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Definitions of U- and g-value in case of double skin facades or vented windows

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Contents

1. Introduction

In case of vented windows or vented facades, the heat exchange between the window or façade and the room is influenced by the heat exchange in the vented cavity.
This document gives a brief description of the different heat flow components involved, resulting in definitions for:

- the different parts of the U- and g-values: the influence on the energy balance of the room
- the different parts of the energy flows in and out of the window or façade itself: the energy balance of the window or façade system

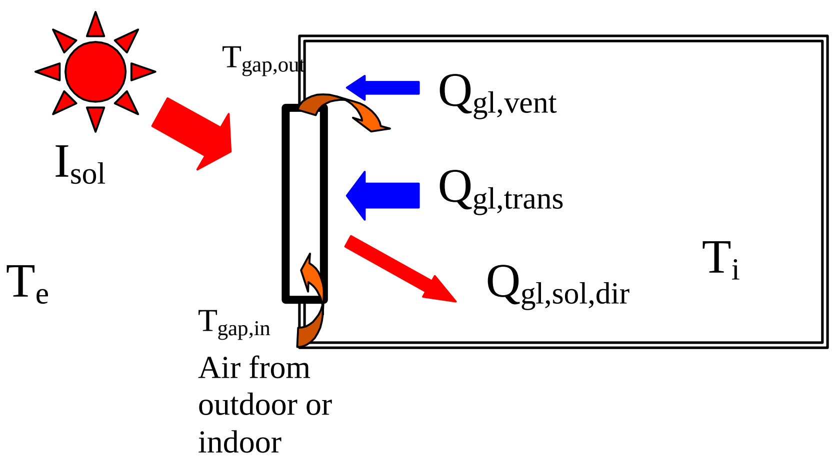
The content of this document is originally based on analysis techniques for vented facades developed within the EU project PASLINK/HYBRID-PAS.
The definitions have been further developed in IEA SHC Task 27 (“Solar Façade Components” and in studies for Permasteelisa (Scheldebouw B.V.).

In the underlying document the equations have again been further developed and the symbols have been modified to increase the consistency and transparency.

Originally we tried to follow the symbols used in draft ISO DIS 15099, but the symbols in that standard are being revised at the moment due to ISO rules.

2. Heat exchange with the room

2.1 Main energy flows



We use the symbol gl ("glazing") for the window or façade, because we concentrate on the transparent ("glazed") part of the system.

$\mathbf{Q_{gl,trans}}$ is the net transmission heat flow from room to window/façade induced by convective and thermal radiative heat exchange from the room to the window/façade, influenced by indoor-outdoor temperature difference (positive contribution if indoor temperature higher) and by absorbed solar radiation (negative contribution: from window/façade to room).

$\mathbf{Q_{gl,vent}}$ is the net ventilative heat flow from room to window/façade induced by air entering the room from the cavity, which is heated or cooled under influence of indoor-outdoor temperature difference (positive contribution if room air temperature is higher than cavity exit temperature) and absorbed solar radiation (usually[1] positive contribution).

$\mathbf{Q_{gl,sol,direct}}$ is the energy gain to the room by direct (meaning short wave) solar radiation, transmitted into the room via the window/façade.

Then, the total net heat flow from room to window/façade is given by:

$$Q_{room,gl} = Q_{gl,trans} + Q_{gl,vent} - Q_{gl,sol,direct}$$

Subscript gl:

As long as we confine ourselves to the interaction between room and the transparent part of the window/façade, we could do without the subscript 'gl'. In that case we only have to avoid that Q_{vent} is mistaken for the ventilation heat loss of the room.

Environment temperature:

For simplicity reasons we assume that the indoor air temperature is equal to the indoor mean radiative temperature (and thus to the indoor environment temperature). The same for the outdoor temperature.
If they are not the same, the temperature difference between indoor and outdoor temperature is based on the weighted mean of air and mean radiant temperatures.
The weighting is done according to the relative contributions[2] in the heat flow.

---

[1] Usually but not necessarily, because the sun may lead to more ventilative cold brought into the room, in case of thermally induced (free) ventilation, if the sun heats cold outdoor air flowing through the cavity, but at the same time the increase in flow rate induced by the sun is relatively higher; in that case more cold is brought into the room: the contribution to the g-value is negative! Similar for the reverse case (warm air into the cavity and decrease in flow rate outweighing the increase in exit temperature)

[2] In a simple case with a surface that is opaque fro IR radiation and impermeable for air (such as glass) the weighting is according to the radiative and convective heat transfer coefficients, h_r and h_c respectively. However, in general there may also be thermal radiation to a second layer, e.g. a glass pane behind a (semi-open) blind; see **Annex 1**

2.2 Equations

$Q_{gl,trans}$:

In the simplest case:

$Q_{gl,trans} = (h_{ci} + h_{ri}) * A_{gl} * (T_i - T_{gl,si})$

Where:

h_{ci} is the indoor convective heat transfer coefficient ($W/(m^2K)$)

h_{ri} is the indoor radiative heat transfer coefficient ($W/(m^2K)$)

A_{gl} is the area of the transparent part of the window/façade (m^2)

T_i is the indoor environment temperature (see earlier footnote and Annex 1) (°C)

$T_{gl,si}$ is the indoor surface temperature of the window (°C)

This 'standard' simple equation for convective and radiative heat flow from room to window can become more complicated due to infrared transparent layers facing the room, such as porous or venetian indoor blinds (compare Annex 1). WIS takes this into account in a proper way.

$Q_{gl,vent}$:

$Q_{gl,vent} = \rho * c_p * \phi_v * W * (T_i - T_{gap,out})$

where:

ρ is the volumetric density of air = 1.21 * 273 / (273 + T_{gap}) (kg/m^3K) (with T_{gap}: the mean temperature in the gap)

T_i is the indoor environment temperature (°C)

$T_{gap,out}$ is the temperature of the air at the exit of the cavity (°C)

c_p is the thermal capacity of air = 1010 J/(kgK)

ϕ_v is the cavity air flow (m^3/s per m window width[3])

W is window width (m)

Note:

The temperature difference is the difference between the *room* temperature and the exit of the gap. It is **this** difference that affects the heat balance of the room, irrespective of the *inlet* temperature of the cavity.

$Q_{gl,sol,direct}$:

Standard equation:

$Q_{gl,sol,direct} = \tau_{sol} * A_{gl} * I_{sol}$

where:

τ_{sol} is the direct (short wave) solar transmittance of the window/façade

A_{gl} is the area of the transparent part of the window/façade (m^2)

[3] The flow rate is given per m width of the window, to emphasize that the ventilation assumes vertical flow movement and is homogeneous in horizontal direction; consequently, in WIS the result of the transparent system with vented cavities does not change with the given width of the transparent system.

I_{sol} is the amount of incident solar radiation (W/m^2)

2.3 U- and g-values

This paragraph describes how the U- and g-values are defined, using the three components of energy flow between room and window/façade.

The thermal transmittance or U-value is defined as the heat flow through the window/façade under the influence of an indoor-outdoor temperature difference, without solar radiation (“dark”), divided by the window area and indoor-outdoor temperature difference.

The total solar energy transmittance or g-value is defined as the difference in heat flow through the window/façade with and without solar radiation, divided by the window area and the intensity of the incident solar radiation.

The U-value can be split into a part related to the transmission heat flow from room to window/façade, U_{trans} and a part related to the heat flow from room to air from vented cavity(-ies) in the window/façade, U_{vent}.
The g-value can be split into the direct (short wave) solar transmittance, g_{dir} and the additional solar heat gain g_{add} which can be further split into $_{trans}$ and g_{vent}, similar to the U-value.

The U- and g-value components are then **defined** by the following equations:

$$U_{trans} = [Q_{gl,trans}]_{dark} / (A_{gl} * (T_i - T_e))$$

$$U_{vent} = [Q_{gl,vent}]_{dark} / (A_{gl} * (T_i - T_e))$$

$$g_{dir} = ([Q_{gl,sol,dir}]_{with\ sun}) / (A_{gl} * I_{sol}) \qquad [\text{note: } = \tau_{sol}]$$

$$g_{trans} = ([Q_{gl,trans}]_{dark} - [Q_{gl,trans}]_{with\ sun}) / (A_{gl} * I_{sol})$$

$$g_{vent} = ([Q_{gl,vent}]_{dark} - [Q_{gl,vent}]_{with\ sun}) / (A_{gl} * I_{sol})$$

2.4 Application of U and g

The U-value and g-value components are used in the following equations, for a given situation with certain T_i, T_e and I_{sol}:

<u>Grouped by type of energy flow:</u>

Heat flow from the room to the window by transmission:

$$Q_{gl,trans} = [U_{trans} * (T_i - T_e) - g_{trans} * I_{sol}] * A_{gl}$$

Heat flow from the room to the window by air flow from cavity(-ies) to the room:

$$Q_{gl,vent} = [U_{vent} * (T_i - T_e) - g_{vent} * I_{sol}] * A_{gl}$$

Note that application of this equation does not require input on the cavity air flow rate(s), but of course the air flow rates are implicitly taken into account.

Energy flow into the room by direct (short wave) solar transmittance:

$$Q_{gl,sol,direct} = g_{dir} * A_{gl} * I_{sol} \quad [\text{note: } = \tau_{sol} * A_{gl} * I_{sol}]$$

$$Q_{gl,total} = Q_{gl,trans} + Q_{gl,vent} - Q_{gl,sol,dir}$$

Note:
The properties U and g change with environment conditions (temperatures, amount and incident angle(s)of solar radiation, wind), so the results should be used with care, if extrapolated to other conditions than those used to determine the numbers.
This restriction is not unique for the vented case, but in a vented case the sensitivity may e higher than in the unvented case!

<u>Same, but grouped by thermal ("dark") and solar parts of energy flow:</u>

Heat flow from the room to the window under influence of indoor-outdoor temperature difference, without sun ("dark"):

$$Q_{gl,dark} = (U_{trans} + U_{vent}) * (T_i - T_e) * A_{gl}$$

Heat flow from the room to the window under influence of solar radiation, no indoor-outdoor temperature difference:

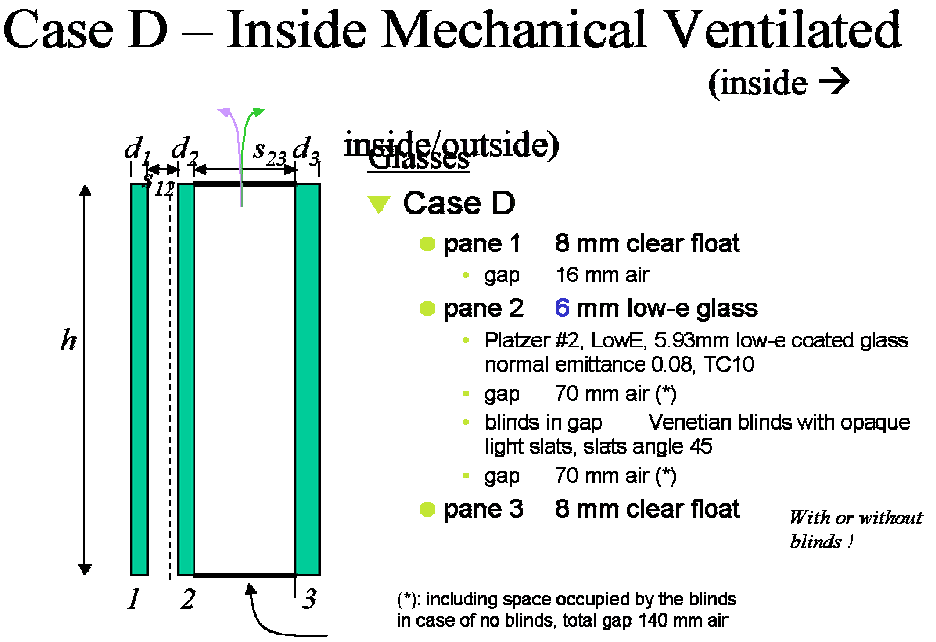
$$Q_{gl,solar} = - (g_{dir} + g_{trans} + g_{vent}) * I_{sol} * A_{gl}$$

$$Q_{gl,total} = Q_{gl,dark} + Q_{gl,solar}$$

2.5 Numerical examples

The new (version 2.0.1, Nov. 19, 2003) output of WIS contains the separate components of U and g.

Example: case D from WinDat Double Envelope benchmark cases:



Subcase:

- Summer
- with blinds
- with ventilation
- ventilation: unvented

Output from WIS:

```
--- Split U-value ---

 Uconv                                    :    0.393        [W/m2.K]
 Uir                                      :    0.627        [W/m2.K]
 Uvent                                    :    0.000        [W/m2.K]
                                            ----------------- +
 Utotal                                   :     1.02        [W/m2.K]


--- Split solar factor (g) into fractions ---

 solar direct transmittance               :    0.121        [-]
 solar factor convective                  :    0.106        [-]
 solar factor thermal radiative ir        :    0.193        [-]
 solar factor ventilation                 :    0.000        [-]
                                            ----------------- +
 solar factor (g)                         :    0.420        [-]
```

```
--- Split solar gain coefficients to outdoor side into fractions ---

 solar fraction reflected to outdoor     :    0.230        [-]
 solar fraction convected to outdoor     :    0.258        [-]
 solar fraction th. radiated to outdoor  :   0.0916        [-]
 solar fraction ventilated to outdoor    :    0.000        [-]
                                            ----------------- +
 solar fraction to outdoor               :    0.580        [-]
```

Subcase:

- Summer
- with blinds
- with ventilation
- ventilation to ***outdoor***

Output from WIS:

```
--- Split U-value ---

 Uconv                                   :    0.218        [W/m2.K]
 Uir                                     :    0.348        [W/m2.K]
 Uvent                                   :    0.000        [W/m2.K]
                                           ----------------- +
 Utotal                                  :    0.566        [W/m2.K]


--- Split solar factor (g) into fractions ---

 solar direct transmittance              :    0.121        [-]
 solar factor convective                 :   0.0664        [-]
 solar factor thermal radiative ir       :    0.115        [-]
 solar factor ventilation                :    0.000        [-]
                                           ----------------- +
 solar factor (g)                        :    0.302        [-]

--- Split solar gain coefficients to outdoor side into fractions ---

 solar fraction reflected to outdoor     :    0.230        [-]
 solar fraction convected to outdoor     :    0.223        [-]
 solar fraction th. radiated to outdoor  :   0.0785        [-]
 solar fraction ventilated to outdoor    :    0.166        [-]
                                            ----------------- +
 solar fraction to outdoor               :    0.698        [-]
```

Note:
The solar fractions to indoor plus to outdoor do ***not*** need to add up to the value =1.
One can work out the equations to find out that the sum may deviate from the value one if under solar conditions the mass flow rate multiplied by the thermal capacity ($\rho * c_p * \phi_v$) differs from the value at dark conditions.

Note:
If the cavity uses room air as the inlet, and the air is vented to outdoor, U_{trans} will be lower than without vented cavity. This is indeed a way to reduce the heat losses from the room.
One should note, however, that in the overall heat balance of the room or the building:

(1) this air needs to be brought to room temperature anywhere: where the air enters the room
(2) it is no longer available as such in a heat recovery unit; so it is not always ‘free’ heat.

Subcase:

- Summer
- with blinds
- with ventilation
- ventilation to ***indoor***

Output from WIS:

```
--- Split U-value ---

 Uconv                                    :    0.219        [W/m2.K]
 Uir                                      :    0.347        [W/m2.K]
 Uvent                                    :    0.680        [W/m2.K]
                                            ----------------- +
 Utotal                                   :     1.25        [W/m2.K]

--- Split all 'dark' heat flow coefficients into fractions (h-values)
---

--- Split solar factor (g) into fractions ---

 solar direct transmittance               :    0.121        [-]
 solar factor convective                  :   0.0664        [-]
 solar factor thermal radiative ir        :    0.115        [-]
 solar factor ventilation                 :    0.166        [-]
                                            ----------------- +
 solar factor (g)                         :    0.468        [-]

--- Split solar gain coefficients to outdoor side into fractions ---

 solar fraction reflected to outdoor      :    0.230        [-]
 solar fraction convected to outdoor      :    0.223        [-]
 solar fraction th. radiated to outdoor   :   0.0785        [-]
 solar fraction ventilated to outdoor     :    0.000        [-]
                                             ----------------- +
 solar fraction to outdoor                :    0.532        [-]
```

Note: $\mathbf{g_{vent}}$ ***can be negative***; see footnote before.

2.6 Alternative description: efficiency of heat exchange by cavity ventilation

Air from indoor:
In case of a cavity with air circulation from the room and back to the room, such as in case of indoor blinds, it is obvious that the involved heat exchange is added to the U- and g-value (U_{vent} resp. g_{vent}).

If the air does not flow back to the room, it still influences implicitly the transmission heat flow (U_{trans} resp. g_{trans}), but U_{vent} and g_{vent} are zero.

Air from other source than indoor:
If the air comes from another source, such as from outdoor, then it could be discussed whether it should be better to present the effect of vented air separately.

If the air does not flow back to the room, it –again- still influences implicitly the transmission heat flow (U_{trans} resp. g_{trans}), but U_{vent} and g_{vent} are zero.

If the air flows back to the room, it both influences implicitly the transmission heat flow (U_{trans} resp. g_{trans}) and it adds a ventilative part: U_{vent} and g_{vent} .
An alternative description is possible, describing the heat exchange in the cavity in terms of **heat exchanger efficiency**, to emphasize that the air circulation is not a closed but open loop:

Definition:

Heat exchange efficiency ε :

For the case where $T_{gap,in} = T_e$:

$$\varepsilon = (T_{gap,out} - T_e) / (T_i - T_e)$$

Note: it seems not so obvious how to split the solar ("g-value") part from the "dark"("U-value") part, because the air flow rate may change from dark to solar conditions.

This has to be further discussed and completed in near future.

Application:

$Q_{gl,vent} = (1 - \varepsilon) * [\rho * c_p * \phi_v * W * (T_i - T_e)]$

In which ε expresses the heat recuperated in the cavity before the outdoor air enters the room. Note that the recuperation is at the cost of higher transmission loss.

Numerical example:

Same cases as in the previous paragraphs:

Subcases:

- Summer
- with blinds
- ventilation: a) unvented; b) vented *from outdoor to indoor*

a) unvented:

```
--- Split U-value ---

 Uconv                                    :    0.393        [W/m2.K]
 Uir                                      :    0.627        [W/m2.K]
 Uvent                                    :    0.000        [W/m2.K]
                                            ----------------- +
 Utotal                                   :     1.02        [W/m2.K]


--- Split solar factor (g) into fractions ---

 solar direct transmittance               :    0.121        [-]
 solar factor convective                  :    0.106        [-]
 solar factor thermal radiative ir        :    0.193        [-]
 solar factor ventilation                 :    0.000        [-]
                                            ----------------- +
 solar factor (g)                         :    0.420        [-]
```

b) vented from outdoor via cavity to indoor

```
 --- Split U-value ---

 Uconv                                    :    0.873        [W/m2.K]
 Uir                                      :     1.40        [W/m2.K]
 Uvent                                    :     3.49        [W/m2.K]
                                            ----------------- +
 Utotal                                   :     5.77        [W/m2.K]


--- Split solar factor (g) into fractions ---

 solar direct transmittance               :    0.121        [-]
 solar factor convective                  :   0.0668        [-]
 solar factor thermal radiative ir        :    0.117        [-]
 solar factor ventilation                 :    0.162        [-]
                                            ----------------- +
 solar factor (g)                         :    0.467        [-]
```

Note that U_{conv} and U_{IR} are increased by the ventilation, while g_{conv} and g_{IR} are decreased.

Note that:

- application of the equation using the heat exchange efficiency requires input on the air flow rate;
- as stated before (see above) the split between dark and solar recuperation is not self evident

Relation with U and g:

To be further completed in future

3. Energy balance of the window/façade itself

3.1 Main energy flows

The energy flows in the previous chapter present the ***effect of the window/façade on the energy balance of the room***.

From the interest in the properties of the window/façade, we are interested in the **energy balance of the window/façade itself**, as a system.

Although some of the energy flows are the same as those presented for describing the energy exchange with the room, there are a few differences.

The main applications of the analysis of the enrgy balance of the window itself are:

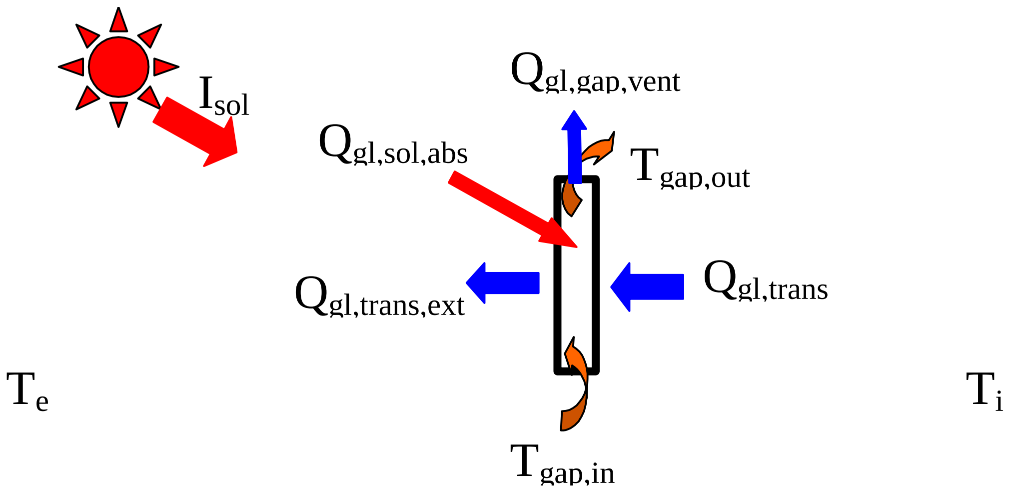
- To understand the relative sizes of the different parts of the energy flow, which will help to understand the performance of the window/façade
- To be able to compare calculation results with results from measurements or other calculations, at the level of the different components (model validation and development)
- To check the energy balance of the window, for the optical part and the thermal part (verification)

The optical part of the energy balance is simply given by:

Incident solar radiation = transmitted solar radiation + reflected solar radiation + absorbed solar radiation .

The thermal part of the energy balance is given by:

$Q_{gl,sol,abs} + Q_{gl,trans} - Q_{gl,trans,ext} - Q_{gl,gap,vent} = 0$



$\mathbf{Q_{gl,trans}}$ **:**
(known already from the energy exchange with the room)
is the net transmission heat flow from room to window/façade (if negative value: net gain) induced by convective and thermal radiativen heat exchange from the room to the window/façade, influenced by indoor-outdoor temperature difference (positive influence if indoor temperature higher) and by absorbed solar radiation (negative contribution: from window/façade to room).

$\mathbf{Q_{gl,gap,vent}}$ **:**
$Q_{gl,gap,vent}$ is the net ventilative heat gain in the cavity, from inlet to exit, under influence of indoor-outdoor temperature difference and absorbed solar radiation; if positive: more heat leaves the cavity exit than has been brought in at the inlet.

$\mathbf{Q_{gl,trans,ext}}$ **:**
$Q_{gl,trans,ext}$ is the net transmission heat flow from the window at the outdoor surface, under influence of indoor-outdoor temperature difference (positive if indoor temperature is higher) and absorbed solar radiation (positive).

$\mathbf{Q_{gl,sol,abs}}$ **:**
The heat gain by solar radiation absorbed in the window system.

3.2 Equations

The optical part of the energy balance is simply given by:

τ_{sol} : the direct (short wave) solar transmittance
ρ_{sol} : the solar reflectance
$a_{sol,abs} = \Sigma\ (abs_i)$: the sum of the absorption fractions in all layers of the window system.

$\mathbf{Q_{gl,trans}}$ **:**
See paragraph 2.2.

$\mathbf{Q_{gl,gap,vent}}$ **:**

$Q_{gl,gap,vent} = \rho * c_p * \phi_v * W * (T_{gap,out} - T_{gap,in})$

where:
ρ is the volumetric density of air = 1.21 * 273 / (273 + T_{gap}) (kg/m^3K) (with T_{gap}: the mean temperature in the gap)
T_i is the indoor environment temperature (°C)
$T_{gap,in}$ is the temperature of the air at the inlet of the cavity (°C)
$T_{gap,out}$ is the temperature of the air at the exit of the cavity (°C)
c_p is the thermal capacity of air = 1010 J/(kgK)
ϕ_v is the cavity air flow (m^3/s per m window width[4])
W is window width (m)

Note: if positive: more heat leaves the cavity at the exit than enters the cavity at the inlet.

$Q_{gl,trans,ext}$:
Simple case:
$Q_{gl,trans,ext} = (h_{ce} + h_{re}) * A_{gl} * (T_{gl,se} - T_e)$

Where:
h_{ce} is the outdoor convective heat transfer coefficient ($W/(m^2K)$)
h_{re} is the outdoor radiative heat transfer coefficient ($W/(m^2K)$)
A_{gl} is the area of the transparent part of the window/façade (m^2)
T_e is the outdoor environment temperature (see earlier footnote and Annex 1) (°C)
$T_{gl,se}$ is the outdoor surface temperature of the window (°C)

Note: this 'standard' equation for convective and radiative heat flow from room to window can become more complicated due to infrared transparent layers, such as porous or venetian blinds.

$Q_{gl,sol,abs}$:
The amount of solar radiation absorbed in the window system.
$Q_{gl,sol,abs} = \Sigma (abs_i) * A_{gl} * I_{sol}$

Where:
$\Sigma (abs_i)$ is the sum of the absorption fractions in all layers of the window system.

3.3 Definition of characteristic (h- and a-) components

To avoid confusion with U- and g-value components that are related to the heat exchange between window and room, we define here (***new!***)

[4] The flow rate is given per m width of the window, to emphasize that the ventilation assumes vertical flow movement and is homogeneous in horizontal direction; consequently, in WIS the result of the transparent system with vented cavities does not change with the given width of the transparent system.

h is the coefficient of heat transfer induced by indoor-outdoor temperature difference ($W/(m^2K)$).

a is the coefficient of heat transfer induced by incident solar radiation (-).

The optical part of the energy balance is trivial and does not require special definitions.

The h- and a-value components are defined by the following equations:

$h_{trans} = U_{trans}$ (see sections on heat exchange with room)

$h_{gap,vent} = [Q_{gl,gap,vent}]_{dark} / (A_{gl} * (T_i - T_e))$

Note:
$h_{ap,vent}$ ***will be negative*** if the inlet temperature is T_i and T_i is higher than T_e

$h_{trans,ext} = [Q_{gl,trans,ext}]_{dark} / (A_{gl} * (T_i - T_e))$

$a_{trans} = g_{trans}$ (see sections on heat exchange with room)

$a_{gap,vent} = ([Q_{gl,gap,vent}]_{with\ sun} - [Q_{gl,gap,vent}]_{dark}) / (A_{gl} * I_{sol})$

Note:
$a_{gap,vent}$ ***can be negative*** if the air flow is by free convection and happens to be lower with sun, than in case of dark conditions; the *decrease* in air flow rate should be stronger than the *increase* in temperature in the gap.

$a_{trans,ext} = ([Q_{gl,trans,ext}]_{with\ sun} - [Q_{gl,trans,ext}]_{dark}) / (A_{gl} * I_{sol})$

$a_{abs} = Q_{gl,sol,abs} / (A_{gl} * I_{sol})$

Note that if the **inlet air is the room air** one should expect:

$Q_{gl,gap,vent} = - Q_{gl,vent}$

➔ $h_{gap,vent} = - U_{vent}$ (see sections on heat exchange with room)

➔ $a_{gap,vent} = g_{vent}$ (see sections on heat exchange with room)

Reconstruction of the equations, using h- and a-components

If we fill in the h- and a-values we obtain the following equations for the different components in the energy balance:

$Q_{gl,trans} = [h_{trans} * (T_i - T_e) - a_{trans} * I_{sol}] * A_{gl}$

$Q_{gl,gap,vent} = [h_{gap,vent} * (T_i - T_e) + a_{gap,vent} * I_{sol}] * A_{gl}$

Note the plus sign!

$Q_{gl,trans,ext} = [h_{trans,ext} * (T_i - T_e) + a_{trans,ext} * I_{sol}] * A_{gl}$

Note the plus sign!

$Q_{gl,sol,abs} = a_{abs} * A_{gl} * I_{sol}$

3.4 Application to check the energy balance

An elegant check of the energy balance is now possible, by checking the sum of the coefficients, taking the “dark” and “solar” properties separately:

“Dark” properties:

$h_{trans} – h_{trans,ext} - h_{gap,vent} = 0$

Solar optical properties:

$\tau_{sol} + \rho_{sol} + a_{sol,abs} = 1$

Thermal “solar” properties:

$a_{sol,abs} - a_{trans} - a_{gap,vent} - a_{trans,ext} = 0$

Note:
The values of the h- and a-components change with environment conditions (temperatures, amount and incident angle(s)of solar radiation, wind), so the results should be used with care, if extrapolated to other conditions than those used to determine the numbers.
This restriction is not unique for the vented case, but in a vented case the sensitivity may e higher than in the unvented case!

3.5 Numerical examples

Same cases as in the previous chapter:

Subcase:

- Summer
- with blinds
- ventilation: *unvented*

Output from WIS:

```
---- Split all 'dark' heat flow coefficients into fractions (h-
values) ---

 h_conv,indoor                              :    0.393        [W/m2.K]
 h_ir,indoor                                :    0.627        [W/m2.K]
 h_conv,outdoor                             :    0.762        [W/m2.K]
 h_ir,outdoor                               :    0.255        [W/m2.K]
 h_vent                                     :    0.000        [W/m2.K]
                                              ----------------- +
 checksum (expected value = h_indoor - h_outdoor - h_vent = 0) :
0.000        [W/m2.K]


--- Split all solar fractions, optical part ---

 solar direct transmittance                 :    0.121        [-]
 solar direct reflectance                   :    0.230        [-]
 solar absorption fraction layer 1          :    0.227        [-]
 solar absorption fraction layer 2          :    0.000        [-]
 solar absorption fraction layer 3          :    0.149        [-]
 solar absorption fraction layer 4          :    0.000        [-]
 solar absorption fraction layer 5          :    0.250        [-]
 solar absorption fraction layer 6          :    0.000        [-]
 solar absorption fraction layer 7          :   0.0225        [-]

                                              ----------------- +
 checksum (expected value = 1)              :     1.00        [-]

--- Split all solar fractions, thermal part (a-values) ---

 solar absorbed                             :    0.649        [-]
 conv indoor                                :    0.106        [-]
 ir indoor                                  :    0.193        [-]
 conv outdoor                               :    0.258        [-]
 ir outdoor                                 :   0.0916        [-]
 gap vent                                   :    0.000        [-]
                                              ----------------- +
 checksum (abs-others. expected value = 0) : 0.000        [-]
```

Subcase:

- Summer
- with blinds
- ventilation from indoor to ***outdoor or indoor*)***

*): note that the energy balance of the window/façade does not change if the air at the outlet of the cavity(-ies) flows to outdoor or to indoor or to whatever…

Output from WIS:

```
 h_conv,indoor                                  :    0.219        [W/m2.K]
 h_ir,indoor                                    :    0.347        [W/m2.K]
 h_conv,outdoor                                 :    0.936        [W/m2.K]
 h_ir,outdoor                                   :    0.313        [W/m2.K]
 h_vent                                         :   -0.680        [W/m2.K]
                                                  ---------------- +
 checksum  (expected  value  =  h_indoor  -  h_outdoor  -  h_vent  =  0)  :
0.000        [W/m2.K]

--- Split all solar fractions, optical part ---

 solar direct transmittance                     :    0.121        [-]
 solar direct reflectance                       :    0.230        [-]
 solar absorption fraction layer 1              :    0.227        [-]
 solar absorption fraction layer 2              :    0.000        [-]
 solar absorption fraction layer 3              :    0.149        [-]
 solar absorption fraction layer 4              :    0.000        [-]
 solar absorption fraction layer 5              :    0.250        [-]
 solar absorption fraction layer 6              :    0.000        [-]
 solar absorption fraction layer 7              :   0.0225        [-]

                                                  ---------------- +
 checksum (expected value = 1)                  :     1.00        [-]

--- Split all solar fractions, thermal part (a-values) ---

 solar absorbed                                 :    0.649        [-]
 conv indoor                                    :   0.0664        [-]
 ir indoor                                      :    0.115        [-]
 conv outdoor                                   :    0.223        [-]
 ir outdoor                                     :   0.0785        [-]
 gap vent                                       :    0.166        [-]
                                                  ---------------- +
 checksum (abs-others. expected value = 0) : 0.000        [-]
```

Note that, as expected, if the inlet temperature is the room temperature and the air from the cavity flows to indoor:

$h_{gap,vent} = - U_{vent}$:

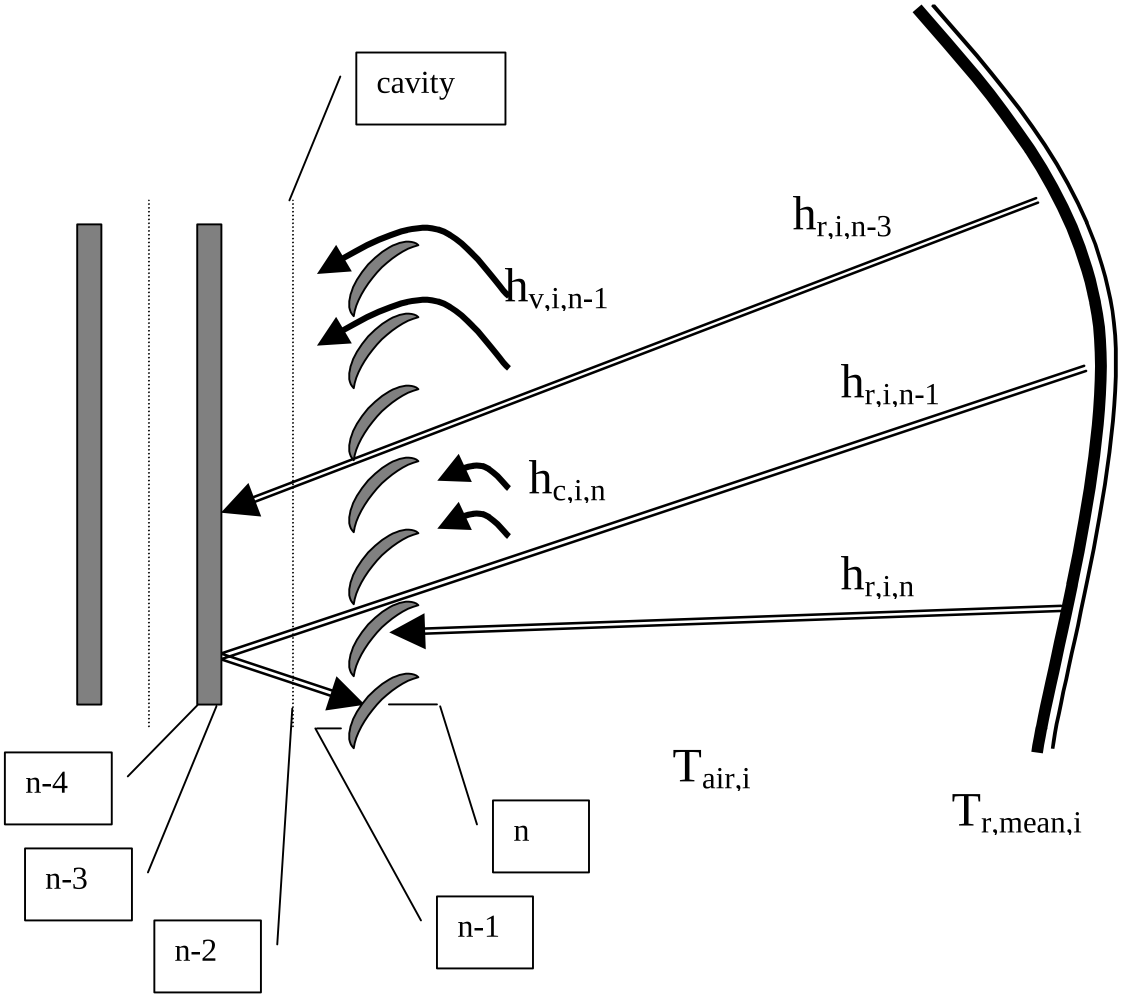
```
 Uvent :    0.680        [W/m2.K]
 h_vent:   -0.680        [W/m2.K]
```

and $a_{gap,vent} = + g_{vent}$:

```
 solar factor ventilation :    0.166        [-]
 gap vent                 :    0.166        [-]
```

Annex 1 Environment temperature in case of ventilated facades/windows

Example: internal venetian blinds:



Heat is exchanged by convection, thermal radiation and ventilation from the indoor environment to the window/façade.
But to be more precise:
Heat is exchanged by radiation between the mean indoor radiant temperature and the surfaces of the window/façade "seen" from the indoor environment. In case of indoor venetian blinds this includes:

- the room facing surface of the blinds
- the pane behind the blind (seen through the openings in between the slats, but also seen after reflection at the slats
- the outdoor facing side of the blind, after multiple reflections

Heat is exchanged by convection and ventilation to the indoor facing surface of the blind and the cavity between the blind and the pane.

The indoor environment temperature is defined as the equivalent indoor temperature that gives the same heat exchange with the window/façade as the separate air and mean radiant indoor temperatures.
In equation:

$$q_i = \sum_{j=1}^{n} h_{ij} (T_{env,i} - T_j)$$

with j: any plane in the window j = 1,..,n as illustrated in the figure.

Without changing anything we can split the equation into radiative components (k) and convective/ventilative components (l):

$$q_i = \sum_{k=1}^{n} h_{r,ik} (T_{env,i} - T_k) + \sum_{l=1}^{n} h_{cv,il} (T_{env,i} - T_l)$$

This equation should be the same as the equation describing the physical process:

$$q_i = \sum_{k=1}^{n} h_{r,ik} (T_{r,mean,i} - T_k) + \sum_{l=1}^{n} h_{cv,il} (T_{air,i} - T_l)$$

This means that we can write:

$$T_{env,i} = \frac{\sum_{k=1}^{n} h_{r,ik} T_{r,mean,i} + \sum_{l=1}^{n} h_{cv,il} T_{air,i}}{\sum_{k=1}^{n} h_{r,ik} + \sum_{l=1}^{n} h_{cv,il}}$$