT$$

where ρ = Density of air (kg/m^3)

V = Ventilation/Infiltration rate (m^3/s)

C = Specific heat capacity ($\text{kJ}/\text{kg K}$)

dT = Temperature difference
inside to outside (K)

Units of heat loss = Watts.

- continued.

- Heat loss due to air change inside a building can be simplified to

$$\text{Heat loss} = 0.33 \times N \times v \times dT$$

where N = Number of air change/hour

v = Volume of room (m^3)

dT = Temperature difference
inside to outside (K)

See assumptions made on the next page.

- continued.

- Assumptions made when using

$$\text{Heat loss} = 0.33 \times N \times v \times dT$$

a) ρ = density of air - 1.2kg/m³ at 20 Deg C

b) C = specific heat capacity – 1000 J/kg K

Source: Building Services & Equipment- Volume 1 - 3rd edition
 – Chapter 4. Author – F Hall. ISBN 0-582-23652-5

- continued.

- Heat loss = $0.33 \times N \times v \times dT$
- When designing buildings

The volume of the building (v) is set by the owners needs.

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

Only the number of air changes per hour (N) can be changed by the designer of the building.

- To minimise heat loss – must minimise N .

- continued.
- To reduce heat loss from buildings it appears that designers, builders and owners should strive for the lowest air change rate possible, i.e. low air change = low heat loss.
- However it is necessary to have a minimum amount of air change to provide high indoor air quality.
- Reasons for ventilation are shown on the next page.

- continued.

Reasons for ventilation / air change.

- Rapidly dilute pollutants which do not pose a health risk
- Remove harmful pollutants
- Remove water vapour in areas where it is produced in excess quantities
- Disperse residual water vapour
- Provide an adequate supply of fresh air for respiration

- continued.
- Minimum requirements for ventilation of buildings differ across European countries.
- Ventilation in excess of these minimum requirements will increase heat loss from a building.
- During design, construction and occupation, maximum effort should be made to reduce the air change to at or near minimum requirements.
- Also maximum effort should be made to recover heat energy from any warm air being pushed out of the building.

- continued.
- As previously stated, air change in a building is due to a combination of ventilation and infiltration.
- Ventilating is the deliberate process of replacing air in any space to provide high indoor air quality. This can be minimised to save air heating costs but should not / can not be eliminated.
- Infiltration is the uncontrolled entry of fresh air into a dwelling through air leakage paths in the building. This should be eliminated if possible.

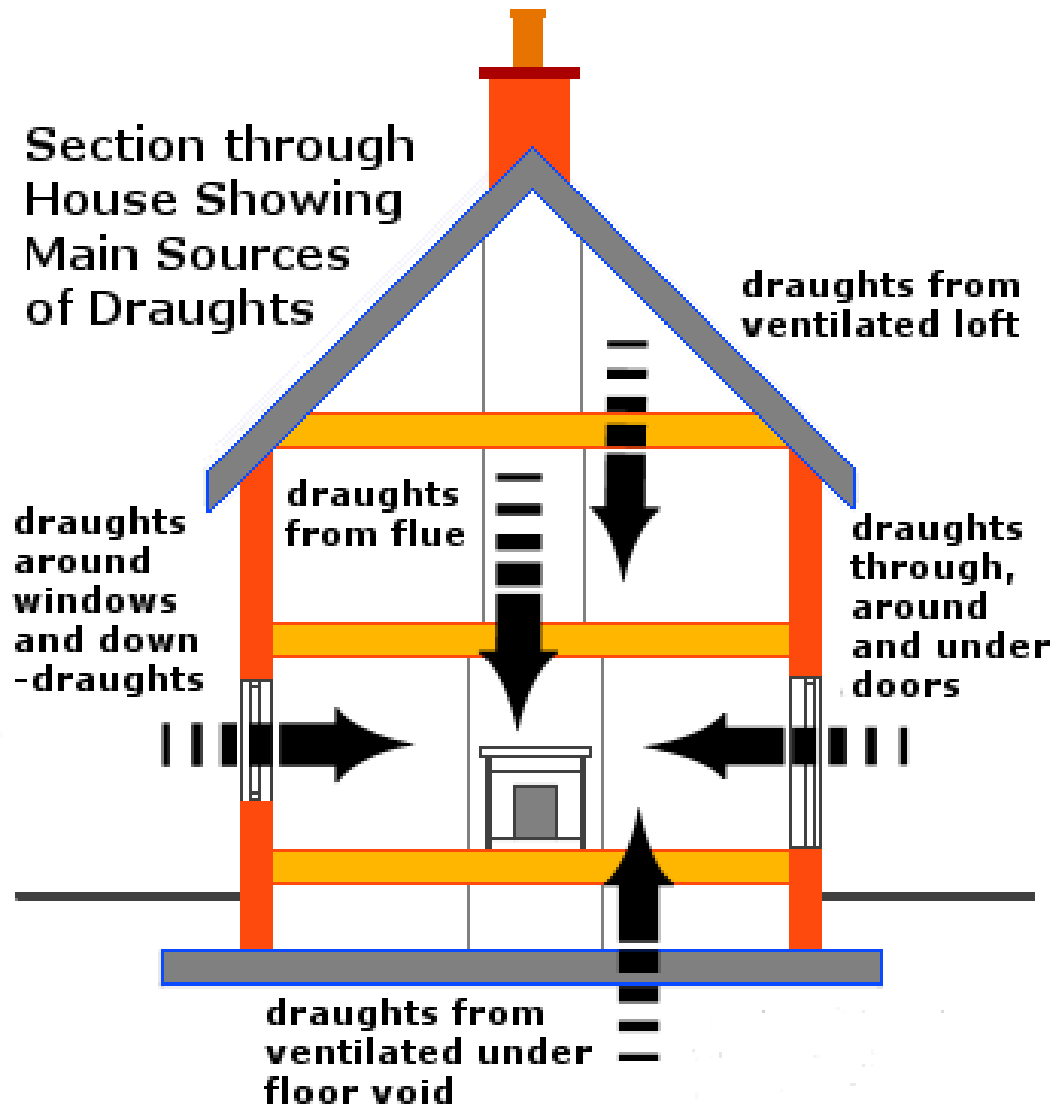
- continued.
- Conclusion: To reduce heat loss due to air change in buildings, designers, builders and owners should strive for the lowest possible infiltration rate,
i.e. lowest possible infiltration rate = lowest possible heat loss due to air change.
- This assumes that alternative controlled ventilation systems are put in place to comply with minimum ventilation rates set by government regulations.

How to achieve lowest possible infiltration rates.

To minimise air infiltration, all uncontrolled air flow paths should be closed off.

Image source:

www.lowenergyhouse.com/draught-proofing.html



- continued.

To minimise air infiltration, an airtight envelope (red) must be formed around the building.

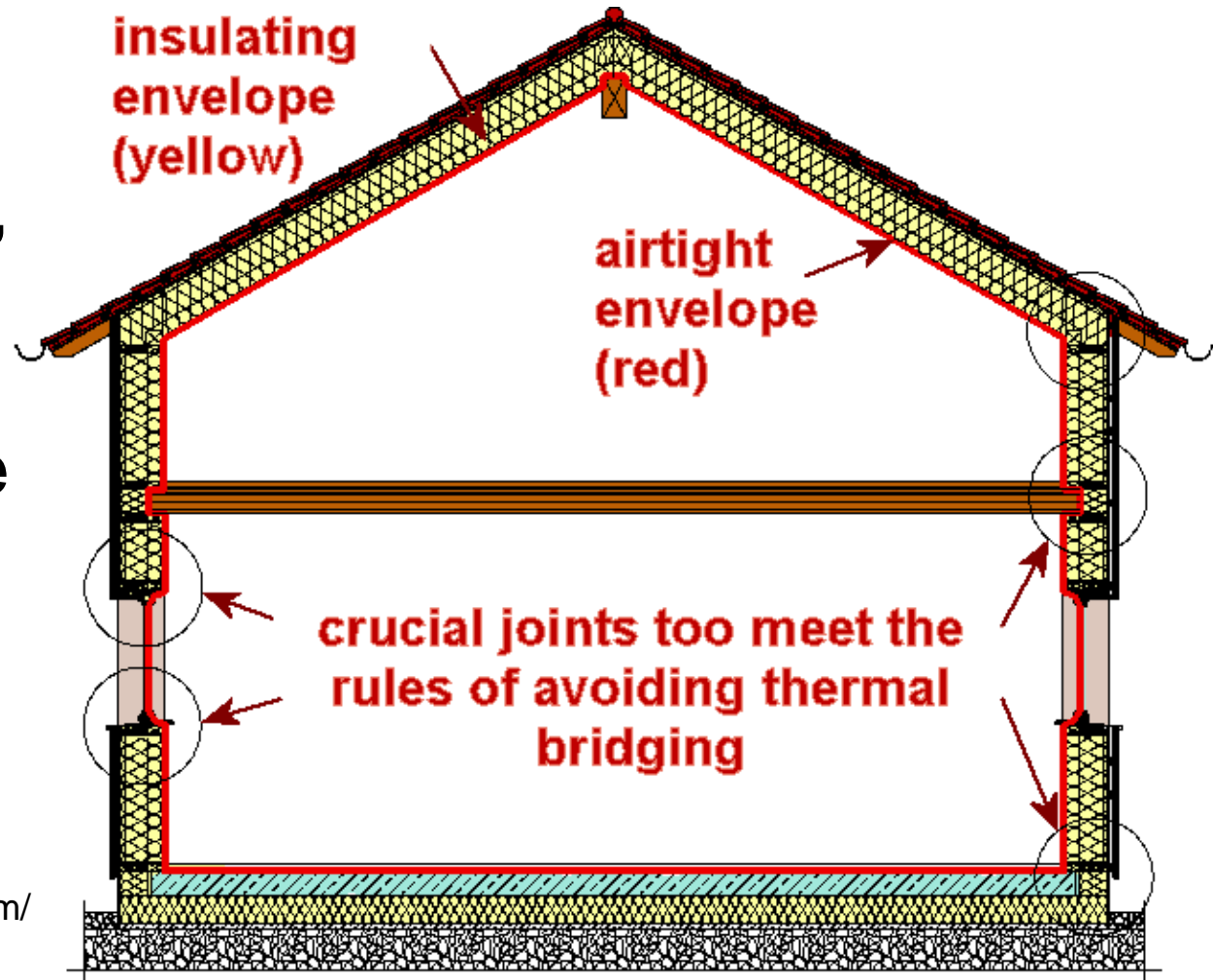


Image source;
www.springtimehomes.com/green_building_science

Acceptable infiltration rates.

- Standards for maximum infiltration rates are not specified by all European countries.
- Current Passive House standard suggests air leakage rates of ≤ 0.6 times the house volume per hour when tested at 50Pa pressure.
- Some European countries have developed “Accredited construction details” to show designers and builders examples of good practice to achieve air tightness and to minimize thermal bridging of insulation layers.

Source of acceptable construction details.

- Source Denmark - Not found.
- Source France - Not found.
- Source Spain - Not found.
- Source Germany.

Passivhaus Institut - '*Protokollband #16*'

- Source Ireland.

<http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards>

- continued.

- Source United Kingdom.

<http://www.planningportal.gov.uk/england/professionals/buildingregs/technicalguidance/bcconsfp partl/bcassociateddocuments9/bcptlaccdet/>

- Source Scotland.

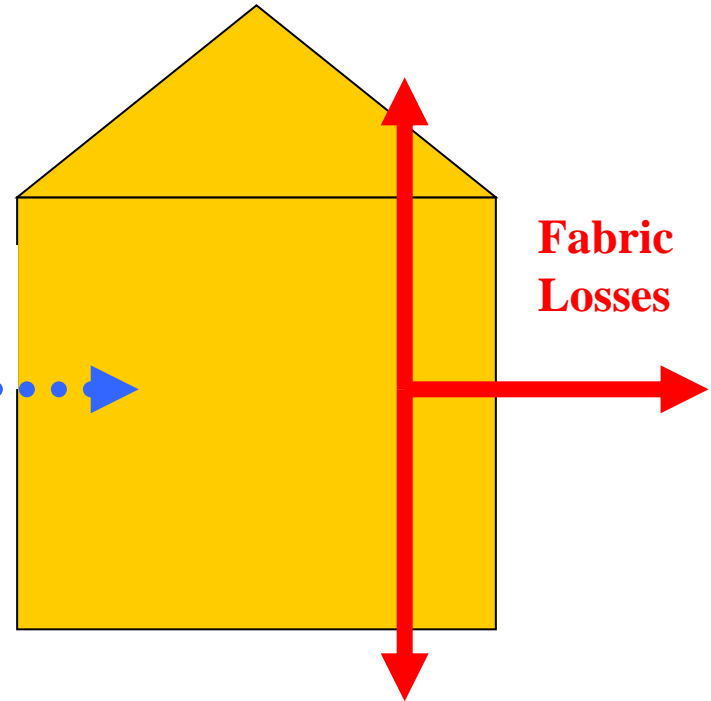
<http://www.scotland.gov.uk/Resource/Doc/217736/0088295.pdf>

• Basic Heat Loss Equation

$$Q = \sum UA\Delta T + 0.33Nv\Delta T$$

↑
↑
Fabric Loss **Infiltration Loss**

Infiltration Losses



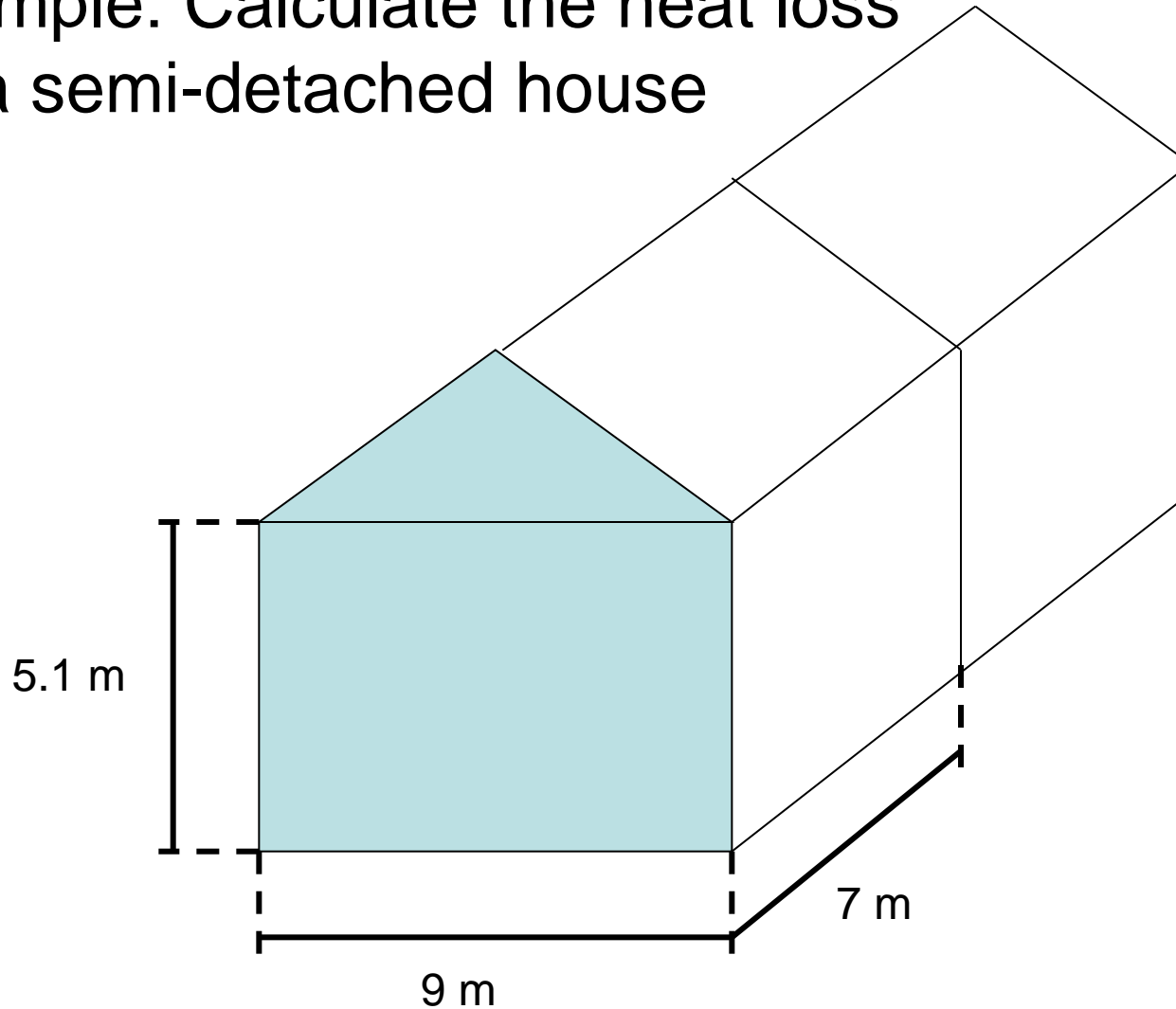
- Q Total heat transfer rate (W)
- U Thermal transmittance (W/m²K)
- A Surface area through which heat transfer occurs (m²)
- ΔT Difference between inside and outside air temperatures (°C or K)
- N Infiltration rate (ac/h)
- v Volume enclosed by the building (m³)

- Other ways to represent the heat loss equation

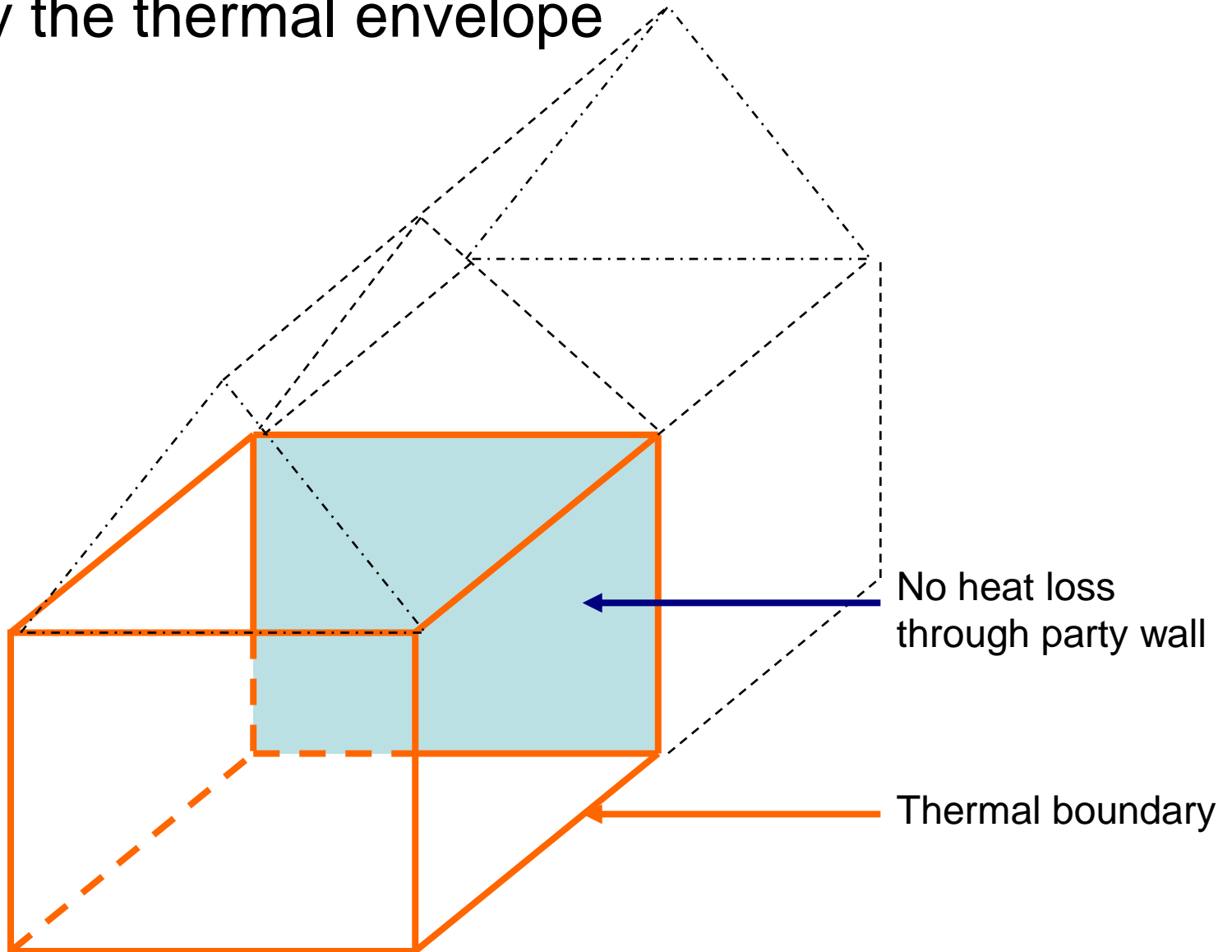
$$Q = \left[\sum AU + C_v \right] \Delta T \quad C_v \text{ Ventilation Conductance}$$

$$Q = [hlc] \Delta T \quad hlc \text{ heat loss coefficient}$$

Example: Calculate the heat loss for a semi-detached house



Identify the thermal envelope



Specification

Surface	Description	U value (W/m ² K)
Wall	Cavity wall 100mm insulation 0.03 W/mK	0.25
Roof	270 mm insulation 0.04 W/mK between and over ceiling joists	0.15
Floor	Slab on ground floor with 100 mm insulation 0.03 W/mK	0.20
Windows	25% of total floor area, double glazed, soft coat, 16mm gap, argon filled, pvc	1.70
Door	Solid wooden door, 1.85 m ²	3.00
Infiltration rate 0.4 air change per hour		

Calculate $\Sigma(AU)$			
Surface	A (m ²)	U (W/m ² K)	A x U (W/K)
External walls	83.95	0.25	20.99
Roof	63	0.15	9.45
Floor	63	0.20	12.60
Windows	31.5	1.70	53.55
Door	1.85	3.00	5.55
$\Sigma(AU)$			102.14

Calculate Ventilation Conductance

N (ac/h)	V (m ³)	(1/3)NV (W/K)
0.4	5.1 x 9 x 7	42.84

Total Heat Loss

Assume T_{Internal} is 21°C

Assume T_{External} is 5°C

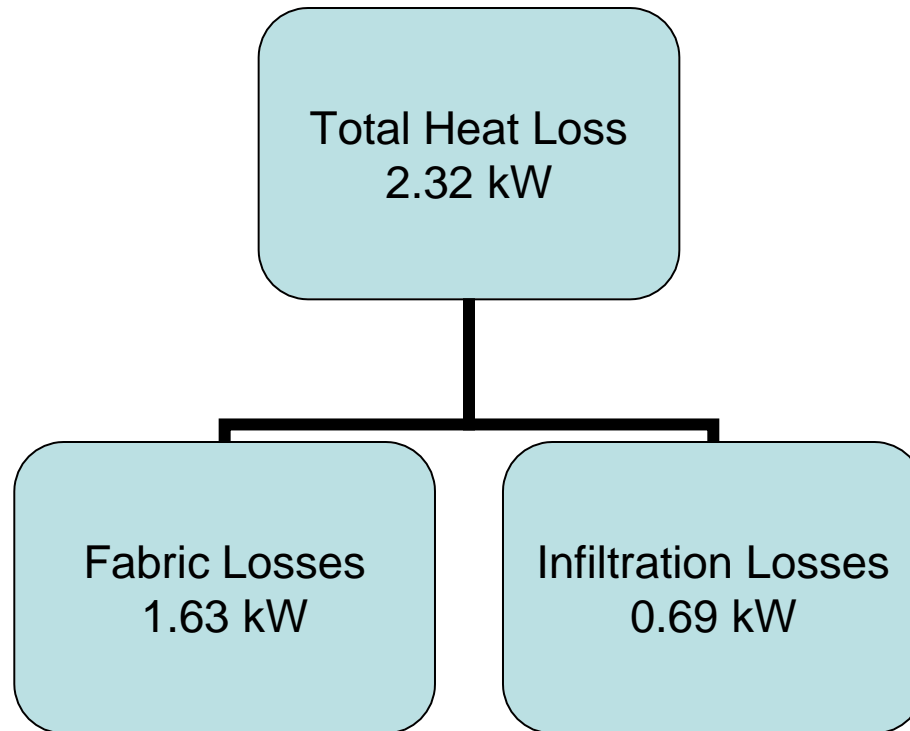
$$Q = \left[\sum AU + \frac{1}{3}NV \right] \Delta T$$

$$Q = (102.14 + 42.84) (21 - 5) \text{ W}$$

$$Q = 1634 + 685 \text{ W}$$

$$Q = 2319 \text{ W}$$

$$Q = 2.32 \text{ kW}$$



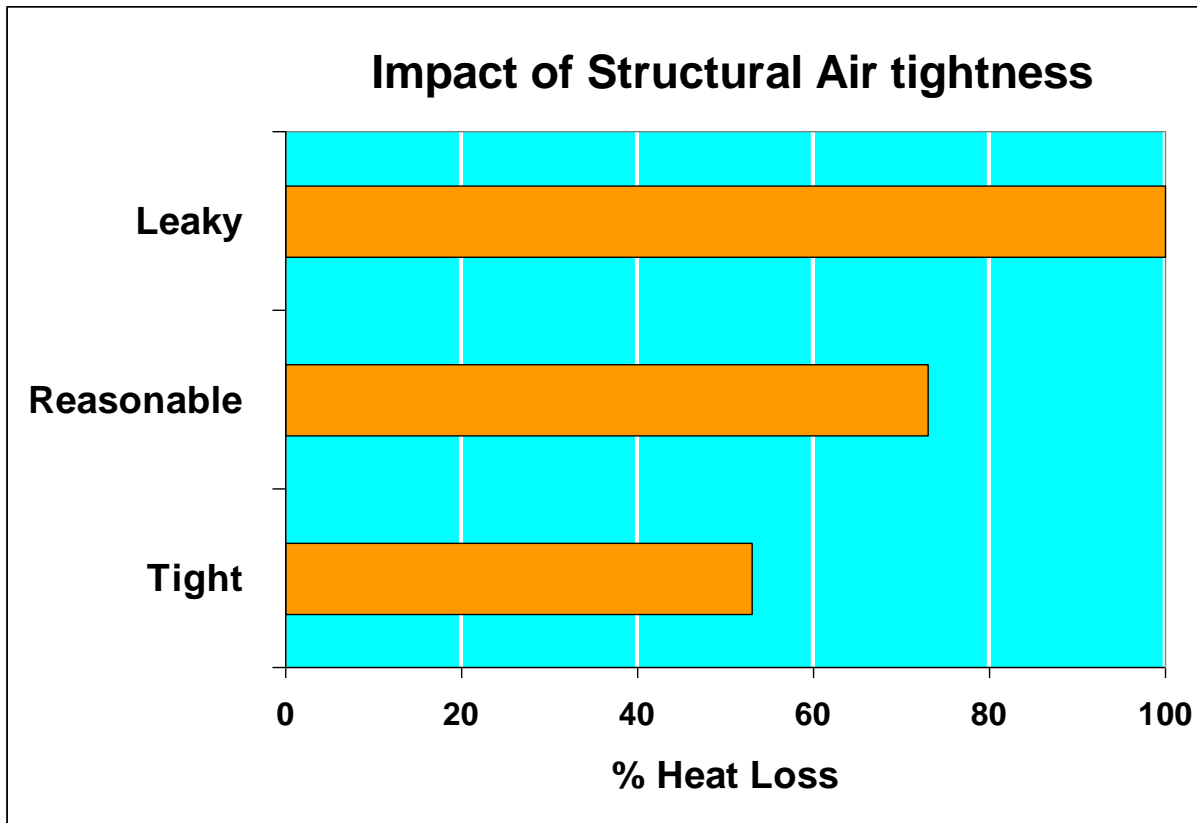
In this example infiltration accounts for 30% of the heat loss

- Consider the impact of structural air tightness on total heat loss.
- Undertake the heat loss calculation for the example house using the same U-values but different air change rates per hour

N (ac/h)	Comment
0.9	Leaky (remember UK study from Ventilation Module)
0.4	Reasonable
0.03	Tight (heading towards Passive House standard)

Impact of Structural Air Tightness

Case	Q_{Total} (kW)	Percentage Heat Loss (%)
Leaky	3.18	100
Reasonable	2.32	73
Tight	1.67	53



Improving structural air tightness from 0.9 ac/h to 0.03 ac/h reduces the heat loss by 47%, all other factors remaining constant.

Do not under-estimate the effect of infiltration

Module summary.

- In most European buildings, winter room temperatures inside are much higher than outside air temperatures.

- Task.

What are the main parts of the building fabric which transfer heat from inside to outside.

Module summary - continued.

- Heat loss through any surface of the building can be calculated using a simple formula.
- Task.

Write down this formula.

What does each letter in the formula represent?

What units are associated with each letter?

What are the units of heat loss?

Module summary - continued.

- Heat loss through any surface of the building can be calculated using a simple formula.
- Task.

Write down this formula.

What does each letter in the formula represent?

What units are associated with each letter?

What are the units of heat loss?

Module summary - continued.

- You have just identified the formula to calculate the heat loss through the fabric of a building.
- Task.

Which of the elements of this formula are typically decided by climate?

Which of the elements of this formula are typically decided by the owners needs?

Which of the elements of this formula are typically decided by the designer?

Module summary - continued.

- Designers, builders and owners want to minimise heat loss and energy cost in their buildings. To do this they must reduce heat loss through the external fabric of the buildings. A U-value is used to describes the thermal transmittance of each of the elements that make up the fabric of the building (floors, walls, roofs, windows and doors).

- Task.

Which of the following is correct?

Low U-value = low heat loss.

High U-value = low heat loss.

Module summary - continued.

- A table earlier in the module identifies recommended U-values for building elements in some European countries at April 2007
- Task.

For the same temperature difference between inside and outside - identify the country which should have the smallest overall heat loss from its buildings.

Identify the country that should have the largest.

Module summary - continued.

- Annual Heating consumption in dwellings can be listed as kWh / m² / year. This allows easy comparison of different size of houses.
- Task.

In 2006 which of the European countries listed on the table had the lowest annual heating consumption (kWh / m² / year)?

How did this value compare with the highest annual heating consumption?

How do these compare with passive house?

Module summary - continued.

- Passive house insulation standards may be adopted by buildings in the future.
- Task.

How will the energy demand change if buildings adopt passive house insulation standards?

How will carbon dioxide emissions change?

How will typical insulation thickness change?

Module summary - continued.

- Ventilation and infiltration both bring outside fresh air into buildings.

- Task.

Explain the difference between ventilation and infiltration.

Which of these two is necessary to maintain high indoor air quality.

Which of these two should be minimised or eliminated.

Module summary - continued.

- Heat loss due to air change in a building can be calculated using a simple formula.
- Task.

Write down this formula.

What does each letter in the formula represent?

What units are associated with each letter?

What are the units of heat loss?

Module summary - continued.

- Some European countries have drawn up documentation to help designers, builders and owners reduce air infiltration and reduce thermal bridging of insulation.

- Task.

What name is given to these documents?

Where can these documents be found?

References.

- www.eurima.org/u-values-in-europe/
- www.odyssee-indicators.org
- Building Services & Equipment - Volume 1 –
3rd edition – Chapter 4. Author – F Hall.
ISBN 0-582-23652-5
- www.passivhaus.de/
- www.environ.ie
- www.planningportal.gov.uk
- www.scotland.gov.uk