DTU Civil Engineering
Department of Civil Engineering

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# EUROPEAN ENERGY LABELING SCHEME FOR WINDOWS

**Department of Civil Engineering**
Report 2008

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**Aim:**

To show that it is possible to have a simple energy rating scheme across borders within EU, for replacement of windows in the existing residential buildings

**Why:**

EC has in their proposal for revision of the energy labeling directive suggested to included windows.

And instead of having each single member of the EU to have their own labeling scheme for windows, we suggest to use a few and simple schemes, which all are based on the same set of assumptions.

**How:**

Energy rating is expressed by the Energy Balance of windows that takes into account the passive solar gain and heat loss through the window.

This is done for both the heating AND cooling season

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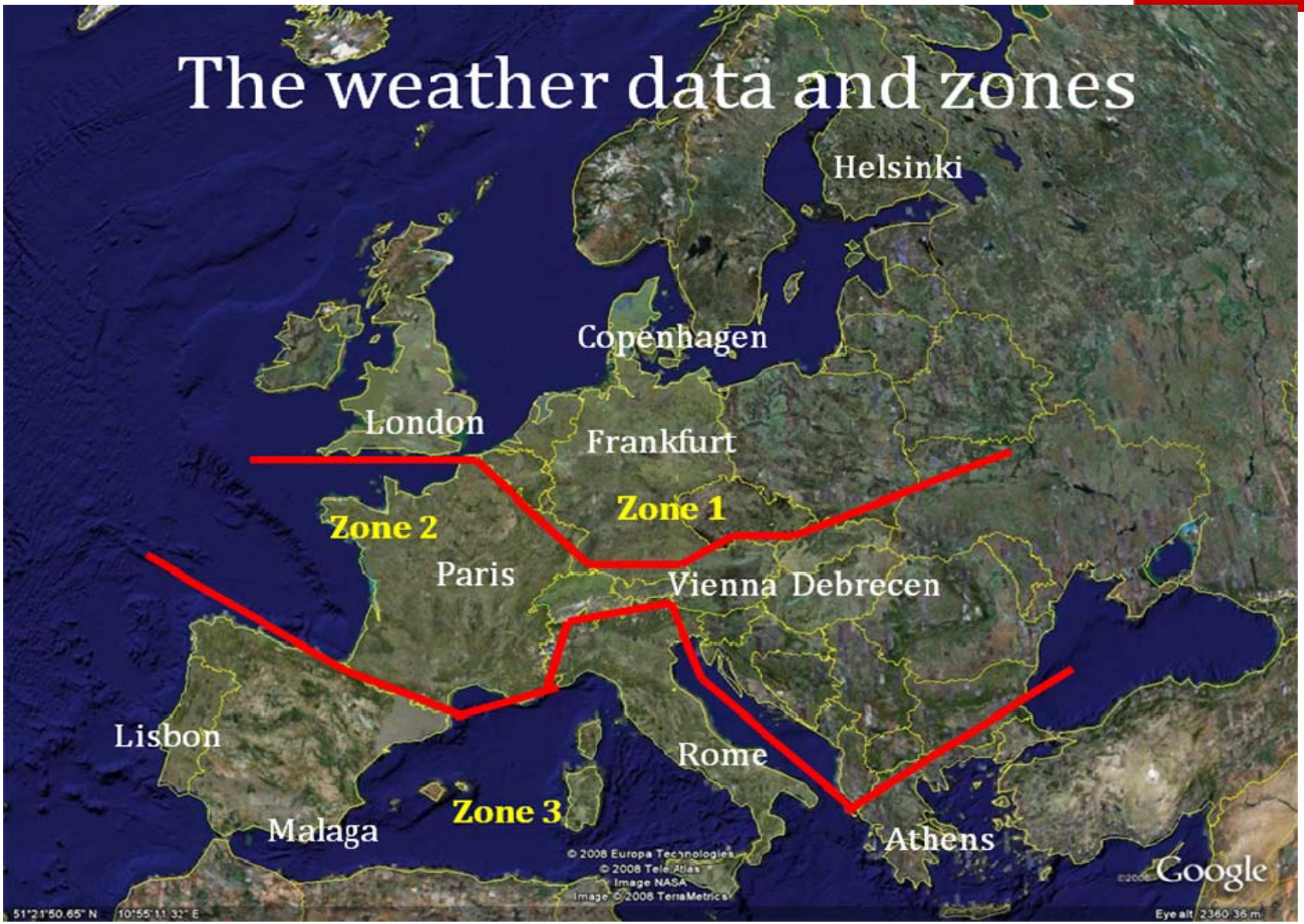
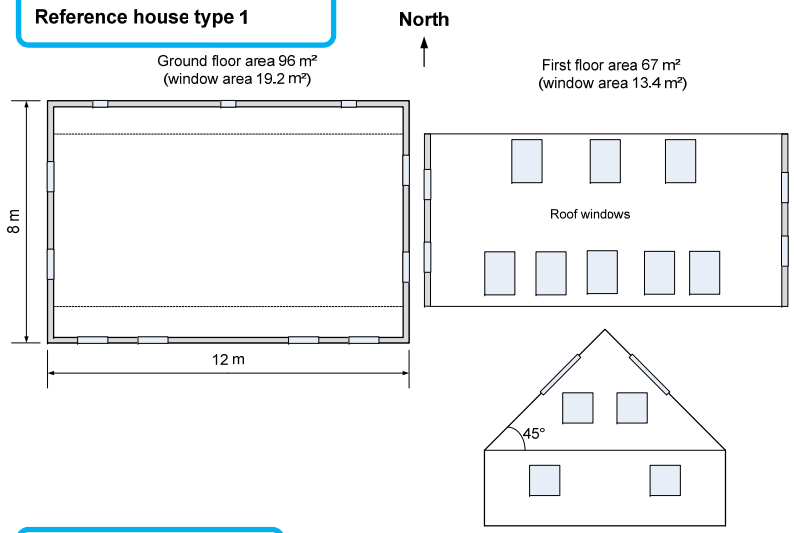
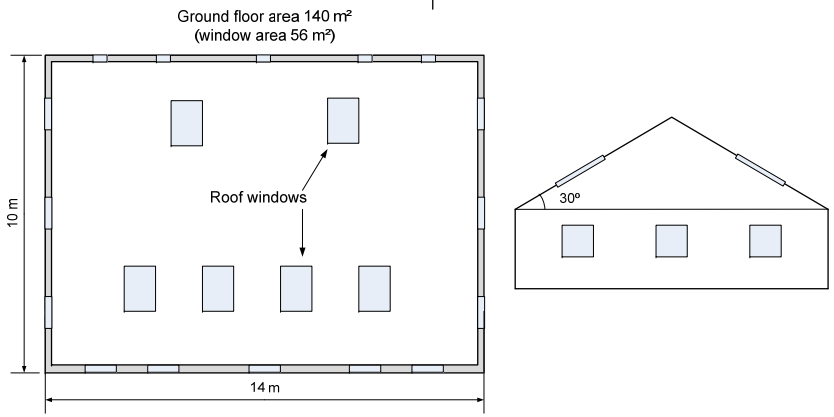

The weather data and zones
Helsinki
Copenhagen
London
Frankfurt
Zone 1
Zone 2
Paris
Vienna
Debrecen
Lisbon
Rome
Zone 3
Malaga
Athens
Google

**Reference house type 1**

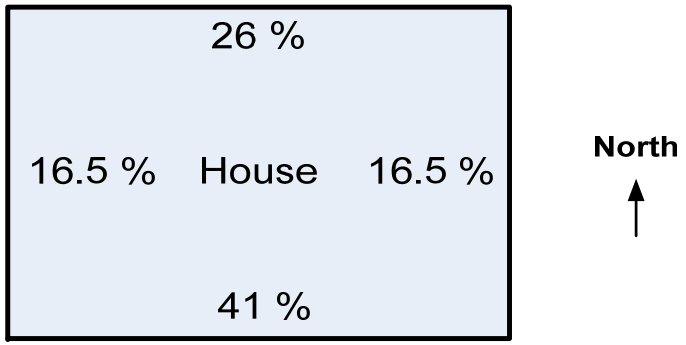



**Reference house type 2**




Window area = 20 % of ground/first floor area

Window distribution of the houses



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| | | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|---|
| Construction | Roof | 0.2 | 0.5 | 0.8 |
| | Wall | 0.3 | 1.0 | 1.2 |
| | Floor | 0.2 | 0.8 | 0.8 |
| Ventilation [$h^{-1}$] | Winter | 0.5 | 0.5 | 0.5 |
| | Summer | 1.5 | 2.0 | 2.5 |
| Window | $U_w$ [$W/m^2K$] | 2.0 | 3.5 | 4.2 |
| | $g_w$ | 0.50 | 0.58 | 0.58 |
| House Type 1 Heat Capacity | Category | medium | medium | medium |
| | C [$J/Km^2$] | 165 000 | 165 000 | 165 000 |
| House Type 2 Heat Capacity | Category | heavy | heavy | heavy |
| | C [$J/Km^2$] | 260 000 | 260 000 | 260 000 |

# HEATING & COOLING SEASON

Table 2. Calculated heating and cooling seasons for selected EU cities

| Zone | Location | Reference house | | | |
|---|---|---|---|---|---|
| | | Type 1 | | Type 2 | |
| | | Heating | Cooling | Heating | Cooling |
| 1 | Helsinki | 9 Aug – 18 May | 13 Jun – 15 Aug | 5 Sept – 27 May | 5 Jul – 26 Jul |
| | Copenhagen | 17 Sept – 14 May | 12 Jun – 21 Aug | 12 Sept – 23 May | 12 Jul – 30 Jul |
| | Frankfurt | 2 Oct – 24 Apr | 2 Jun – 2 Sept | 27 Sept – 30 Apr | 23 Jun – 24 Aug |
| | London | 24 Sept – 10 May | 21 Jun – 22 Aug | 16 Sept – 25 May | 10 Jul – 29 Jul |
| 2 | Paris | 19 Sept – 27 May | 3 Jul – 22 Aug | 14 Sept – 7 Jun | 15 Jul – 16 Aug |
| | Vienna | 19 Sept – 19 May | 26 Jun – 23 Aug | 15 Sept – 1 Jun | 6 Jul – 18 Aug |
| | Debrechen | 23 Sept – 8 May | 5 Jun – 27 Aug | 18 Sept – 15 May | 13 Jun – 22 Aug |
| 3 | Lisbon | 1 Nov – 25 Apr | 1 Jun – 28 Sept | 29 Oct – 2 May | 17 Jun – 20 Sept |
| | Rome | 25 Oct – 27 Apr | 30 May – 24 Sept | 23 Oct – 1 May | 9 Jun – 18 Sept |
| | Athens | 10 Nov – 14 Apr | 13 May – 9 Oct | 7 Nov – 17 Apr | 21 May – 3 Oct |

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# Energy Balance of a Window

$$E_{ref,cooling} = I_{cooling} \cdot F_s \cdot g_w - D_{cooling} \cdot U_w$$

$$E_{ref,heating} = I_{heating} \cdot F_s \cdot g_w - D_{heating} \cdot U_w$$

# Number of Degree hours

$$D_{heating} = \sum_{i=\text{heating start}}^{\text{heating stop}} T_{base,heating} - T_{out} \quad for\ the\ heating\ season$$

$$D_{cooling} = \sum_{i=\text{cooling start}}^{\text{cooling stop}} T_{out} - T_{base,cooling} \quad for\ the\ cooling\ season$$

# Solar Radiation

$$I_{90°} = 0.26 \cdot I_{north,90°} + 0.165 \cdot I_{west,90°} + 0.165 \cdot I_{east,90°} + 0.41 \cdot I_{south,90°}$$

$$I_{45°} = 0.26 \cdot I_{north,45°} + 0.165 \cdot I_{west,45°} + 0.165 \cdot I_{east,45°} + 0.41 \cdot I_{south,45°}$$

$$I_{30°} = 0.26 \cdot I_{north,30°} + 0.165 \cdot I_{west,30°} + 0.165 \cdot I_{east,30°} + 0.41 \cdot I_{south,30°}$$

$$I_{heating} = \sum_{i=\text{heating start}}^{\text{heating stop}} I_{90°} \quad ,for\ the\ heating\ seseason$$

$$I_{cooling} = \sum_{\text{i=cooling start}}^{\text{cooling stop}} I_{90°} \ \textbf{for}\ I_{90°} > 300W\ and\ T_{out} > 23\ ºC$$

# ENERGY BALANCE, EACH SELECTED CITY

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| | | | Heating season | | | | Cooling season | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Solar radiation (kWh/m²) | | | Degree hours (kKh) | Solar radiation (kWh/m²) | | | Degree hours (kKh) |
| | Location | Ref. House | I_90º | I_45º | I_30º | D | I_90º | I_45º | I_30º | D |
| Zone 1 | **Helsinki** | Type 1 | 252 | 420 | 434 | 119 | 16 | 35 | 43 | 0 |
| | **Copenhagen** | Type 1 | 203 | 335 | 343 | 88 | 12 | 27 | 34 | 0 |
| | **Frankfurt** | Type 1 | 164 | 273 | 281 | 73 | 37 | 105 | 126 | 0 |
| | **London** | Type 1 | 200 | 333 | 342 | 71 | 22 | 63 | 74 | 0 |
| Zone 1 | **Helsinki** | Type 2 | 230 | 382 | 394 | 118 | 14 | 30 | 38 | 0 |
| | **Copenhagen** | Type 2 | 227 | 381 | 393 | 90 | 12 | 27 | 34 | 0 |
| | **Frankfurt** | Type 2 | 183 | 308 | 317 | 76 | 37 | 104 | 125 | 0 |
| | **London** | Type 2 | 234 | 398 | 413 | 75 | 11 | 32 | 38 | 0 |
| Zone 2 | **Paris** | Type 1 | 239 | 422 | 443 | 72 | 26 | 78 | 95 | 0 |
| | **Vienna** | Type 1 | 241 | 424 | 445 | 83 | 41 | 130 | 156 | 0 |
| | **Debrecen** | Type 1 | 235 | 409 | 426 | 83 | 58 | 184 | 219 | 1 |
| Zone 2 | **Paris** | Type 2 | 265 | 476 | 502 | 75 | 17 | 54 | 65 | 0 |
| | **Vienna** | Type 2 | 269 | 483 | 510 | 85 | 29 | 88 | 106 | 0 |
| | **Debrecen** | Type 2 | 256 | 449 | 471 | 84 | 48 | 158 | 188 | 1 |
| Zone 3 | **Lisbon** | Type 1 | 283 | 459 | 466 | 33 | 107 | 390 | 458 | 2 |
| | **Rome** | Type 1 | 248 | 417 | 430 | 42 | 111 | 388 | 457 | 1 |
| | **Athens** | Type 1 | 216 | 366 | 378 | 32 | 161 | 564 | 653 | 4 |
| Zone 3 | **Lisbon** | Type 2 | 302 | 500 | 510 | 34 | 87 | 323 | 379 | 2 |
| | **Rome** | Type 2 | 253 | 428 | 442 | 43 | 98 | 340 | 401 | 1 |
| | **Athens** | Type 2 | 226 | 383 | 396 | 33 | 157 | 547 | 634 | 4 |

# EACH ZONE - AVERAGED

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| Net energy gain [kWh/m²] | Slope angle | Heating | Cooling |
|---|---|---|---|
| Zone 1 | 90° | $E_{ref,heating} = 212 \cdot g_w - 89 \cdot U_w$ | $E_{ref,cooling} = 20 \cdot g_w - 0 \cdot U_w$ |
| | 45° | $E_{ref,heating} = 354 \cdot g_w - 89 \cdot U_w$ | $E_{ref,cooling} = 53 \cdot g_w - 0 \cdot U_w$ |
| | 30° | $E_{ref,heating} = 365 \cdot g_w - 89 \cdot U_w$ | $E_{ref,cooling} = 64 \cdot g_w - 0 \cdot U_w$ |
| Zone 2 | 90° | $E_{ref,heating} = 251 \cdot g_w - 80 \cdot U_w$ | $E_{ref,cooling} = 36 \cdot g_w - 1 \cdot U_w$ |
| | 45° | $E_{ref,heating} = 444 \cdot g_w - 80 \cdot U_w$ | $E_{ref,cooling} = 116 \cdot g_w - 1 \cdot U_w$ |
| | 30° | $E_{ref,heating} = 466 \cdot g_w - 80 \cdot U_w$ | $E_{ref,cooling} = 138 \cdot g_w - 1 \cdot U_w$ |
| Zone 3 | 90° | $E_{ref,heating} = 254 \cdot g_w - 36 \cdot U_w$ | $E_{ref,cooling} = 120 \cdot g_w - 2 \cdot U_w$ |
| | 45° | $E_{ref,heating} = 426 \cdot g_w - 36 \cdot U_w$ | $E_{ref,cooling} = 425 \cdot g_w - 2 \cdot U_w$ |
| | 30° | $E_{ref,heating} = 437 \cdot g_w - 36 \cdot U_w$ | $E_{ref,cooling} = 497 \cdot g_w - 2 \cdot U_w$ |

BFRC has 218 kWh/m2 as solar radiation and 69 kKh
DK uses 196 kWh/m2 as solar radiation and 90 kKh

VELUX further studies are showing that for DK typical building with 45 °slope $E_{ref,heating}$= 345 * gw – 90*Uw based on data from the Technical University in Denmark

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# EACH LOCATION – FACADE WINDOWS

| Window type | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| U-value - 90 degrees | 0.8 | 0.8 | 1 | 1 | 1.2 | 1.2 | 1.4 | 1.4 | 1.6 | 1.6 |
| g-value for the window | 0.24 | 0.32 | 0.32 | 0.40 | 0.40 | 0.48 | 0.40 | 0.48 | 0.40 | 0.48 |
| Location/Energy balance [kWh/m²] | | | | | | | | | | |
| Helsinki | -35 | -15 | -38 | -18 | -42 | -22 | -66 | -46 | -90 | -69 |
| Copenhagen | -21 | -5 | -23 | -6 | -24 | -8 | -41 | -25 | -59 | -43 |
| Frankfurt | -19 | -6 | -20 | -7 | -22 | -9 | -36 | -23 | -51 | -38 |
| London | -8 | 8 | -7 | 9 | -5 | 11 | -19 | -3 | -33 | -17 |
| Helsinki | -39 | -21 | -44 | -26 | -49 | -31 | -73 | -54 | -96 | -78 |
| Copenhagen | -18 | 0 | -18 | 1 | -18 | 1 | -36 | -17 | -54 | -36 |
| Frankfurt | -17 | -2 | -17 | -3 | -18 | -3 | -33 | -18 | -48 | -33 |
| London | -4 | 15 | 0 | 19 | 4 | 23 | -11 | 8 | -26 | -7 |
| Paris | 0 | 19 | 4 | 23 | 9 | 28 | -6 | 14 | -20 | -1 |
| Vienna | -9 | 10 | -6 | 13 | -4 | 16 | -20 | -1 | -37 | -18 |
| Debrecen | -10 | 9 | -7 | 11 | -5 | 14 | -22 | -3 | -38 | -19 |
| Paris | 4 | 25 | 10 | 31 | 16 | 38 | 1 | 23 | -13 | 8 |
| Vienna | -4 | 18 | 1 | 22 | 5 | 27 | -12 | 10 | -29 | -8 |
| Debrecen | -6 | 15 | -2 | 18 | 1 | 22 | -16 | 5 | -32 | -12 |
| Lisbon | 42 | 64 | 58 | 80 | 74 | 96 | 67 | 90 | 60 | 83 |
| Rome | 26 | 46 | 37 | 57 | 49 | 69 | 41 | 60 | 32 | 52 |
| Athens | 26 | 43 | 37 | 54 | 48 | 65 | 41 | 58 | 35 | 52 |
| Lisbon | 45 | 70 | 63 | 87 | 80 | 104 | 73 | 98 | 67 | 91 |
| Rome | 27 | 47 | 39 | 59 | 50 | 71 | 42 | 62 | 33 | 54 |
| Athens | 28 | 46 | 39 | 57 | 51 | 69 | 44 | 62 | 37 | 55 |

| | |
|---|---|
| | Best performing product |
| | 2. best performing product |
| | 3. best performing product |
| | 4. best performing product |
| | Worth performing product |

# EACH LOCATION – ROOF WINDOWS

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| Window type | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U-value - 45 degrees | 0.95 | 0.95 | 1.15 | 1.15 | 1.4 | 1.4 | 1.6 | 1.6 | 1.8 | 1.8 | 1 | 1 | 1.2 | 1.2 | 1.5 | 1.5 | 1.7 | 1.7 | 1.9 | 1.9 |
| g-value for the window | 0.24 | 0.32 | 0.32 | 0.40 | 0.40 | 0.48 | 0.40 | 0.48 | 0.40 | 0.48 | 0.24 | 0.32 | 0.32 | 0.40 | 0.40 | 0.48 | 0.40 | 0.48 | 0.40 | 0.48 |
| Location/Energy balance [kWh/m²] | 45 ° | | | | | | | | | | 30° | | | | | | | | | |
| Helsinki | -12 | 21 | -2 | 31 | 1 | 35 | -22 | 11 | -46 | -13 | -15 | 20 | -4 | 31 | -5 | 30 | -29 | 6 | -53 | -18 |
| Copenhagen | -3 | 24 | 6 | 33 | 11 | 38 | -6 | 21 | -24 | 3 | -5 | 22 | 5 | 32 | 6 | 33 | -11 | 16 | -29 | -2 |
| Frankfurt | -4 | 18 | 4 | 25 | 7 | 29 | -7 | 14 | -22 | 0 | -6 | 17 | 2 | 25 | 3 | 25 | -12 | 11 | -26 | -4 |
| London | 13 | 39 | 25 | 52 | 34 | 61 | 20 | 47 | 6 | 33 | 11 | 39 | 25 | 52 | 31 | 58 | 17 | 44 | 2 | 30 |
| Helsinki | -20 | 11 | -13 | 18 | -12 | 19 | -35 | -5 | -59 | -28 | -23 | 8 | -15 | 16 | -19 | 13 | -43 | -11 | -66 | -35 |
| Copenhagen | 6 | 36 | 18 | 49 | 26 | 56 | 8 | 38 | -10 | 20 | 4 | 36 | 17 | 49 | 22 | 53 | 4 | 35 | -14 | 17 |
| Frankfurt | 2 | 27 | 11 | 36 | 17 | 42 | 2 | 27 | -13 | 11 | 0 | 26 | 11 | 36 | 13 | 39 | -2 | 24 | -17 | 9 |
| London | 25 | 57 | 42 | 73 | 55 | 87 | 40 | 72 | 25 | 57 | 24 | 57 | 42 | 75 | 53 | 86 | 38 | 71 | 23 | 56 |
| Paris | 33 | 67 | 52 | 86 | 68 | 102 | 53 | 87 | 39 | 73 | 34 | 70 | 55 | 91 | 69 | 104 | 55 | 90 | 40 | 76 |
| Vienna | 23 | 56 | 40 | 74 | 53 | 87 | 36 | 70 | 20 | 53 | 23 | 59 | 42 | 78 | 53 | 88 | 36 | 72 | 19 | 55 |
| Debrecen | 20 | 52 | 36 | 68 | 48 | 80 | 31 | 64 | 15 | 47 | 20 | 54 | 37 | 71 | 46 | 81 | 30 | 64 | 13 | 47 |
| Paris | 43 | 81 | 66 | 105 | 86 | 124 | 71 | 109 | 56 | 94 | 46 | 86 | 71 | 111 | 89 | 129 | 74 | 114 | 59 | 99 |
| Vienna | 35 | 74 | 57 | 95 | 74 | 113 | 57 | 95 | 40 | 78 | 37 | 78 | 61 | 102 | 76 | 117 | 59 | 100 | 42 | 83 |
| Debrecen | 28 | 64 | 47 | 83 | 62 | 98 | 45 | 81 | 28 | 64 | 29 | 66 | 50 | 87 | 62 | 100 | 45 | 83 | 28 | 66 |
| Lisbon | 79 | 116 | 109 | 146 | 138 | 174 | 131 | 168 | 125 | 161 | 79 | 116 | 110 | 147 | 137 | 174 | 130 | 168 | 124 | 161 |
| Rome | 60 | 94 | 85 | 119 | 108 | 142 | 100 | 133 | 92 | 125 | 61 | 96 | 87 | 122 | 109 | 143 | 101 | 135 | 92 | 127 |
| Athens | 57 | 86 | 80 | 109 | 101 | 130 | 95 | 124 | 88 | 117 | 58 | 89 | 82 | 112 | 103 | 133 | 96 | 126 | 90 | 120 |
| Lisbon | 88 | 128 | 121 | 161 | 152 | 192 | 146 | 186 | 139 | 179 | 89 | 129 | 123 | 163 | 153 | 194 | 146 | 187 | 140 | 180 |
| Rome | 62 | 97 | 88 | 122 | 112 | 146 | 103 | 138 | 95 | 129 | 64 | 99 | 90 | 126 | 113 | 148 | 104 | 140 | 96 | 131 |
| Athens | 61 | 91 | 85 | 115 | 107 | 138 | 100 | 131 | 94 | 124 | 62 | 94 | 87 | 119 | 109 | 140 | 102 | 134 | 96 | 127 |

| | |
|---|---|
| | Best performing product |
| | 2. best performing product |
| | 3. best performing product |
| | 4. best performing product |
| | Worth performing product |

# CONCLUSION

**Possible to develop an European scheme for windows** where Europe is divided into zones as the performances of windows for the heating season do not differ significant in the zones

The energy performance of **sloped windows differs from vertical windows**, where the passive solar radiation for sloped windows is much higher than for vertical windows and thereby the **energy performance of sloped windows is better than for vertical windows**

**The best performing façade window for replacement** in the northern part of Europe is low energy window with U-values between 0.8 and 1.2 however the difference between the 3 best windows are below 10 kWh/m² in northern climate. The best performing façade window on an **overall evaluation** will be a window with a **U-value of approximately 1.2 W/m²K and a g-value of approximately 0.48 for the total window**

**The performance of best sloped windows for replacement** is the same for all Europe, with a **U-value of 1.2 W/m²K and a g-value of 0.48 for the total window**

By replacing the windows in the existing building stock an energy saving in Europe can be up to about **135 GWh/year if existing old windows are replaced with new windows with a U-value of 1.2 W/(m²K) and a g-value of 0.5 for the total window**

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# DISCUSSION – FURTHER WORK TO BE DONE

- Fraction of windows
- Insulations values of the building envelope
- Flat Roof Windows – 0 degrees
- Diagrams for Uw vs. gw for R&D purposes
- Others?