

# Module 3.8

## Window U-value

# Learning Outcomes

- On successful completion of this module learners will be able to
  - Describe the concept of U-values and alternative energy rating system for windows.

# Calculation of U-value of windows.

- 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 ( $\text{m}^2$ )

$dT$  = Temperature difference  
inside to outside ( K )

Units of heat loss = Watts.

- continued.
- 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,

- continued.

- Full details about calculating the U-value of windows or doors are given in

- EN ISO 10077-1 : 2006.

Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General

- EN ISO 10077- 2 : 2003.

Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames.

- continued.

- EN ISO 10077-1 : Part 1: General

The calculation of U-value is based on four component parts of the overall thermal transmittance:

- a) for elements containing glazing, i.e. windows, the thermal transmittance of the glazing, i.e. glass or plastic; single or multiple glazing; with or without low emissivity coatings, and with spaces filled with air or other gases.
- b) for elements containing opaque panels, i.e. doors, the thermal transmittance of the opaque panels

- continued.

- c) the thermal transmittance of the frame,  
 calculated using ISO 10077-2,  
 or taken from Annex D of ISO 10077-1.  
 wood, plastic, metallic with and without  
 thermal barrier, metallic with pinpoint, metallic  
 connections or any combination of materials.
- d) the linear thermal transmittance of the frame /  
 glazing  
 junction,  
 calculated according to ISO 10077-2  
 or taken from Annex E of ISO 10077-1.
- In addition, where appropriate, calculations in ISO 10077 allows for the additional thermal resistance introduced by different types of closed shutter, depending on their air permeability.

# Single or multiple glazing.

- Options are single, double or triple glazing.
  - Single glazing – virtually obsolete apart from historical buildings.
  - Double glazing – currently the most popular option in existing buildings.
  - Triple glazing – becoming more popular for new build buildings.
- 
- Advantages / disadvantages of triple glazing?
  - Better insulator, i.e. lower U-value when using the same glass coatings, gap and gas filling.
  - Heavier glass section limits the window openings.



# Low emissivity coatings.

- The best glass has an unnoticeable low emissivity metal oxide coating on one side, typically on the internal pane, next to the gap .
- This (Low-E) coating allows short wave radiation, from the high temperature sun, pass in through the glass, but restricts the amount of long wave radiation, from the lower temperature room, passing out through the glass.

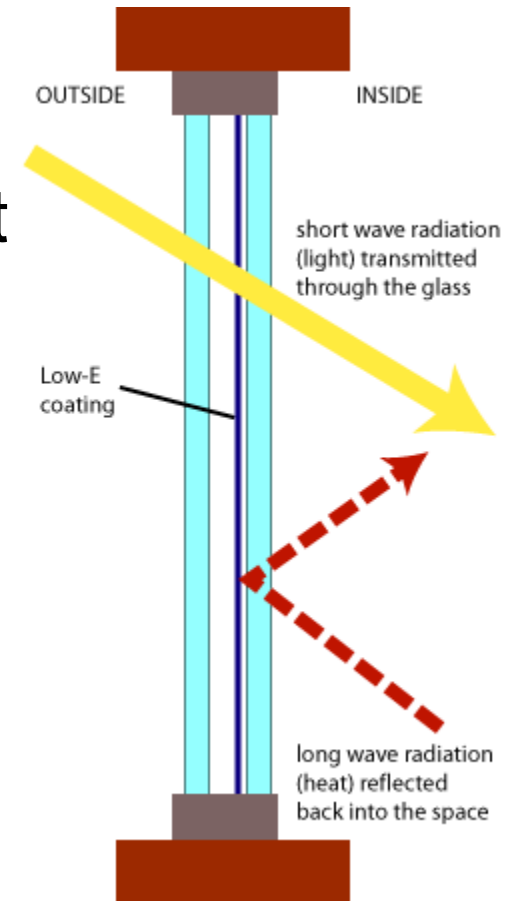


Image source:

[www.greenspec.co.uk/html/materials/glass.html](http://www.greenspec.co.uk/html/materials/glass.html)

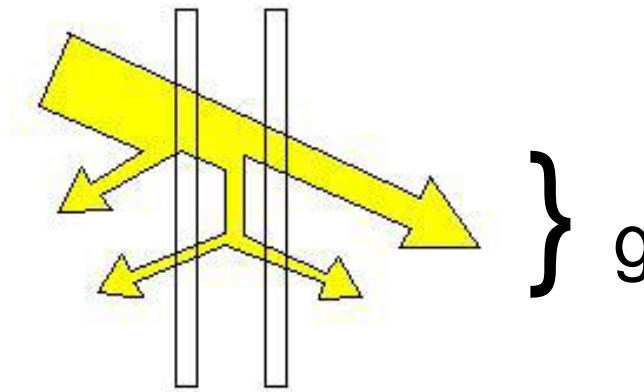
## Low emissivity coatings - continued.

- Restricting the amount of long wave radiation that can pass out through the glass helps these windows retain more of the solar gain collected during the daytime.
- The low-E coating does also restrict the solar gain entering the building, but the restriction is small when compared with the reduced heat loss due to the trapped long wave radiation.
- Low-E coatings are classified as “hard” or “soft”. Soft coatings tend to be slightly more expensive but are best at lowering U-value.

# Low emissivity coatings - continued.

- Solar factor  $g$  = proportion of solar radiation transmitted + absorbed and emitted inwards

Solar radiation



- Higher  $g$  value for low iron glass but expensive

# Gas fill in the cavity between glass panes.

- Air was the first gas used in the sealed cavity between the panes of glass.
- Argon is now the most widely used gas.
- Argon does not conduct heat as quickly as air, and so using argon reduces the U-value by approximately 10%.
- Some window manufacturers use xenon or krypton gas between the panes of glass.

# Impact on glazing U-value – indication only.

Use manufacturers certified data for accurate calculations.

Glazing type	U-value W/m <sup>2</sup> K	Solar factor g in %
<b>Double glazing</b>		
12mm air gap no coating on glass	3.0	78
12mm air gap + low e hard coating	1.9	72
12mm air gap + low e soft coating	1.7	58
16mm argon gap + low e hard coating	1.5	72
16mm argon gap + low e soft coating	1.1	58
16mm argon gap + low iron glass + soft coating	1.1	75
<b>Triple glazing</b>		
12mm argon gap + low e hard coating 2 panes	0.9	42
12mm krypton gap + low e soft coating 2 panes	0.6	42
As above (krypton gap) + low iron glass	0.6	62

# Window frames.

- Often the choice of window frame will depend on the owners personal taste.
- uPVC frames are most common since they come in a number of colours, need very little maintenance and have a long life.
- The material can be moulded into strong hollow sections that provide insulating air cavities and reduce thermal bridging.

# Window frames - continued.

- uPVC.
- Hollow section frame with metal reinforcing.
- Insulating air cavities.
- Low thermal bridging.

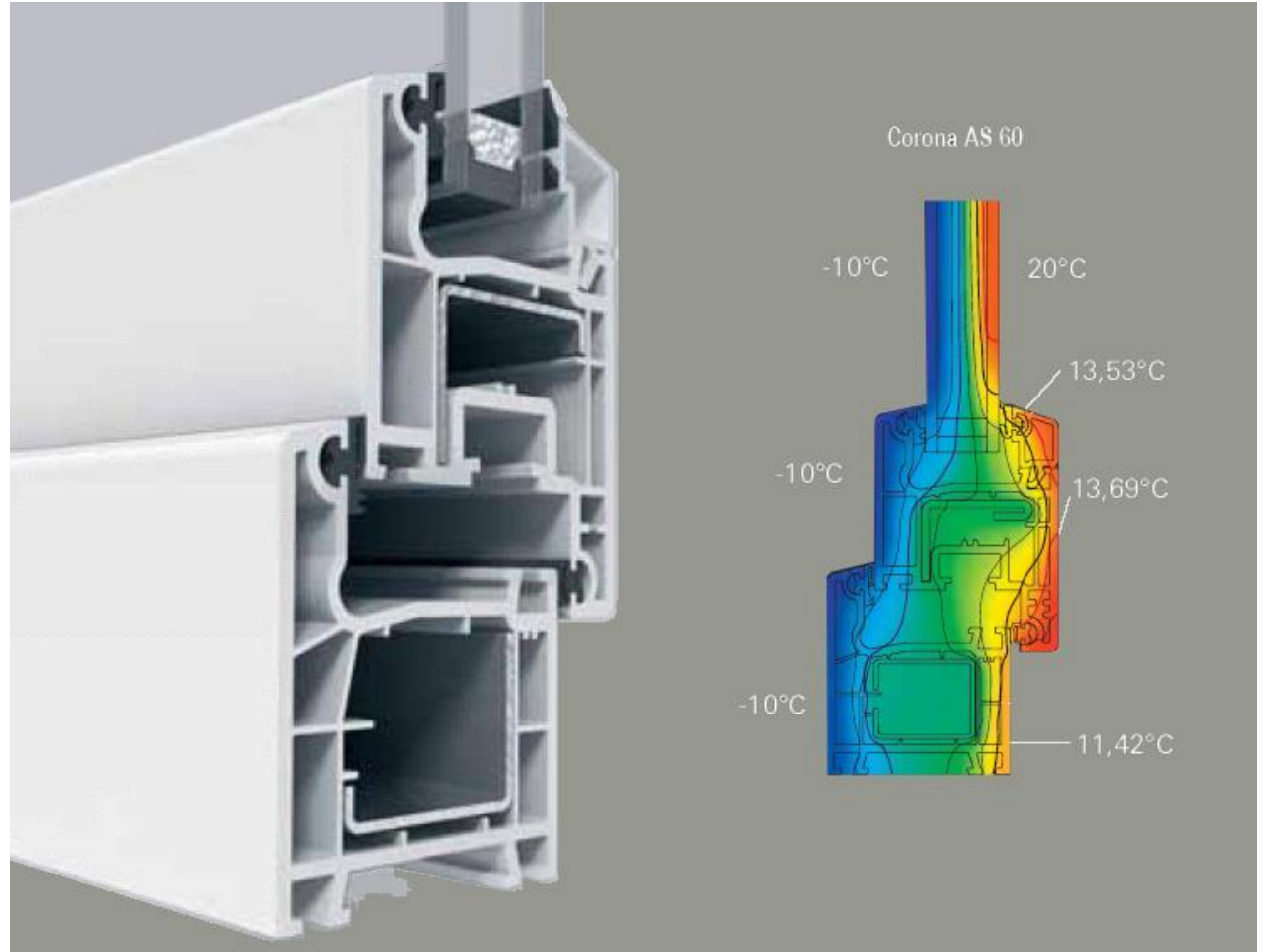


Image source: [www.polishsolutions.eu/images/PVC-window-frame](http://www.polishsolutions.eu/images/PVC-window-frame)

# Window frames - continued.

- Wooden frames have a lower environmental impact but require annual maintenance.





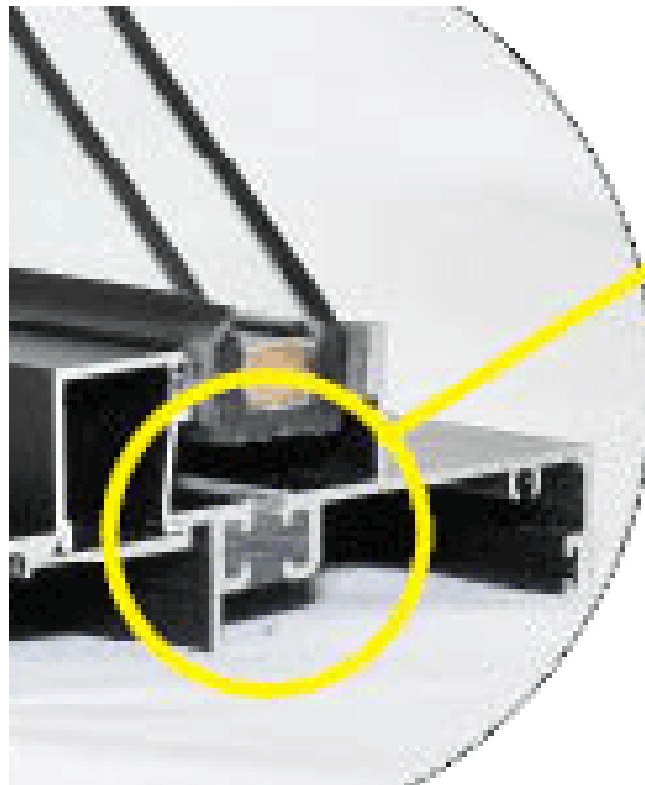
# Window frames - continued.

- Composite frames have an inner timber frame covered by an external uPVC or metal layer.



# Window frames - continued.

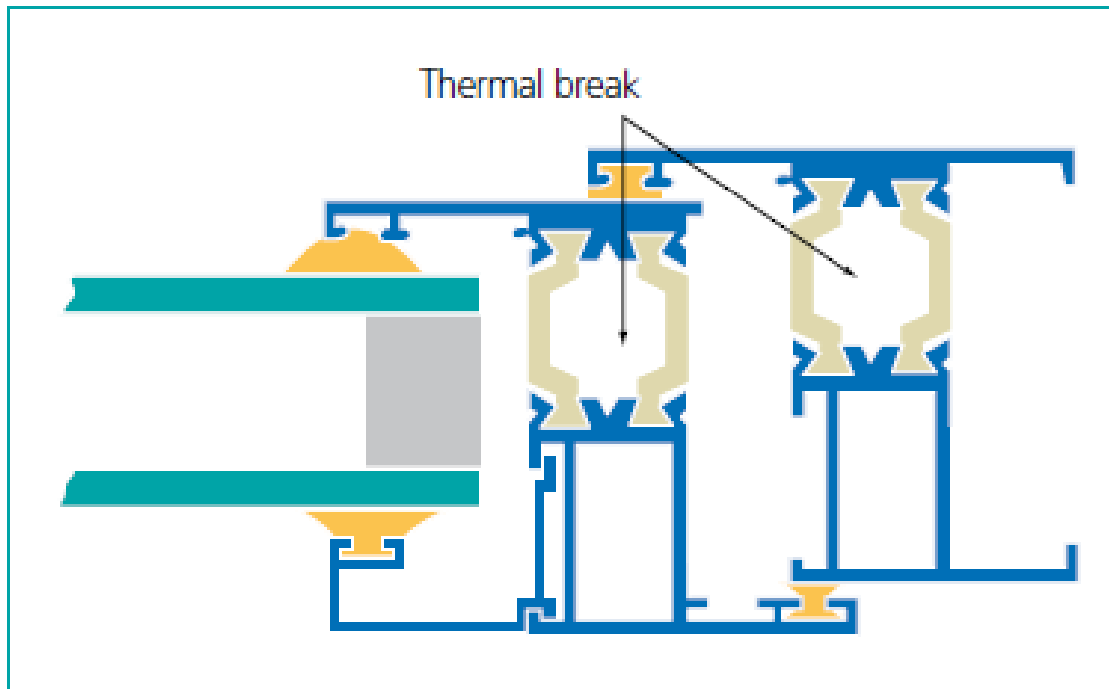
- Aluminium or steel frames are slim and long lasting and can be recycled. Metals have a high thermal conductivity and window frames must be made with a thermal break to avoid high heat loss.



**Thermal  
Break**

# Window frames - continued.

- Aluminium or steel frames are slim and long lasting and can be recycled. Metals have a high thermal conductivity and window frames must be made with a thermal break to avoid high heat loss.



# Window frames - continued.

- The stated U-value (thermal transmittance) of window frames varies greatly.
- Sample values are as follows.
  - uPVC 2 hollow chamber 2.2 W/m<sup>2</sup>K
  - uPVC 3 hollow chamber 2.0 W/m<sup>2</sup>K
  - Wood (50mm hardwood) 2.4 W/m<sup>2</sup>K
  - Wood (50mm softwood) 2.0 W/m<sup>2</sup>K
  - Composite frames See manufacturers
  - Metal + thermal break See manufacturers

# Ratio of window frame to glazing area.

- Typical default ratio of window frame to glazing area are as follows –
 

uPVC	30% frame 70% glass.
Wood	30% frame 70% glass.
Metal	20% frame 80% glass.
- The frame area will increase for windows with multiple openings  
multiple small panes of glass.
- Since the U-value of glass is less than that of the frame, windows with larger frame area will typically have higher overall U-value and higher heat loss.

# Balancing heat losses and heat gains through windows.

- When choosing glazing for a building the designer should take into account the heat balance of the glazing.
- This will vary according to
  - the climate,
  - the solar exposure of the façade,
  - the characteristics of the building (particularly thermal mass),
  - and its use (and particularly the indoor temperature level).
- See the appendix of this module for an example.

# Alternative energy rating system for windows.

- Energy efficient windows are available in a variety of frame materials and styles.
- They also vary in their energy efficiency, depending on
  - how much sunlight travels in through the glass
  - how well they stop heat from passing back out through the window,
  - and how little air can leak in or out around the window.

- continued.
- The European Commission has proposed to expand the labeling directive to include energy saving products like windows This is similar to the label you may have seen on appliances such as your fridge, or washing machine.
- A-rated windows are the most efficient.





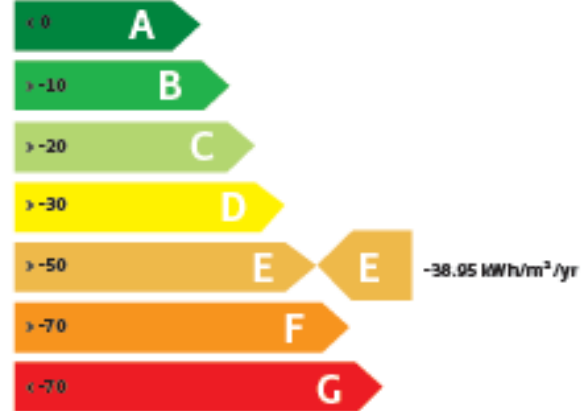
- continued.
- The rating system is based on the net energy gain for windows used in reference houses in three zones in EU.
- The energy rating system includes vertical façade windows and sloped roof windows.
- The energy performance of sloped windows is much higher than for vertical windows, since the passive solar radiation for sloped windows is much higher than for vertical windows.

- continued.
- The rating system fixes numerous parameters in its calculations such as orientation, number of days in a heating season, effects of solar radiation, over shading, and others, in order to allow useful comparisons between window designs.
- The rating system combines the following characteristics calculate a rating
  - U-value (thermal transmittance)
  - The solar factor  $g$
  - The air leakage.

## Window Energy Performance (WEP)

Window Energy Performance Rating for this window is: **E**

MOST EFFICIENT



ENERGY INDEX (KWH/M<sup>2</sup>/YEAR): **-38.95**

(Energy index certified by NSAI Agreement and based on Irish standard window. The actual energy consumption for a specific application will depend on the building, the local climate and the indoor temperature)

CLIMATE ZONE **IRL**

### ENERGY PERFORMANCE CRITERIA

Thermal Transmittance	$U_{window}$	= 1.8 W/m <sup>2</sup> .K
Effective Air Leakage	$L_{factor}$	= 0.02 W/m <sup>2</sup> .K
Solar Factor	$g_{window}$	= 0.38

### ADDITIONAL PERFORMANCE CRITERIA

Condensation Resistance CR = 51

This label is not a statutory requirement. It is a voluntary label provided as a customer service to allow consumers to make informed decisions on the energy performance of competing products.

- continued.
- Least efficient windows will have a large negative energy balance.
- This label shows energy band E when the energy balance is negative, i.e. minus 38.96 kWh/m<sup>2</sup>/year.
- Most efficient windows will have an A rating, i.e. less than zero energy loss = positive energy balance.

# Module summary.

- Full details about calculating the U-value of windows or doors are given in an I.S. EN standard.

- Task.

What is the number of this I.S. EN Standard.

What components of the window are considered when calculating the U-value for a window.

# Module summary – continued.

- Window glass may be installed as single glazing or multiple glazing.
- Task.

Describe the different types of multiple glazing  
 Give examples of the type of buildings using the different types of glazing.

# Module summary – continued.

- Low emissivity coating may be added to double glazing or triple glazing.
- Task.

What are these coatings typically made of.

Where are the coatings applied, in relation to the cavity between the panes of glass.

What is the advantage of adding these coatings.

What is the disadvantage of adding these coatings.

# Module summary – continued.

- The cavity between the panes of glass can be filled with a number of different gases.
- Task.

List four gases that may be used in the cavity.

Arrange these in order, showing the least resistant gas first.

# Module summary – continued.

- Window frames are typically divided into four main types
- Task.

List the four main types and briefly describe how each is constructed.

Typically, how would the area of window frame compare with the area of glass.



# Module summary – continued.

- The European Commission has proposed to expand the labelling directive to include energy saving products like windows.

- Task.

Will this energy label for windows look like any existing energy labels?

What units of energy will be used on these labels.

What energy loss will A rated windows have?

# References.

- I.S. EN ISO 10077-1 : 2006.  
Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General
- I.S. EN ISO 10077- 2 : 2003.  
Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames.

# Appendix.

Example of how choice of window construction and choice of window orientation can impact on the heat loss / heat gain balance.

- The following example is described in an IntelligentEnergy-Europe programme  
TREES - Training for Renovated Energy  
Efficient Social housing

Section 1 Techniques

1.2 Replacement of glazing

[www.cep.ensmp.fr/trees/Material/TREES\\_1.2\\_glazing\\_texts\\_071107.pdf](http://www.cep.ensmp.fr/trees/Material/TREES_1.2_glazing_texts_071107.pdf)

- continued.

- Standard conditions for this example are as follows.
- Climate – Paris.
- Solar exposure of the facade – South facing.
- The characteristics of the building –
  - a) The thermal mass of the building is medium, which corresponds for instance to heavy floors (20 cm concrete) and light facades.

The solar gains would be less useful with a very light building (e.g. wooden structure and floor)

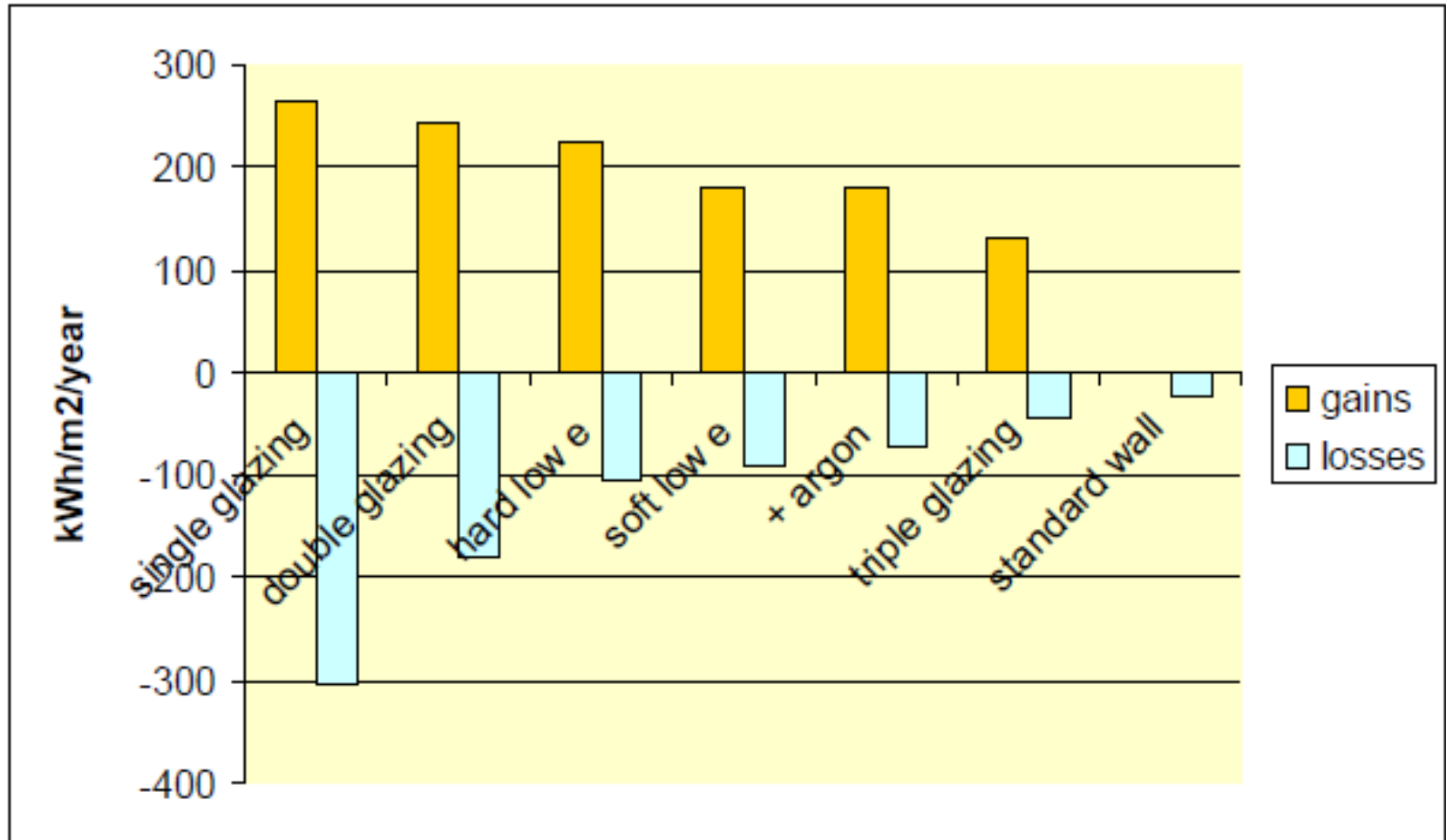
- continued.

The solar gain would be more useful in a very heavy structure (e.g. 20 cm concrete in floors and walls, with external insulation).

In a heavy structure, the solar gains can be stored from day-time until evening and the reduction of the energy consumption is therefore higher.

- b) The glazing area is taken as 1 m<sup>2</sup>. The first m<sup>2</sup> of glazing are more efficient than adding one supplementary m<sup>2</sup> to an already very glazed space : the supplementary solar radiation would mainly contribute to overheating of the space.
- c) Indoor air temperature is taken as 20 Deg C.

# Example heat balance of 1 m<sup>2</sup> south facing glazing in the Paris climate



- From this diagram.

- For single glazing – Heat loss > Heat gain.
- For all other glazing – Heat loss < Heat gain.
- For standard wall – Heat loss only, no heat gain.

• Adding low e coatings slightly reduces solar heat gains but greatly reduces heat losses.

• Approximate net heat gain

hard low e coating      110 kWh/m<sup>2</sup>/year

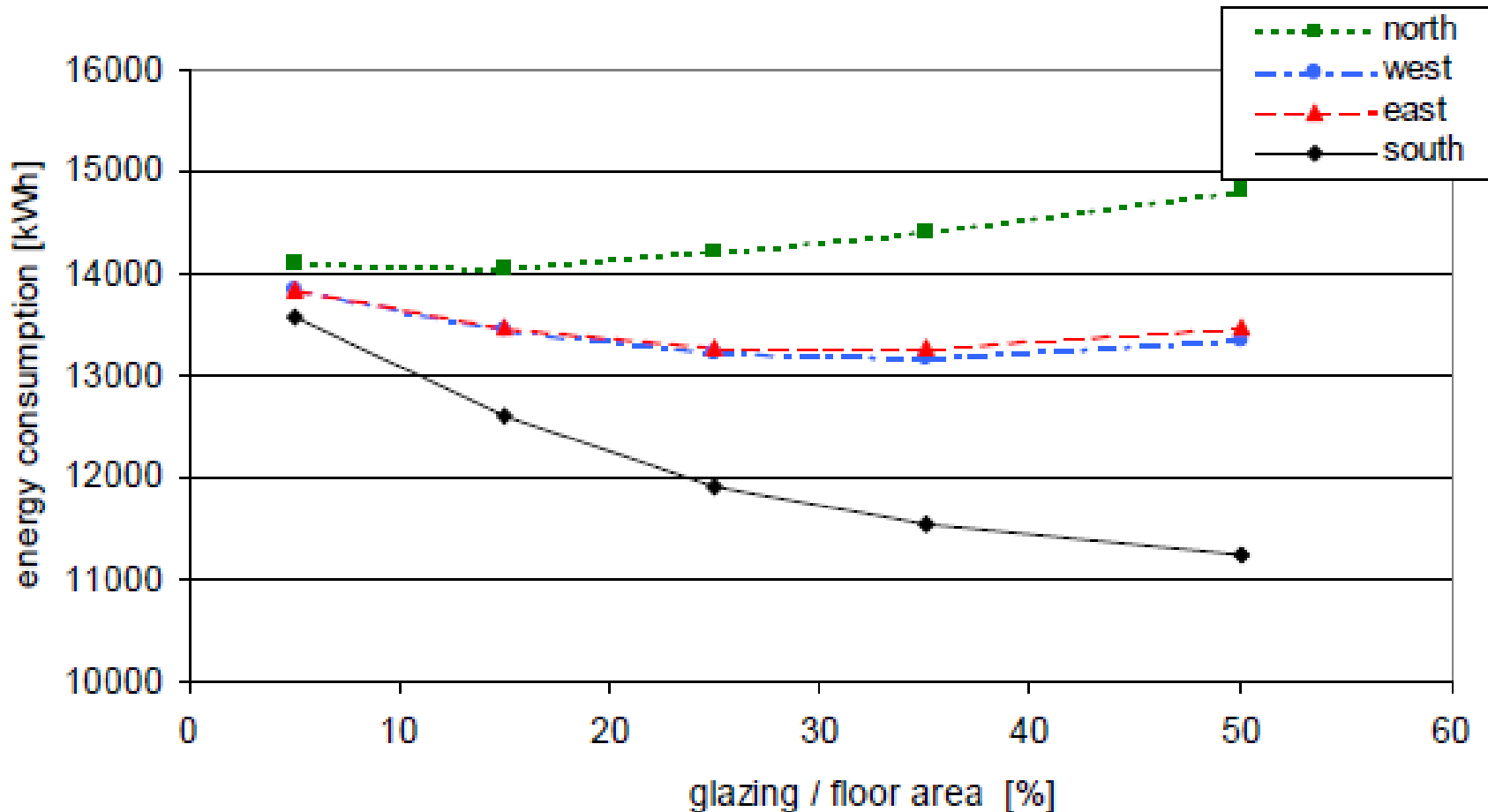
soft low e coating      90 kWh/m<sup>2</sup>/year

Conclusion – better net heat gain with hard low e coating in this climate, but this may be different in other climates.

- Replacing air in the gap with argon reduces the heat losses with no reduction of the solar gains.



# Orientation of the façade for this example.



Energy consumption kWh/year (space + water heating) V's Glazing ratio.

- From this diagram.
- Changes in energy consumption when the glazing ratio is increased from 5 – 50%.
- For south facing façade –  
Increasing the glazing ratio reduces the annual energy consumption by approximately 15%.
- For north facing façade –  
Increasing the glazing ratio increases the annual energy consumption by approximately 5%.
- For east or west facing façade –  
Increasing the glazing ratio reduces the annual energy consumption by approximately 5%.
- These conclusions may be different in other climates.

# Module summary – continued.

- For this building in Paris consider the following.
- Task.

How does the combination of solar gain and a heavy structure help to reduce the overall energy consumption of a building.

# Module summary – continued.

- For this building, changes in the type of glazing produces changes in the heat loss / heat gain balance in the building.

- Task.

Explain how each change of glazing influenced the energy balance.

Would these changes give the same results in other climates?

# Module summary – continued.

- For this building, changes in the orientation of the glazing produced changes in the heat loss / heat gain balance in the building.

- Task.

Explain how each change of glazing orientation influenced the energy balance.

Would these changes give the same results in other climates?

# References.

- [www.greenspec.co.uk/html/materials/glass.html](http://www.greenspec.co.uk/html/materials/glass.html)
- [www.polishsolutions.eu/images/PVC-window-fram](http://www.polishsolutions.eu/images/PVC-window-fram).
- IntelligentEnergy-Europe programme  
 TREES - Training for Renovated Energy  
 Efficient Social housing Section 1 Techniques  
 1.2 Replacement of glazing  
[www.cep.ensmp.fr/trees/Material/TREES\\_1.2\\_glazing\\_texts\\_071107.pdf](http://www.cep.ensmp.fr/trees/Material/TREES_1.2_glazing_texts_071107.pdf)