

Thermal and solar modelling and characterisation; the role of IEA SHC Task 27

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Introduction

The objective of Subtask A (“Performance”) of IEA SHC Task 27 “Solar Façade Components” is to further develop, structure and integrate the energy performance assessment methodology for windows and other solar building envelope components. Such a methodology will facilitate selection of components and enable comparative performance to be made. Particular emphasis is given to the assembly and integration of high performance, novel and/or complex solar components into functional building envelope elements. Those assemblies may incorporate highly insulating glazings/frames, anti-reflecting or chromogenic switchable glazings, PV windows, solar shading devices and other daylight components. The work intends to directly support manufacturers in improving product characterisation and specification. But also provide the necessary links to building simulation and building performance characterisation.

Buildings are one of the largest energy consuming sectors. While thermal insulation and more attention for reducing infiltration and controlled ventilation have helped to already strongly reduce fossil energy needs, the impact of windows and facades is becoming more and more important. This is particularly the case because the façade combines many vital functions of the building (aesthetics, view through, daylight, protection against noise/sun/cold/wind, safety, ...) which asks for properties that are easily conflicting and time variant, both diurnal and seasonal.

Consequently, the energy performance of a window or façade element cannot be isolated from the performance of the building, with its occupants, environment and (HVAC) systems.

However, performance assessment at the building level is not the prime topic of research within Task 27. In particular, because there are a wide number of “barriers” on the component and assembly level that need to be removed, because they block or misguide further steps on the higher aggregation level.

In Task 27, subtask A we try to find a good balance between both aspects.

In general we can make the following, arbitrary but practicably useful, distinction in aggregation levels, see figure 1.

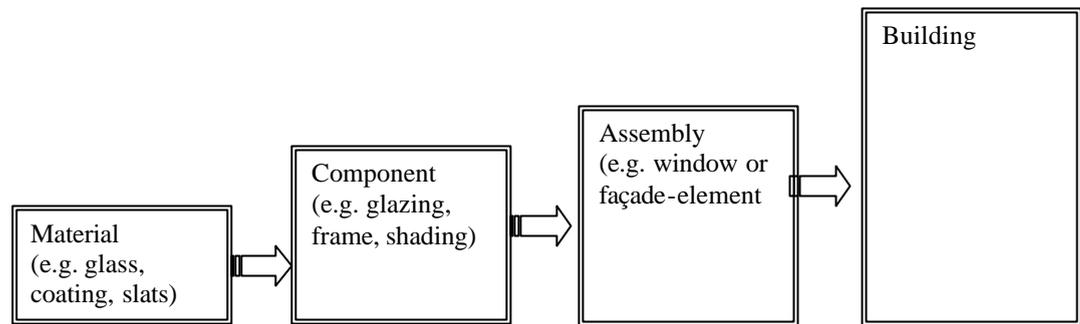


Fig. 1 Illustration of successive aggregation levels

Properties and performance

Ideally, at each aggregation level we can define the **properties** that are relevant for the energy performance and the performance for other functions affected by the choice of the product.

For instance at material level the thermal conductivity and spectral optical properties; at component level the U-value and solar and light transmittance, at assembly level the linear thermal transmittance and at the building level the specific transmission heat loss, etcetera.

And at each aggregation level we can determine the **performance** for the functions that are relevant at the given level. Of course we do that application oriented. We keep the end use in the building in mind and of course we don't forget which functions are relevant for e.g. transport and mounting and for demolition.

That is the theory. In practice the determination of the relevant properties is an ongoing process, dictated by the most urgent needs at certain moment in practice. Properties often serve directly as performance indicators and are too poor to be used in another context. For instance, we would like to see the thermal conductivity as a universal property that we could carry through the chain from left to right despite the required performance. But already this basic property is in many cases subject to variations due to moisture, temperature, mounting and degradation. Another example are the spectral solar properties of glazings which are measured and stored for normal incidence angle. For classical glazing types and for the old building regulations and calculation models this was sufficient; a simple correction factor was all that was needed to obtain a value that was representative for a situation in real practice. However, for modern coated glazings the simple correction is no longer evident and certainly for scattering glazings and for solar shading devices such as venetian blinds and diffusing screens additional (angular) properties should be measured and stored as basis for a correct performance assessment.

Figure 2 illustrates the kind of inputs and outputs at the successive aggregation levels. The conditions to obtain the properties are typically (a

range of) standard conditions. The conditions to obtain the performance are either standard conditions (for product comparison) or adapted to the specific situation (for design).

Subtask A is primarily focused on removing the barriers for performance assessment at the different levels.

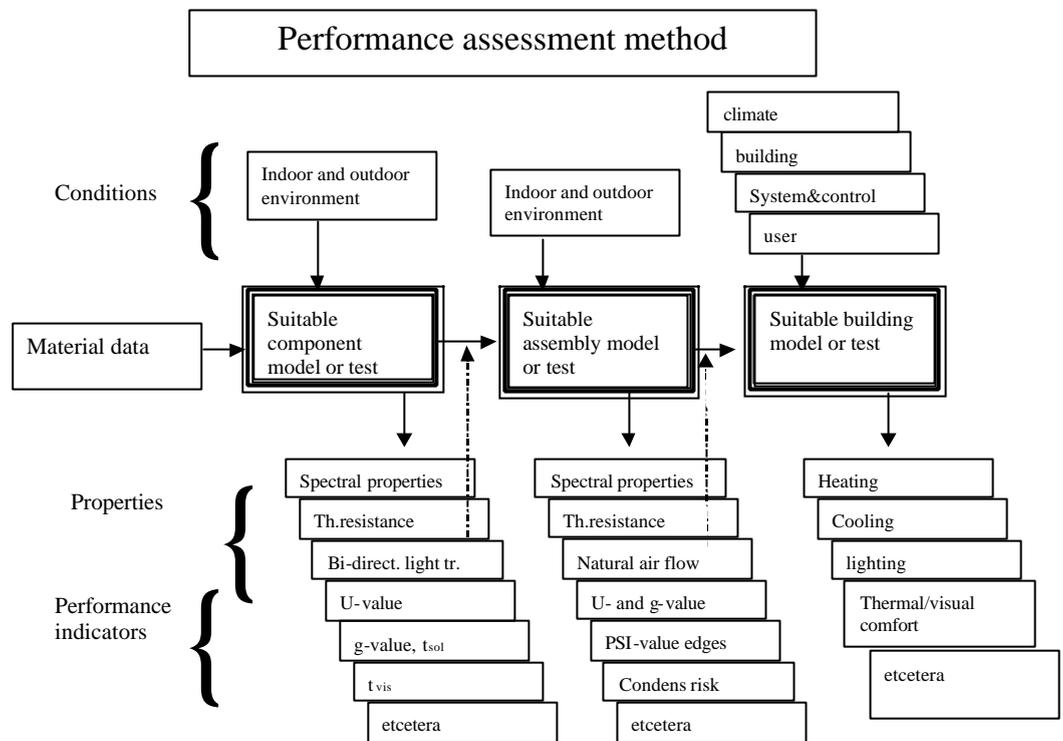


Fig. 2 Examples of properties and performance indicators at different aggregation level

Classification

Already in IEA SHC Task 18 a classification system was developed for different types of advanced glazing components, depending on the type of properties that have to be measured or calculated and stored.

In Task 27 this classification is being further expanded, to include also edges and frames and vented systems (exhaust windows, double facades), see table 1.

Table 1. Solar façade components, some product families with examples

| | product families | Information |
|--------------------|---|---|
| Transparent layer | Clear or coated Specular materials | clear or tinted glass, polymer., coated glass, laminated glass |
| | Diffusing homogenous materials | diffusing tinted glass, diffusing polymer, aerogel, diffusing coated glass or laminated glass |
| | Low thickness Heterogeneous materials | Closed structure: dense solar protection screen, printed glass Open structure: Open solar protection screen Flat or non-flat surface... |
| | | |
| | Geometric media | Closed structure: Multi ribbed wall Open structure: Venetian blinds |
| | | |
| | | |
| Transparent system | Clear or coated Specular system | clear or specular coated complex glazing with or without plastic film inside |
| | System with diffusing or low thickness Heterogeneous materials | system with diffusing or printed pattern, system with static laminated shading blinds |
| | System with transparent insulator materials | system with capillary material |
| | System with fixed or moving blind | system with static laminated shading blinds, system with venetian blinds |
| | System with variable transparent glass | system with electrochrome, photochrome and thermochrome composites |
| Frame, mounting | Multiple glazing edge | Metal or other spacer |
| | Conventional frame | Wood, plastic, metal with thermal break, combi, ... |
| | Wall connection | Window-wall connection |
| | Other.. | |
| | Mixed opaque/transparent | Double skin façade, curtain wall |
| Note: | <i>Grey shaded</i> | = "Conventional" products |

Calculation versus testing and international standards

Calculation of thermal and solar/light product characteristics and the performance in terms of energy and comfort has replaced testing in a range of areas. The advantages of modelling over testing are numerous. As a rule, they are less expensive, better replicable, faster and more flexible. However, the validity of the output depends on the quality of the measured input, on the suitability of the model for the type of product being investigated (including verification by appropriate experiments) and the expertise of the user.

The number of international standards defining **test methods** for thermal and optical **material and component properties** is slowly increasing to include (some of) the more complex classes (table 1) of products. The

output of the tests should be applicable as basic product information as well as to serve as input for modelling at higher aggregation level and for obtaining specific performance indicators. The latter is however not always evident. It comprises e.g. (guarded) hot plate tests for flat and homogeneous multiple glazings (R-value; EN 674/5, ISO 10291/3), hot box tests for windows (U-value, ISO 12412) and spectral solar and thermal properties of clear or coated specular glazings. Not standardised are equipment used by research institutes (between brackets some relevant international RTD projects), such as large integrating spheres for optical properties of macro-elements (IEA18), goniophotometers for bi-directional optical properties of heterogeneous media (IEA21, EU REVIS), angular solar and thermal radiation properties of coated glazing (EU ADOPT resp. THERMES) calorimeter-boxes for total solar energy transmittance (EU ALTSET) and outdoor test cells for net heat gain through façade-elements (PASLINK/IQ-test), etc.

With input from leading research groups the number of international standards defining **calculation methods** to characterise **glazing and window assemblies** is steadily increasing, allowing more complex products to be modelled and compared. Again, attention is needed whether the output can or cannot be used as product information and/or as input for building simulations, window energy rating, visual comfort or other performance indicators. Examples are standards for U-value of frames and linear edge transmittance (EN-ISO 10077-2), for U-value resp. solar and light transmittance of multiple glazings (EN 673, ISO 10292 resp. EN 410, ISO 9050) and recently for whole window systems including frames and solar shading devices (ISO/FDIS 15099).

Recently, more and more attention is given to the **harmonisation of product data and the formats** for populating databases for use in (also harmonised) calculation tools. For instance the international (non-scattering) glazing database by LBNL, and the current EU Thematic Network WinDat that also includes development of formats for scattering glazing, shading devices (e.g. venetian and roller blinds), glazing edge spacers and frames, and that includes the further development of a uniform European software tool WIS to calculate the properties of any assembly of such components.

Ideally, the façade component is evaluated as an integral part of the building for the purpose of evaluating the effects of that component on the energy use and other indices of the building. The ancillary effect is how the building and building systems affect the component itself (e.g., forced air heating and cooling systems usually increase the rate of heat transfer from the indoor surface of a window, therefore affecting its thermal performance), and how are those effects in turn affecting back the performance of the whole building. Obviously, some of these effects are occurring simultaneously and cannot be separated, but the analysis of all of them would be prohibitively expensive. This is true now and it is probably true in a near future. Therefore some compromise between accuracy and practicality needs to be achieved.

The rapid development of computer hardware and software technology in recent years has allowed for increased complexity of algorithms and procedures that are used in simulating the performance of building façade components, or thermal performance of whole buildings. Increased complexity until now often meant that user had to deal with complex user

interfaces, which are very cumbersome and requiring arduous and time-consuming data preparation process (pre- and post-processing). In addition, various stages of building design and analysis were disconnected, requiring the user to re-enter most of the data necessary to do analysis. With the increased performance of computers, better understanding of the physics of the problem, and utilizing interface standards, it is possible to develop computerized procedures that incorporate very complex algorithms and inner structures, but with very friendly and cost effective user interfaces. The purpose of the work within Task 27 is to push the frontiers of knowledge and science in building energy performance field, and to develop viable methodologies that can be programmed into useful tools for use in building technologies.

On the other hand we have to be careful when we try to implement complex algorithms at a high aggregation level (façade, building) to be used within the constraints of building regulations, such as energy performance (EU ENPER) or comfort. Objectivity and traceability become problematic if the tools are complicated, e.g. when combining dynamic behaviour of building elements, HVAC system, controls, climate and user pattern.

Research topics

The areas that need further attention due to deficient existing methodologies or lack of data are for instance:

- a) Solar radiation exchange and effect of scattering on solar shading devices
- b) Local convection heat transfer in sloped and wide spacing façade cavities
- c) Free or forced convection and associated heat transfer around solar (e.g. venetian) blinds or screens
- c) Thermal bridge effect at window/wall connections and around complex frame profiles (double envelope facades)
- d) Development of additional performance indices
- e) Feed back from calculated building performance to properties on the component level
- f) Emerging technologies (integrated PV windows, switchable glazings, novel daylight products)

Task 27 deals with these and other topics, thus filling in specific gaps in the knowledge that currently prohibits proper assessment of the performance of solar facades. Without trying to be complete, in the following some topics will be briefly introduced. Some topics are extensively dealt with in separate presentations and are therefore skipped here.

Solar shading devices

One of the projects within Task 27-A is solar shading devices.

This topic covers e.g. venetian blinds (diffuse or specular, opaque or translucent), pleated or roller blinds and re-directing shading elements. They may be applied at the indoor surface, outdoor or in cavities, either vented (free or forced) or unvented.

The project comprises for instance inter-laboratory comparison of calculation of thermal and solar properties and comparison with measured data from laboratory and outdoor tests. It involves heat transfer associated with free or forced convection and the suitability or need to expand current calculation methods (e.g. ISO 15099) with CFD or other more detailed techniques. It also concerns the directional solar radiation properties depending on specular, scattering or diffuse reflection at surfaces and in case of scattered transmission, the effect on the required measurement techniques and the need to expand current calculation methods (again, e.g. ISO 15099) e.g. with ray tracing or other more detailed techniques.

The performance of solar blinds may be strongly dependent on the angle of the incident solar radiation.

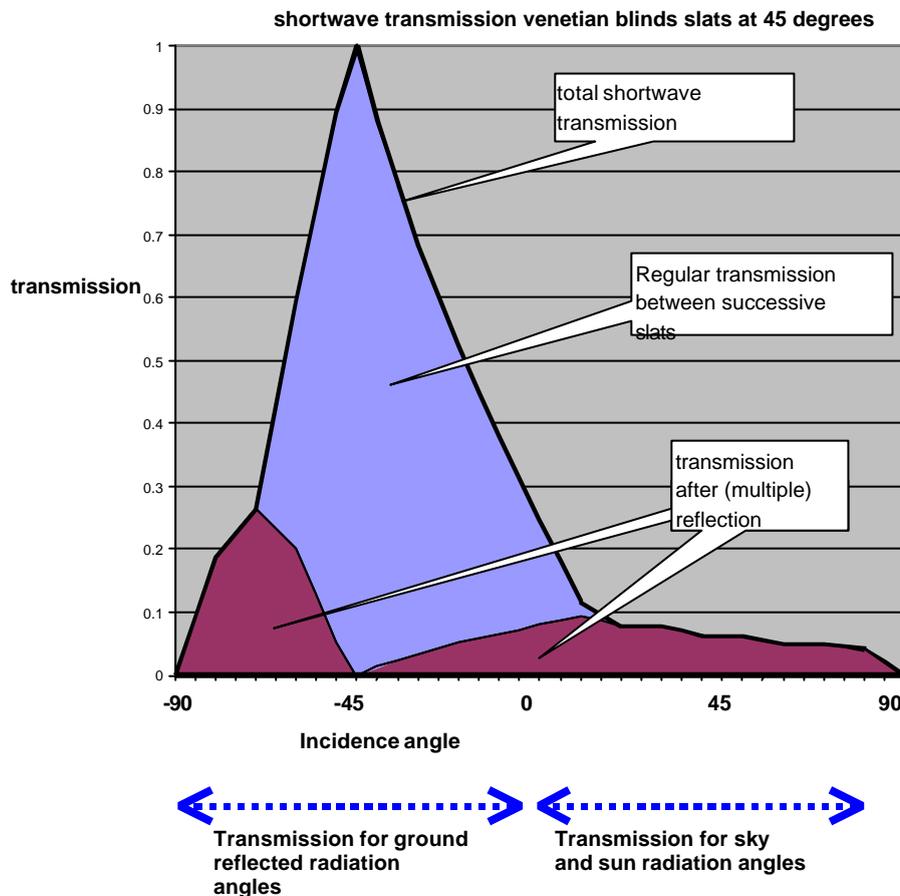


Fig. 3 Effect of incidence angle on solar transmission of venetian blinds

As figure 3 illustrates, the transmission for low and below horizon (=ground reflected) solar radiation may have a strong impact on the actual g-value, despite the relatively low radiation levels involved.

Example:

Example: external white blinds, double glazing:

- $g(0^\circ) = 0.111$
- $g(45^\circ) = 0.045$
- $g(\text{diff}) = 0.196 (!!)$

$g(\text{weighted } 45^\circ:\text{diff}=3:1) = 0.083.$

More detailed study is needed on the spatial distribution of incident solar radiation and its impact on the solar transmittance and the influence on the reported performance of a product. Examples are given in the next illustrations.

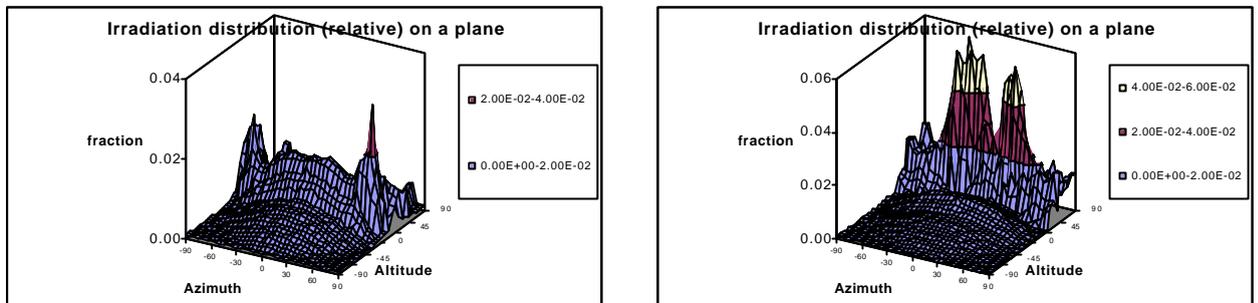


Fig. 4 Example of irradiation distribution (relative scale): South Façade, July. Left: De Bilt (NL); right: Nice (F)

Double envelope facades

The properties of double envelope facades are investigated by comparison of calculation results, applied on a number of different configurations, with and without blinds, with free and with forced ventilation, for the different options of air flow direction: indoor->indoor (winter) and indoor->outdoor or outdoor->outdoor (summer). Preliminary results are being analysed to see the causes for differences.

A particular item is the proper definition of U-value and g-value in case of vented systems. The following figures illustrate the need and proposal to split up the thermal and solar transmission into a part transmitted through the façade itself (tr) and a part through the vented air cavity (v). It further depends whether the interest goes to the heat balance of the room or the heat balance of the façade element. In the latter case the heat exchanged in the gap (gap) is more relevant than the heat exchanged between the cavity and the room (v).

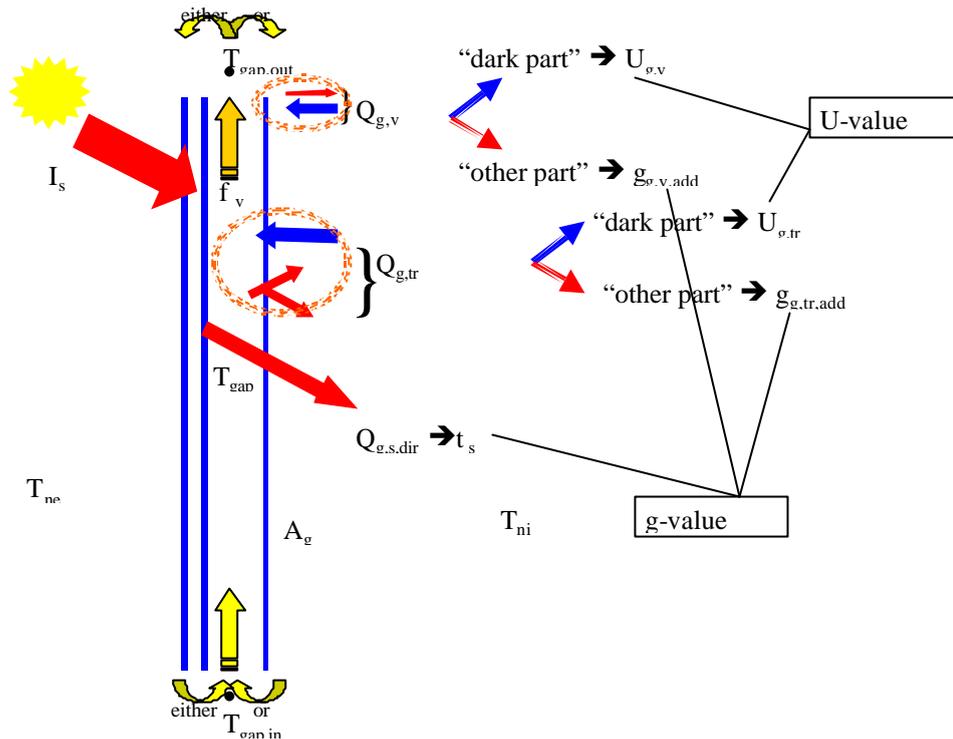


Fig. 5 Main heat exchange elements of vented façade with room.

Without going into the details of the full equations, we can say that the net heat flow from room into glazing system or façade, driven by indoor-outdoor temperature difference and by incidence solar radiation. And that we split up into separate parts:

- Heat loss by transmission from room (in-)to glazing system, including heat gain by indirect (secondary) solar gains.
- Heat gain by direct (short wave) solar transmission.
- Heat exchange via vented air (zero if not blown into room), as net effect of solar radiation and temperature difference.

Which provides us with a corresponding split in U- and g-value that allows us to calculate easily the heat exchange with the room for different circumstances and venting modes.

The next figure shows the split into two parts if we are interested in the heat balance of the facade element itself. This is in particular relevant when comparing or analysing results from tests or calculations.

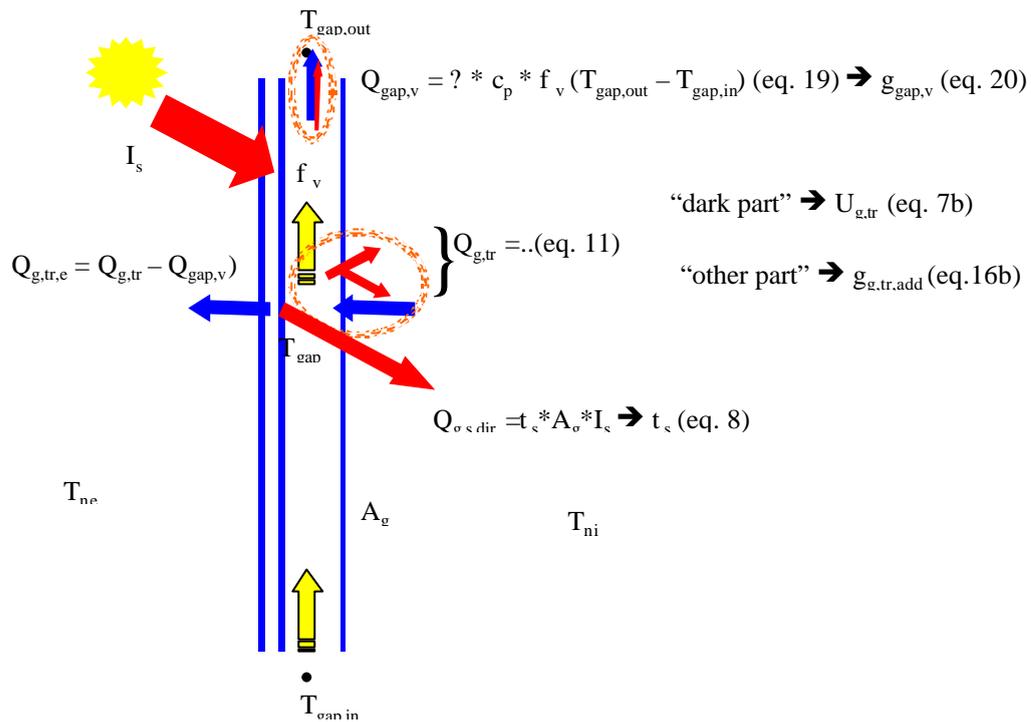


Fig. 6 Heat balance of glazing system.

The study on double envelope facades also includes detailed dynamic building simulations (see Reference Building), which are yet to be analysed and compared.

Window wall connections

The connection of the window to the wall, but also the interconnection of segments of façade elements may lead to serious extra heat losses often neglected in the calculations. It also may involve self-shading effects with respect to the solar and light transmittance.

Inter-laboratory comparisons of calculations are being made on typical designs that demonstrate the need for more attention to this topic in design and standardisation.

Window energy rating

The subject of Task 27 in support of energy rating and labeling is in the development of algorithms and methodologies and harmonised product information and not in defining how to set up successful rating and labeling system.

In this respect it is worthwhile to distinguish 4 different levels:

Level 1: Basic properties. Characterize physical properties (U, g, t_v, BDTF, etc.)

Level 2: Simple energy labelling. Net energy gain for heating season.

Level 3: Reference rating showing effect on heating demand and cooling demand (e.g. with and without additional shading and/or ventilation) for local reference building and reference climate

Level 4: Detailed rating based on heating and cooling demand (and indoor temperature?) for specific building and specific climate

IEA27/Swift reference office building

To facilitate the interlaboratory comparison of results from building simulations a reference office building was developed for thermal, solar and (day-)lighting calculations.

The specifications were developed Task 27 in collaboration with the EU Swift RTD project on visual comfort aspects of switchable glazings.

The reference office is an expansion from the reference office room specified and used within EU REVIS project for daylight and visual comfort studies (see e.g. fig. 4).

The building is a middle-size office building with office modules aligned on two facades, separated by a central corridor, with staircase/service spaces at both ends of the building.

The office building comprises 210 office modules, distributed over 7 floors and 2 orientations: 15 office modules per floor at each of the two orientations.

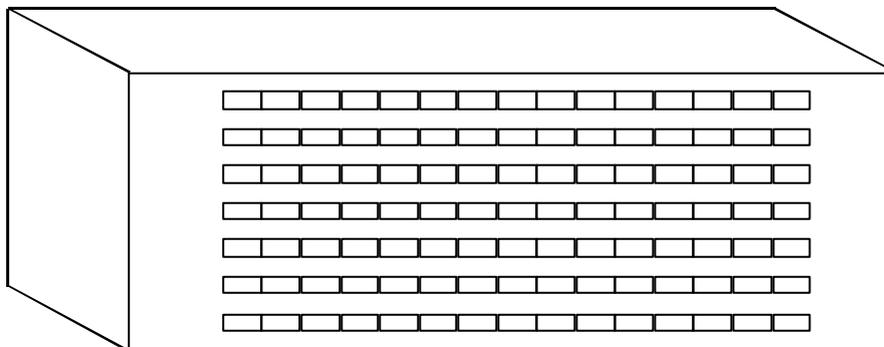


Fig. 7 Front view on IEA27 reference office building.

The reference building specifications contain not only the geometries and construction details, but also the details on air infiltration and ventilation, selected climates, occupation schedule, HVAC system and control, plus specific details for visual comfort studies, etc.

The list of specifications concern:

- Location
- Orientation
- Building geometry
- Zoning
- Material

- Thermal insulation
- HVAC and control
- Facade
- Occupants

However, one reference case would only satisfy the average need. Consequently: would not satisfy anyone. To avoid a wild-growth in variations on the reference case a number of base case variations are defined as well.

The number of base case variations may expand in the future, depending on the needs for specific studies within the IEA 27 or EU Swift or other international projects where the use of this reference building is also considered.

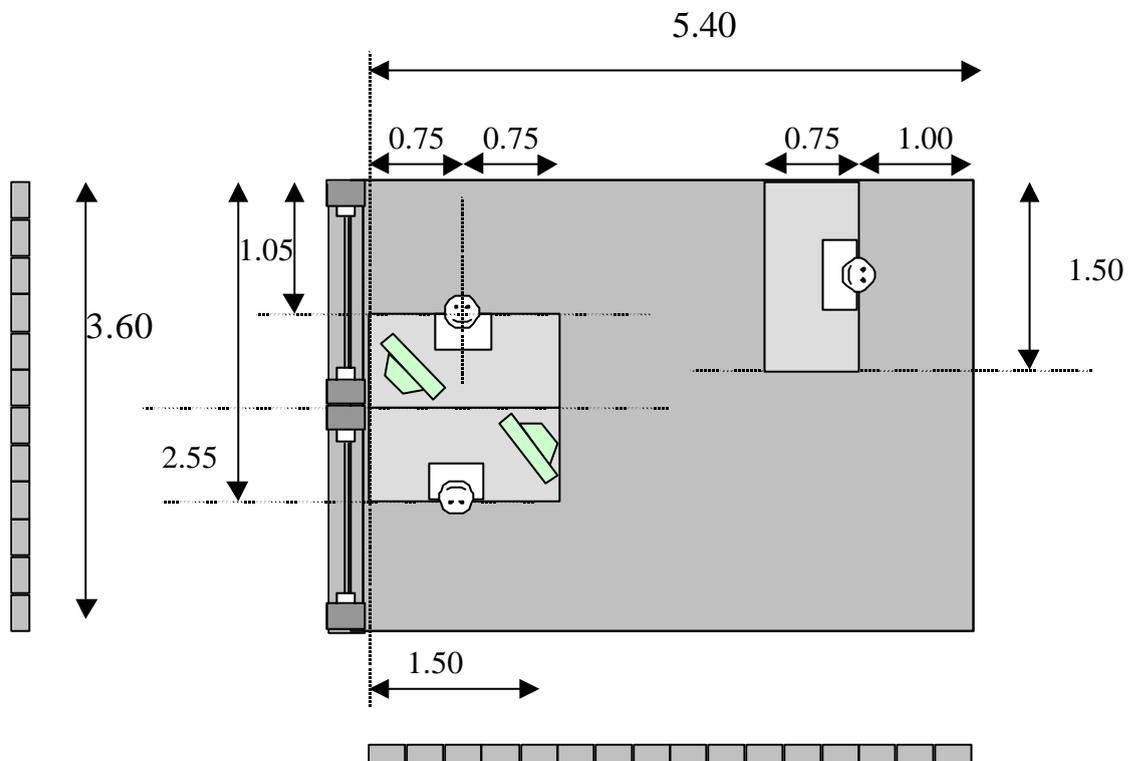


Fig. 8 Details of office module for daylight and visual comfort studies.

Thermal comfort under direct solar radiation exposure

In common practice today the operative temperature is measured and calculated for a location in the shade. Short wave radiation on the body due to the sun is not included. The operative temperature at the workplace if exposed to direct solar radiation could be many degrees higher than the air temperature, leading to poor thermal comfort. This negative effect on the

thermal comfort for facades without proper solar protection devices is normally not taken into account. One of the activities within IEA Task 27 is to discuss this gap between theory and reality and to propose an improved assessment method and define which extra component properties are required.

Disclaimer

The presentation is based on ongoing research activities within IEA SHC Task 27-A and associated activities. It intends to highlight some topics under investigation, rather than giving a complete overview. Moreover, the presented material is still under discussion. A more complete and final overview will be presented in the final reports of Task 27.

Acknowledgements

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For further information on IEA SHC Task 27, see the presentation of the Task 27 overview by Michael Koehl.

References

This paper contains numerous quotes from IEA27 Subtask A working documents by several authors, as well as references to related international projects and standards. Proper referencing will be provided in the final report of Subtask A.