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BuildingCalc
LightCalc
Users guide for version 2.5.2

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Contents

1   Introduction

BuildingCalc (thermal simulation) is a simple tool developed in Matlab useful for calculation of solar radiation on sloped surfaces and simulation of thermal conditions in a room.

The solar radiation on sloped surfaces may be corrected with regard to obstructions blocking the direct solar radiation. Diagrams showing sun path and obstructions may be viewed and exported. The results of the solar calculations may be exported to Matlab workspace or text files as hourly reference years for further investigations.

The simulation of thermal conditions in a room is based on a simple thermal model of the room. The building constructions are simply defined by an overall UA-value, the effective heat capacity and internal surface area. Transmitted solar energy is based on simple window input. The systems in the building include heating, cooling, ventilation with variable air volume and heat recovery, venting and variable solar shading. Internal loads may be given for the room. The systems are controlled by different settings when the building is in use and when the building is not in use. The results of the simulation may be plottet, exported to Matlab workspace on an hourly basis and exported to a text file with monthly values for heating, cooling and hours with indoor air temperature above the cooling setpoint.

LightCalc (daylight simulation) is similarly to BuildingCalc a simple tool developed in Matlab. The program is capable of estimating daylight levels in a room under different sky conditions and with regard to obstructions blocking parts of the sky.
The program is based on the radiosity method and the results may be presented with coloured plots.

BuildingCalc + LightCalc (BC+LC) are a combination of the features of BuildingCalc with the features of LightCalc.
This means that the LightCalc routines are called within BuildingCalc to estimate the daylight levels with regard to a shading control and consequently increase or decrease in the electrical light levels.
The program executes the routines in an iterative manner to account for the exstra heat gain from the electrical lighting.

BuildingCalc and LightCalc can be used for analysis separately, even though they are integrated into the same graphical user interface. For simplicity the integrated programs as a whole are referred to as BuildingCalc.

2   General instructions

2.1   Starting BuildingCalc

BuildingCalc is developed in and requires Matlab[1] to run. Running BuildingCalc.m in the Matlab workspace as shown in Figure 1 opens the graphical user interface (GUI) shown in Figure 2. The menu item "File" is used to load and save projects.
Browse to your 'current directory', where the BuildingCalc files are located. This will be your working directory (coloured circle on Figure 1). All files generated during the simulation will be located in your 'current directory'.

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[1] The Mathworks, Inc., 24 Prime Park Way, Natick, MA 01760-1500, USA. http://www.mathworks.com
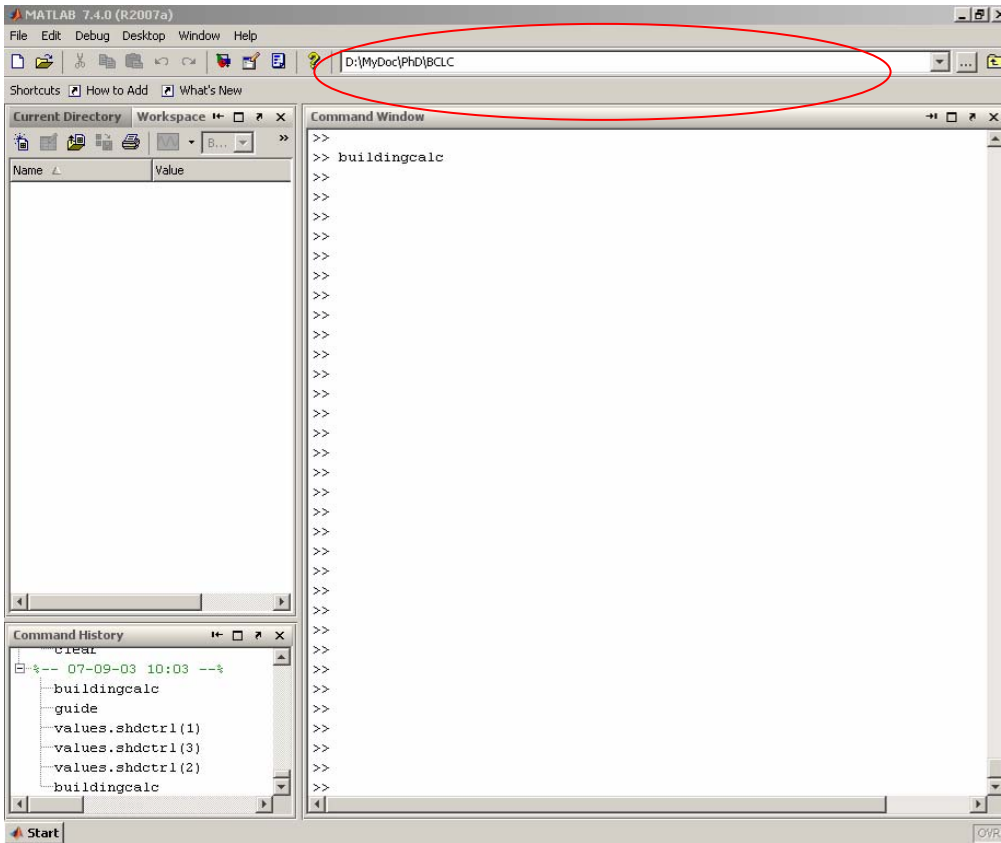
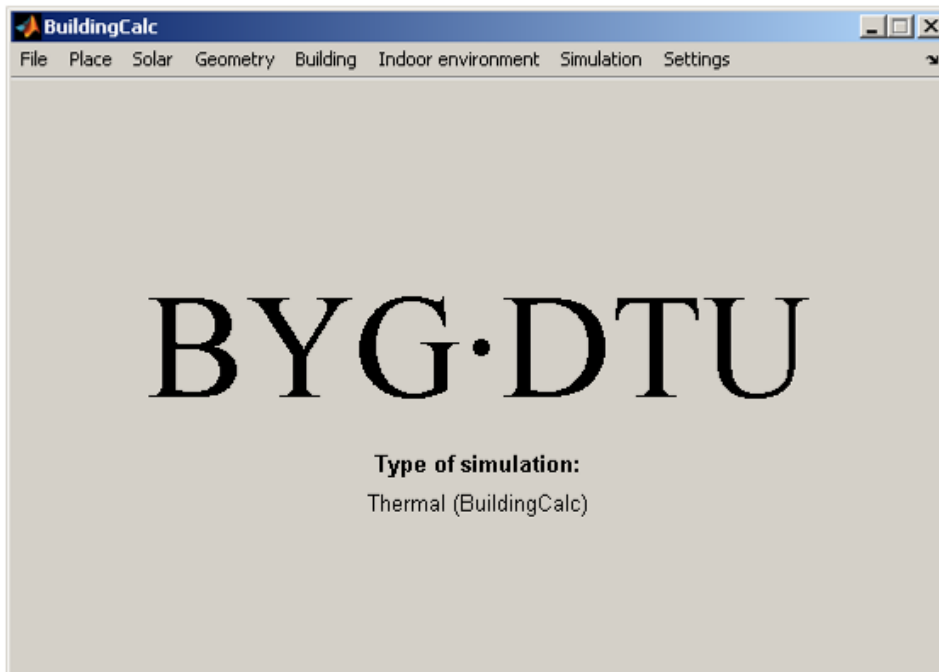Figure 1. Starting BuildingCalc from Matlab.

Figure 2. Opening GUI when running BuildingCalc.m

2.2 Specifying type of project

By default BuildingCalc starts up with the thermal simulation user interface. In order to change the type of project, go to the file menu and specify the desired type of project. The GUI will adjust to comply with the input demands for the chosen type of project.
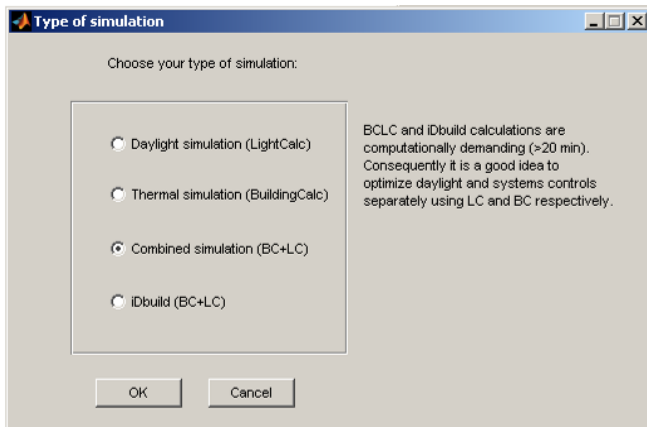
2.3 Specifying location and choosing weather data

Before any calculations can be performed the location and the weather data file must be specified. This is done in the menu item "Place". To specify the location choose the option "Location". The latitude, longitude and local standard time meridian in degrees and the ground albedo as shown in Figure 3 specify the location. The latitude is positive to north and the longitude and local standard time meridian is positive east of Greenwich. The albedo is the solar reflectance of the ground. Default values are entered for Copenhagen.
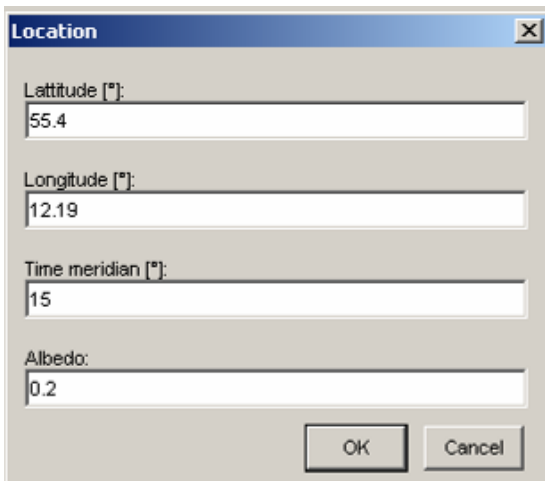

Figure 3. Input dialog for location.

For the given location a weather data file is chosen as shown in Figure 4 by choosing the option "Select weather data". Supplied with the program is the Danish design reference year "Denmark.mat".
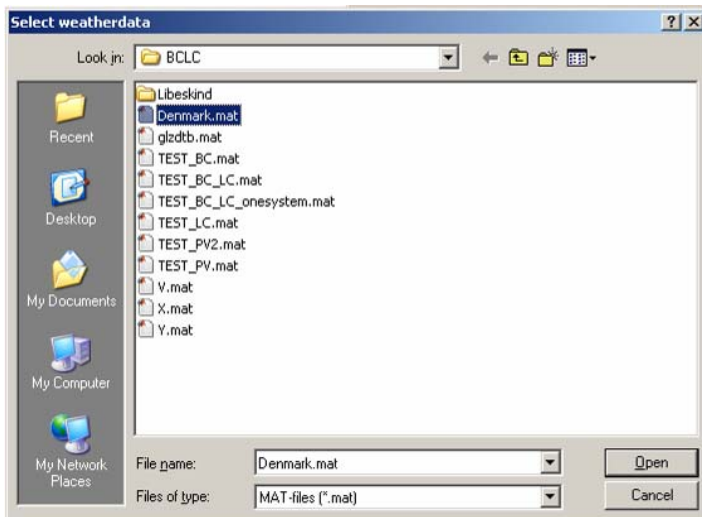
Figure 4. Select weather data file.

3 Calculation of solar radiation

The menu item "Solar calculation" is the entry to calculation of sun path and solar radiation on sloped surfaces and defining shades.

3.1 Sun path

The option "Sun path" starts the GUI used to show diagrams of the sun path. From the menu item "File" the diagram shown in the GUI is exported to a Matlab figure from where the diagram may be saved, printed and in other ways changed from the Matlab workspace. The menu item "Plot" is used to draw the sun path for a single day or all year. If any shades have been entered they can be shown in the diagram by choosing the option "Shades". The shade to be shown is selected from a list of entered shades. The solar azimuth is given in degrees where 0° is south, negative values are east of south and positive values are west of south. The time lines are local standard time. (In periods where the local time deviates from the local standard time e.g. during summer time the local time lines on the diagram must be shifted accordingly. If during summer time the local time is one hour ahead of standard local time the local time lines may be corrected by adding 15° to local standard time meridian. Therefore during summer time changing the local time meridian for Copenhagen to 30° instead of 15° gives the right local time lines on the diagram.)

Figure 5 shows the sun path for Copenhagen.
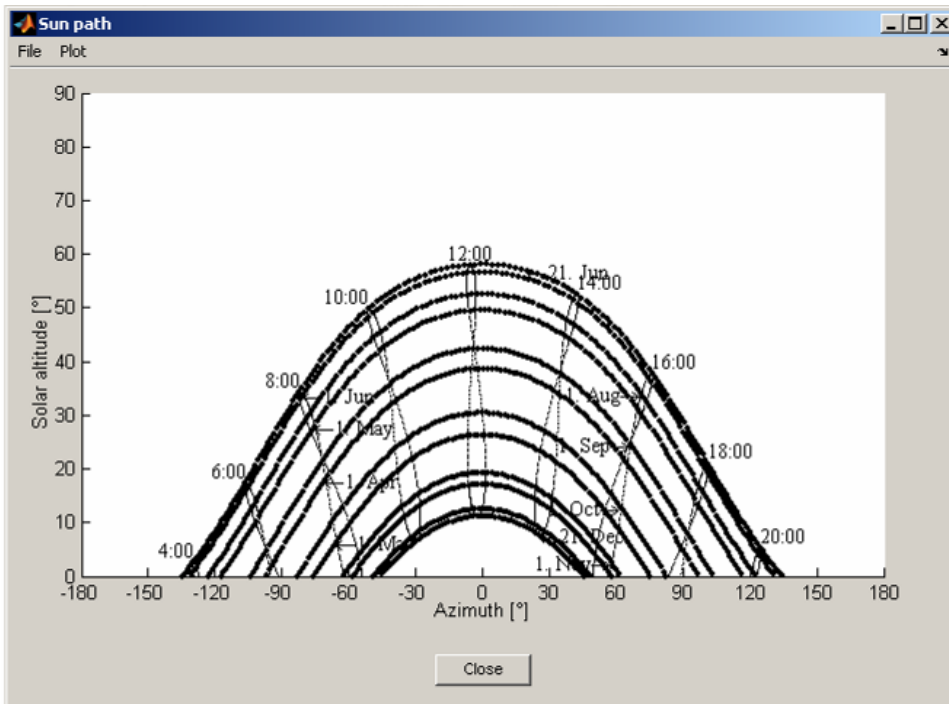
Figure 5. Sun path for all year in Copenhagen.

3.2   Solar radiation on surface

The option "Solar radiation on surface" starts the GUI used to calculate solar radiation on sloped surfaces. Figure 6 shows the GUI with solar data for a vertical surface facing south.
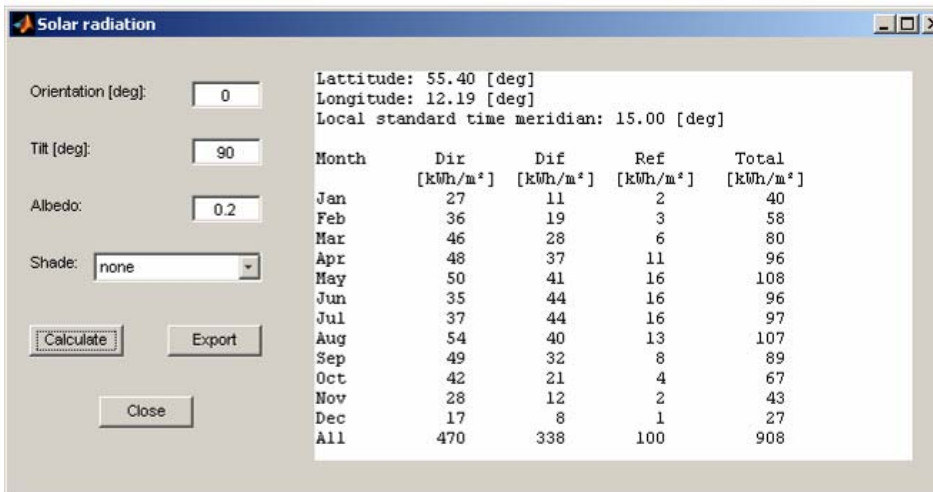
Figure 6. Solar radiation on vertical surface facing south.

The orientation of the surface is entered in degrees where 0° is south, negative values are east of south and positive values are west of south. A surface facing west has an orientation of 90°. The tilt of the surface is 0° for a horizontal facing the sky, 90° for a vertical surface and 180° for a horizontal surface facing the ground. The albedo may be changed in the calculations. (This will not change the albedo for the location and

therefore only influences the actual calculations of solar radiation. Calculations on the building level will use the albedo for the location.). The influence of shades on the solar radiation can be investigated by choosing a shade from the list of shades if any shades have been entered.

The calculations are performed by pressing "Calculate" and may be viewed on the screen for each month divided into direct, diffuse and reflected solar radiation. It is possible to export the results using the "Export" button. The results may be exported as a text report, Matlab reference year and a text reference year. The text report exports a text file containing the monthly values. The other export options give a reference year on an hourly basis with outdoor air and dew point temperatures, solar radiation data for the surface, solar incidence angle on the surface, and horizontal and vertical shadow angle for the surface. The shadow angles can be used to evaluate effects of shades near the surface. The format is either a Matlab variable or a text file and is described in section 10.2. The Matlab reference year is saved as the Matlab variable weather data in the given filename. Together with the Matlab reference year a text file with the same name is generated with the location, orientation and tilt of the surface. The text reference year is saved in a text file where the columns are separated by a single space. Together with the text reference year a text file with the name "head_*filename*" is generated with the location, orientation and tilt of the surface.

Please notice that the calculation method used in this section has the effect that obstructing shades only blocks incident direct light, not diffuse light. In LightCalc direct and diffuse light is blocked by obstructing shades.

3.3 Shades

The option "Shades" starts the GUI used to enter shades for a reference point. Figure 7 show the GUI with two shades entered showing shade 1 in the diagram.
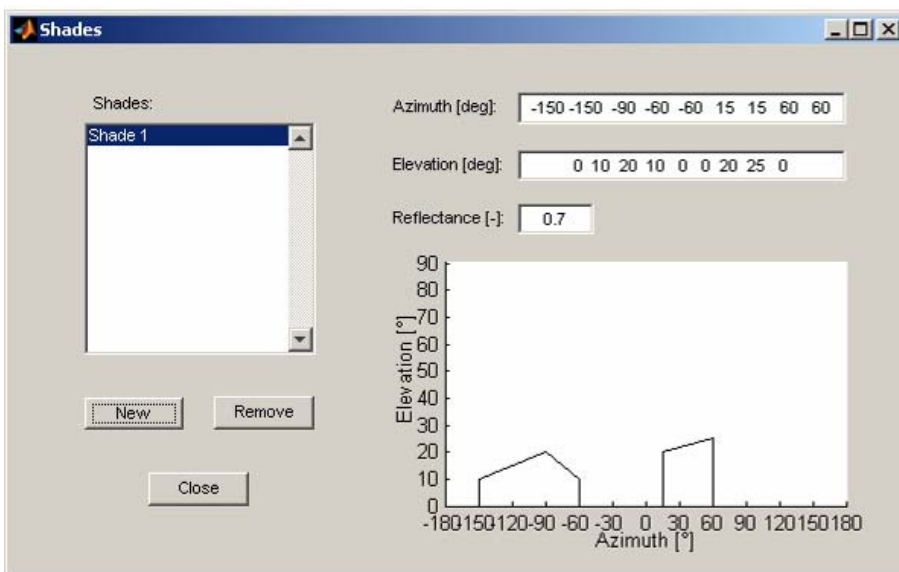
Figure 7. Shades.

Pressing "New" opens a shade dialog. The shade is defined by points of azimuth and elevation. The values are entered as Matlab vectors. Values in the azimuth vector must be larger than or equal to the previous value in the vector. The azimuth of the shade is given in degrees from the reference point where 0° is south, negative values are east of south and positive values are west of south. The elevation is measured in degrees from the reference with respect to a horizontal plane. If the distance from the reference point to an obstruction of height 5m is 20m, then the elevation is atan(5m/20m)=14°.

The reflectance of the obstruction has to be defined for daylight simulations. The reflectance accounts only for one light 'bounce', which means that interreflections between closely spaced facades are not accounted for. In this case the user must reduce the reflectance to a worst-case scenario.

Table 1. Some colours and the corresponding RGB reflectances. The total reflectance is a result of the following formula: $\rho = 0{,}265 \cdot R + 0{,}670 \cdot G + 0{,}065 \cdot B$

Name	Red-reflec.	Green-reflec.	Blue-reflec.	Color	Reflectance
Brown	0,400	0,250	0,050		0,277
White matt	0,800	0,800	0,800		0,800
Tile gray	0,450	0,400	0,400		0,413
Tile light gray	0,700	0,600	0,500		0,620

In figure 7 the input data for shade 1 is shown. Pressing "Remove" deletes the selected shade from the list of shades. The shades in the list of shades can be used in the sun path diagram, the solar radiation calculations and when defining shades for windows in a building.
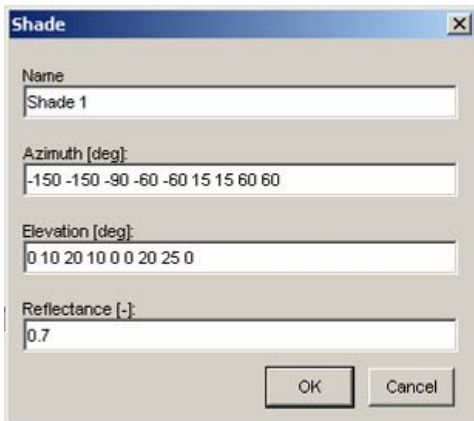
Figure 8. Shade dialog with data for shade 1.

4   Defining building for simulation

The menu item "Building" gives the options for defining the glazing/shading device, windows, constructions and systems in the building.

4.1   Dimensions

The dimensions dialog box specifies the size of the simulated room in internal measures.
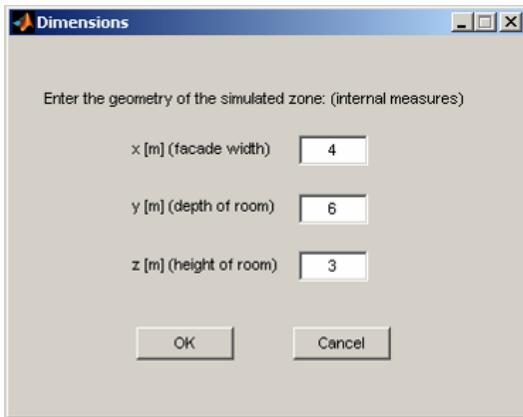
Figure 9. Dimensions dialog box.

4.2 *Window offset*

The window offset dialog box is only applicable for daylight simulations. The values cannot be exact zero. In daylight simulations only one window at a time can be handled.

Figure 10. Placement of window in external wall.

4.3 *Glazings*

The method of defining glazing and shading device depends on the type of project. For a purely thermal simulation in BuildingCalc the amount of input is kept at a minimum. For a simulation involving daylight simulations, the input is somewhat more complex. In the following paragraphs input for BuildingCalc and LightCalc (BC+LC) is described separately.

4.3.1 BuildingCalc

To define a new glazing in Figure 11, fill out the input boxes and press "add". "Remove" deletes your highlighted entry.
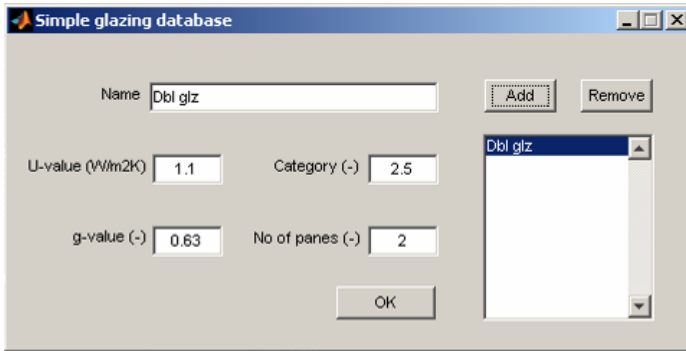
Figure 11. Simple glazing database

The number of panes and glazing category are used to take into account the dependence of the g-value on the incidence angle. The g-value with regard to the incidence angle is calculated according to the method in [Karlsson and Roos, 2000]. In

Table 2 values for typical glazings are given [Karlsson et. al, 2001].

Table 2. Glazing types.

Glazing type	U-value [W/m^{2}K]	g-value	Number of panes	Category
Double glazing	2.9	0.76	2	4
Double glazing with soft low-e coating and argon	1.2	0.63	2	2.5
Double glazing with hard low-e coating and argon	1.5	0.72	2	3.5
TiN, SS, TiN/SS coatings	-	-	-	10
Absorbing glass	-	-	-	1

4.3.2 LightCalc (BC+LC)

The GUI with the advanced glazing and shading devices database can be loaded by selecting "glazings" under "Building". The GUI is shown Figure 13.

The default glazing database can be loaded by pressing "Load database" and choose the 'glzdtb'-file.
All entries in the advanced glazing and shading database consist of at least one set of data for a clear glazing (clear meaning no obscuring shading devices). In addition to the clear glazing a shading device may be defined via more sets of data. All entries are treated as "systems" meaning that the loaded data from the WIS program is defined only for that particular system.

The GUI on Figure 13 consists of several elements: description, thermal properties for direct and diffuse light, visual transmittances for light passing through the system of glazing and shading and database management. The profile angle is the projection of the solar altitude angle on a vertical plane perpendicular to the window.
By choosing the shading position, the thermal properties and visual transmittances will change according to the profile angle. If the user changes the values, remember to press "Update" prior to selecting another shading position or the changes will be lost.
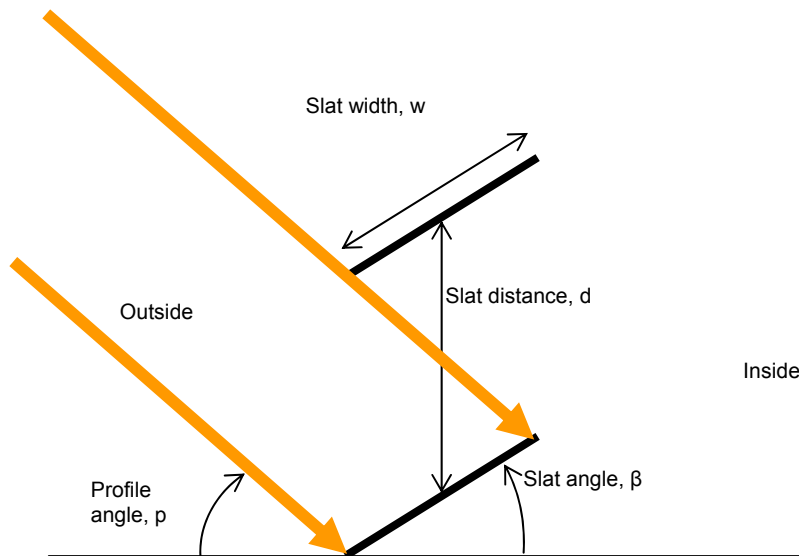
Figure 12. Slat dimensions

The angle dependent visual transmittances are divided into direct and diffuse parts.
- Dir → dir: part of direct light that is transmitted unchanged when it passes the glazing/shading system.
- Dir → dif: part of direct light that is diffused when it passes the glazing/shading system.
- Dir → redir: part of direct light that is redirected by specular shading devices. The angle of redirection is determined by the slat angle. The incident light is only reflected once and not multiple times between the slats. WIS does not currently handle redirected light, so this has to be entered manually.
- Diff, sky: part of diffuse light from sky vault transmitted through the glazing/shading system (replaced by dir→dir within the code)
- Diff, reflec: part of diffuse light from ground transmitted through the glazing/shading system (replaced by dir→dir within the code)

Inner reflectance is the inner reflectance of the glazing and may change in relation to the shading position. Slat angle, β, slat distance d and slat width w are shown on Figure 12.
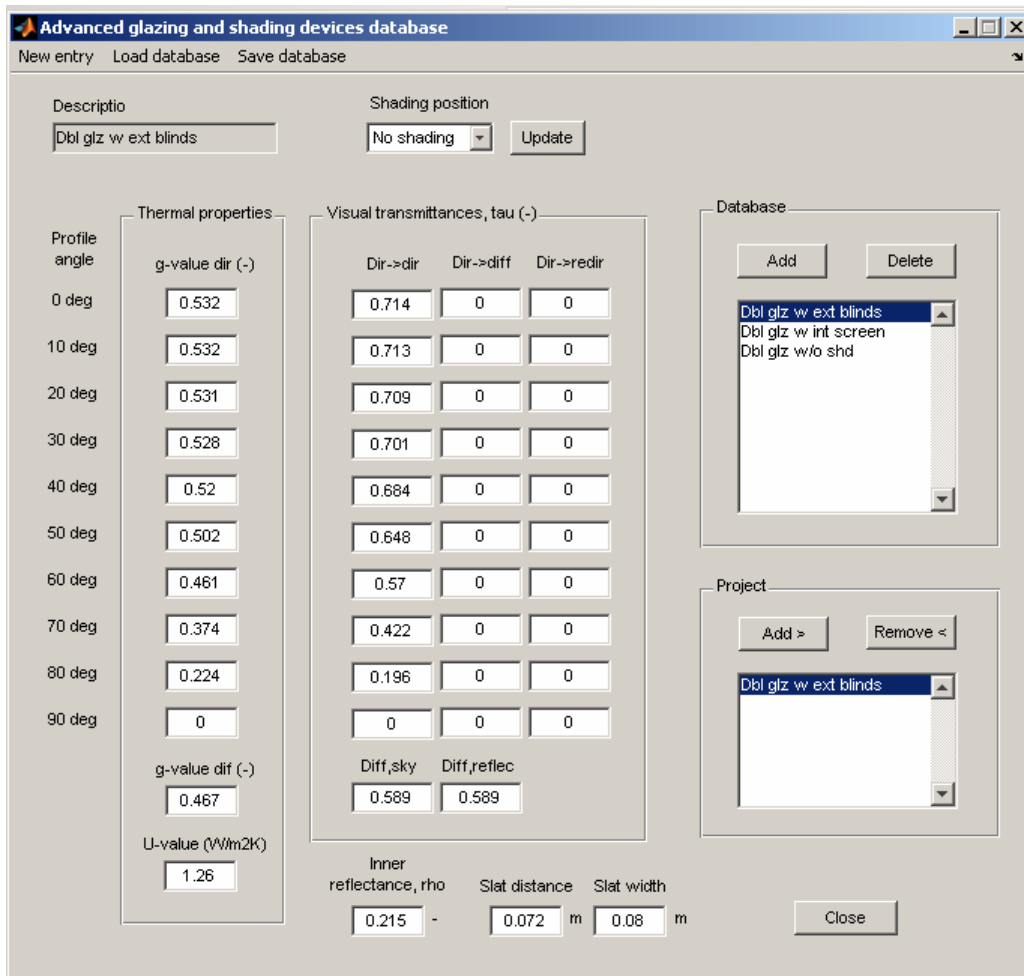
Figure 13. Advanced glazing and shading database

If the user wants to make a new entry, press "New entry". The GUI in Figure 14 pops up and here it is possible to define the wanted entry type. If the user does not want to load data from a file, it is possible to specify this by marking "Enter user data". If blinds are selected, the slat angles has to be entered in consecutive order, e.g. -90 -45 0 45 90. The program interpolates between the defined slat angles. The slat angle is defined on Figure 12.
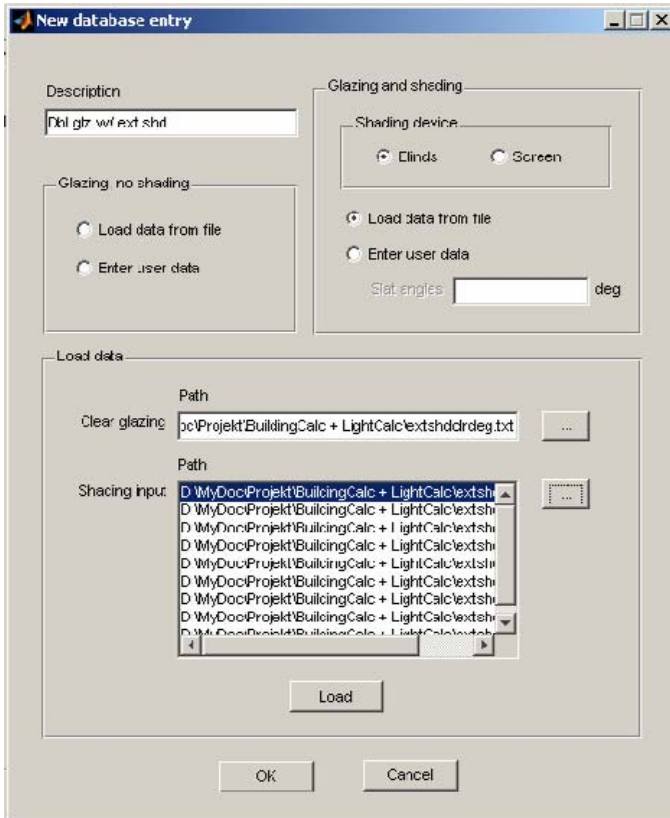
Figure 14. New database entry.

When "OK" in Figure 14 is pressed, the data is moved to the GUI in Figure 13, but it is not added to the glazing database. In order to do so, press "add" under the database panel. To add a particular glazing to the project, press "add" under the project panel. The user will be prompted to save the database before adding a glazing to the project.

Instead of entering your own data it is possible to generate input files in WIS. WIS is capable of calculating the visual transmittances for "systems" of glazings and shading devices and the data can be exported to a simple text file. However WIS can only handle one position of the shading at a time.
In particular for blinds, it is necessary to produce a number of files for different slat positions. It may be up to 20 files ranging from -90 to 90 with interval 10 degrees, but the exact number is voluntary. The number of files defines the accuracy of the simulations.

- For a clear glazing without any shading devices you should only generate one file.
- For a shading device like a screen, you should generate one file with the clear glazing and one file with the combined glazing and screen.
- For a shading device like blinds, you should generate one file with the clear glazing and multiple files with the clear glazing in combination with different slat angles, e.g. for slat angles -85 -80 -60 -40 -20 0 20 40 60 80 85. The program interpolates between the defined slat angles.

Type of entry	No of files necessary
Glazing, no shading	1
Glazing, screen	1 + 1
Glazing, blinds	1 + (10-20)

Please notice that in some cases the values in the inputfiles from WIS are so close to zero (i.e. for 85 or 90 degrees slat angle, that the files generate an error when loaded. In this case load shading position files in the interval [-80:80] instead.)

When using WIS to generate input for the glazing/shading database, the input files have to be of a particular format. This format is achieved by checking the following checkboxes in the report dialog box in WIS:

- ✓ Basics overall
- ✓ Angular overall
- ✓ Angular elements
- ✓ System
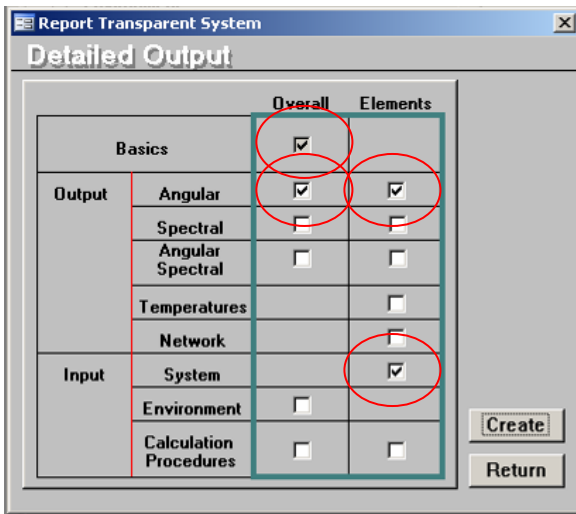
Figure 15. The WIS report dialog box

4.4 Windows

When selecting "Windows" under "Building" the Windows GUI in Figure 16 pops up.
To add a window to the project fill out the input boxes and press "add". To remove a window from the list select the window to remove and press "Remove". To update a window select the window in the list, change the appropriate input box and press "update".
Many windows may be added in a purely thermal simulation. Daylight simulations are only capable of handling one window at a time.
The orientation is given in degrees between 0-180 according to the azimuth definition:

North	180
South	0
East	-90
West	90
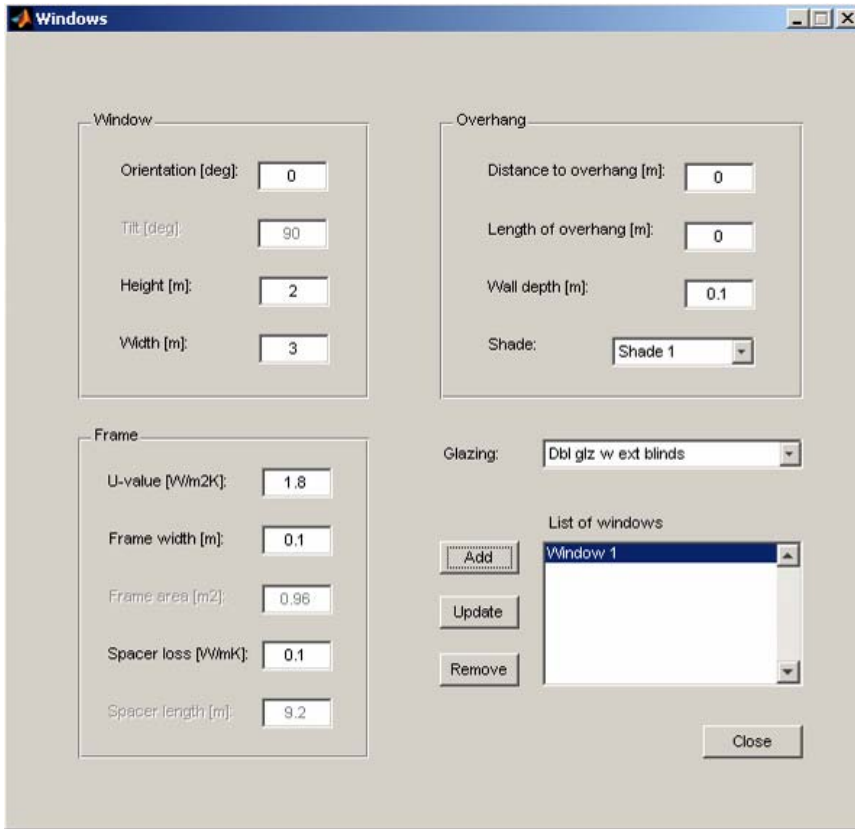
Figure 16. Window definitions.
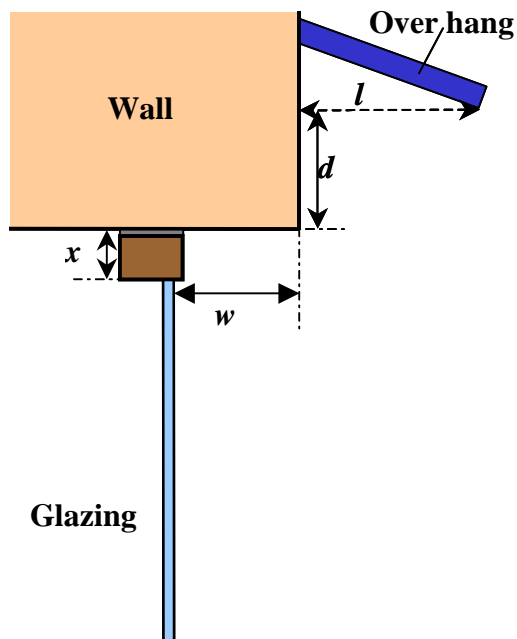
Figure 17. Definition of wall depth w, frame width x, distance to overhang d, and length of overhang l.

Tilt is not an option for daylight simulations where only vertical windows are handled. In thermal

simulations, tilt is defined as the angle between window normal and the zenith vector.

The input include U-value for the frame, frame width and linear thermal transmittance. Framearea and spacer length is calculated automatically.

Shades near the window may be added stating wall depth, distance to overhang and length of overhang. Figure 17 shows the definitions of the wall depth, *w*, frame width, *x*, distance to overhang, *d*, and length of overhang, *l*. Shades from obstructions may be added by choosing a shade from the list of shades.

Only glazings added to the project in the glazing database will come up as glazing options.

4.5 Constructions

The option "Constructions" opens the GUI for defining the building constructions as seen in Figure 18.

Figure 18. Thermal properties for the constructions.

The UA value in Figure 18 is the sum of thermal transmission losses for constructions facing outside *exclusive* windows. The UA-value may be calculated as follows

$$UA = \sum_{Constructions} U \cdot A + \sum_{Linearlosses} \Psi \cdot l$$

with
U: Thermal transmission [W/m²K]
A: Surface area [m²]
Ψ: Linear loss [W/mK]
l: length of linear loss [m]

The value Cw is the effective internal heat capacity and may be estimated using values from Table 3. The effective heat capacity is calculated as:

$$Cw = c \cdot A_{floor}$$

with
c: Specific effective heat capacity from Table 3
A_{floor}: The *floor* area of the room [m²]

The wall thermal resistance, Rw, is the thermal resistance from the surface of the walls to the internal heat capacity. If no better estimation exists values from Table 1 may be used.

The heat capacity of the room air is included through the dimensions of the room. An extra contribution to the room air heat capacity may come from furniture where it is assumed the furniture is always heated to the room air temperature. The extra heat capacity of furniture may be stated in the value Cf. The total heat capacity of the air is calculated as

$$Ca = 1.205 \cdot 1005 \cdot V + Cf \, [J/K]$$

Table 3. Specific effective heat capacity for different types of internal constructions. SBI-184.

Description	Internal constructions	Specific effective heat capacity, c [J/m²K]	Wall thermal resistance, R_w [m²K/W]
Very light	Light walls, floors and ceilings. No heavy parts	144000	0.14
Middle light	A few heavy parts e.g. concrete floor or light concrete walls	288000	0.063
Middle heavy	More heavy constructions e.g. Concrete floor and brick or light concrete walls	432000	0.031
Very heavy	Heavy walls, floors and ceilings made of concrete, brick and tiles	576000	0.016

4.6 Systems

The option "Systems" opens the GUI for defining the systems in the building.

Figure 19 shows the systems input dialog. Set points for heating and cooling are set in °C. To activate heating and mechanical cooling the heating and cooling check boxes must be marked.

It is possible to specify an extra insulation that is activated when heating is needed to lower the heat loss. The extra insulation may be provided by shutters in front of the windows. The extra insulation is given in the same unit as the UA-value and is expressed as the difference between the UA-value when the extra insulation is active and the normal UA-value. This means that the extra insulation is always expressed by a negative value in the input. You have to manually calculate the before and after value of UA. Remember that in the program the shading positions and consequently the different U-values (and g-values) are automatically taken into account.

Internal loads may be entered in W.

The shading definitions are different for thermal and combined simulations. In a purely thermal simulation, the shading factor for variable shading can be set. A shading factor of 0.2 means that the shading, when fully activated, blocks 80% of the incident solar radiation. Choosing a shading factor equal to 1 means that no

variable shading is available. The program dynamically adjusts the necessary shading factor according to the indoor temperature.

For a combined simulation, the min. shading factor option is not available.

Instead the user is asked to define a dynamic or fixed shading control. There are two dynamic controls implemented for blinds:
1. Temp → cut off
2. Temp or glare → cut off

Cut-off is the angle control (for blinds) that cuts off direct light. This means that when overheating occurs, the slat angle will adjust to cut off any direct sun light. The shading device, when active, is either fully lowered or fully raised.

The risk of glare is calculated with the following equation where DGP is the glare threshold in %. Ev is the vertical illuminance in the eye.

$$Ev = \frac{DGP/100 - 0.16}{5.87e-5}$$

The equation is based on a study by (Wienold et al., 2006) that states that the perceived glare is largely correlated linearly with the light that hits the eye.

The glare threshold is specified in the simulation startup box

Ventilation, infiltration and venting rates must be given in h^{-1}. The minimum and maximum air change rates state the interval in which the mechanical ventilation airflow may be controlled. The indoor air temperature controls the air change rate and is activated when the indoor air temperature exceeds the cooling setpoint. If a heat exchanger is present then the efficiency must be set. If the heat exchanger may be bypassed then check the "Bypass" check box. If the bypass box is checked, the bypass is activated when the room air temperature exceeds the heating set point with 1 ^{o}C.
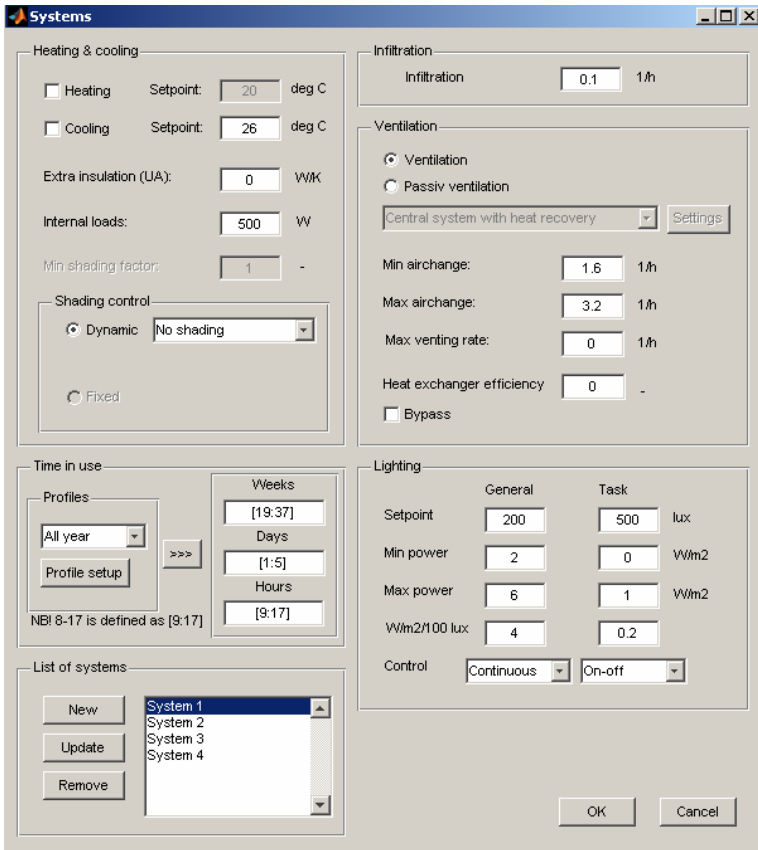
Figure 19. Input data for systems

Infiltration is defined as a constant air change.

Opening windows or doors performs venting. Venting is activated to keep the indoor air temperature below the cooling setpoint.
The cooling systems are activated in the following order:
1. shading
2. venting
3. increased ventilation airchange
4. mechanical cooling (if applicable).

The electrical lighting systems are only active for combined thermal and daylighting simulations. They are defined via setpoints and wattages (power). There are two systems: general and task lighting with different controls. The "Continuous" control involves a linear dimming control of the electrical lighting level with respect to incoming daylight in order to achieve the desired setpoint.

W/m2

Max.
wattage

W/m2/100lux

Min.
wattage

100

Lux
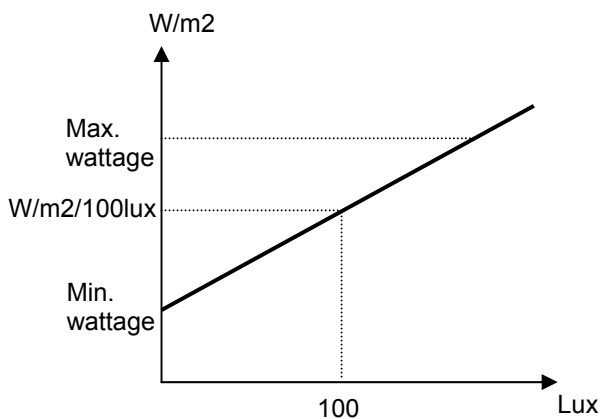
Figure 20. Continuous linear dimming control of the electrical lighting.

The time the systems are in use must be defined in the fields for weeks, days and hours. The statement in Figure 19 means that the system is active the whole year.
Be sure to define the systems so that all hours of the year are covered.
The values must be entered as a Matlab vector in square brackets. Systems with different controls may be defined. Using the "Add new" button adds a new system with the given values to the model. The "Update" button updates the selected system with the stated values and the remove button removes the selected system. The systems are activated with highest priority to the topmost system. This means that if two systems have overlapping time periods the controls specified in the topmost of the two will be active. The relation of the time period of the day to the hour number is given in Table 4. For instance the hours for a system that is active from 8 o'clock to 12 o'clock and again from 14 o'clock to 18 o'clock is in BuildingCalc defined by the vector [9:12 15:18].

Table 4. Definition of hour numbers.

Time period	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Hour nr	1	2	3	4	5	6	7	8	9	10	11	12

Time period	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
Hour nr	13	14	15	16	17	18	19	20	21	22	23	24

4.6.1 Passive ventilation

Passive ventilation is driven by natural driving forces like pressure differences and stack effect. The program has a small feature for calculating simple systems. Two examples of passive ventilation are given in Figure 22.
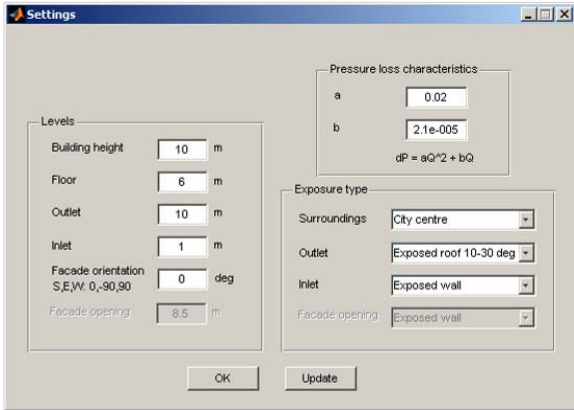
Figure 21. Settings for passive ventilation system

Table 5. Examples of coefficient a and b

	a	b
One heat exchanger	7.5e-5	7e-3
Two heat exchangers	1.5e-4	0.014
System A (20x30 ducts to each office)	0.0196	2.14e-5
System B	less than above	less than above

A
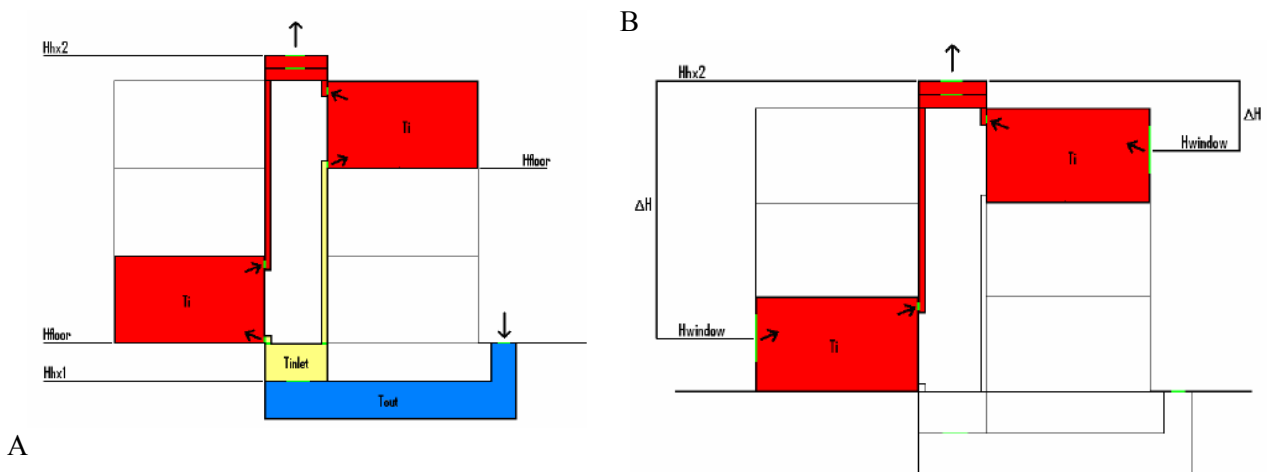
Figure 22. A) Example of passive system with central intake. B) Example of passive system with intake through façade openings (windows)

The passive system control seeks to maintain a ventilation rate between min and max air change rate specified by the user. If the system is unable to fullfill the min requirement a warning is issued and the user should investigate the result to assess the severity of the warning.

5 Settings for indoor comfort

The menu item "Indoor environment" is used to define the settings used to check indoor thermal comfort. Selecting the option "Comfort settings" opens the dialog shown in Figure 23. In this dialog the time period in which you want to evaluate the indoor thermal comfort is stated as the hours the day, days of the week and weeks of the year. In the example the indoor environment is evaluated from 7 o'clock to 18 o'clock on weekdays all the weeks of the year. A temperature may be specified and the program calculated the hours the indoor air temperature exceeds this temperature. This may be used to evaluate problems with over heating within the specified period. The predicted mean vote and predicted percentage dissatisfied occupants are calculated for the specified clothing level in clo and activity in met within the specified period according to the comfort equation [Hansen et. al, 1992].

To adapt the calculation of comfort to the results of this simple simulation model it is assumed that the mean radiant temperature is equal to the air temperature and the relative air velocity is calculated by

$$v_{ar} = v_a + 0.005 \frac{\text{m}^3}{\text{W} \cdot \text{s}} \cdot (M - 58\text{W/m}^2)$$

with mean air velocity in the room $v_a = 0.15$ m/s and the activity M in W/m^2.

Figure 23. Comfort settings dialog.
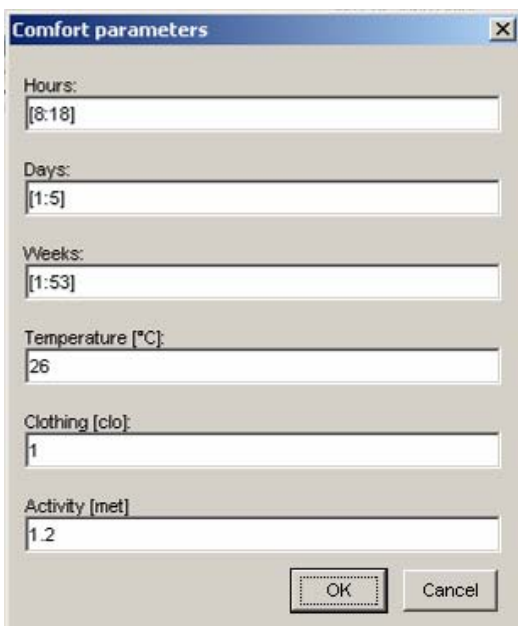
6 Simulation of energy demand and indoor environment

The menu item "Simulation" is the entry to performing calculations and showing reports of results.

Selecting the option "Calculate" opens a dialog box in case of daylight or a combined simulation. Otherwise calculation of heating and cooling demand and indoor environment starts. A dialog shows the progress of the simulation.

In Figure 25 for a daylight simnulation only it is possible to specify options for the output e.g. a specific value in a point or plane of interest. Distance refers to the perpendicular distance from the backside of the plane to the wall.

It is possible to include or exclude the shading and to specify slat angle. The precise options here depend on the kind of user chosen glazing.

It is also possible to select different sky luminance distribution models and to generate a luminance distribution plot by checking generate sky plot. The seven sky models included are:

- Daylight factor, %
  - This is in fact not a sky model – it uses the CIE overcast sky to calculate the internal daylight factor as the ratio between the daylight on an internal surface and the daylight on an unobstructed external surface. Day and hour do not affect daylight factors. External shading should not be included in a daylight factor analysis if it is removable.
- Perez all-weather model, lux
  - This model uses the weather conditions for a user specified day and hour to calculate the incoming daylight. It takes into account the position of the sun and the cloud cover. It is also automatically used for combined simulations.
- CIE overcast sky, lux
  - Output is illuminance values for cloudy sky with no direct sun visible. Day and hour has an influence on the results in terms of the overall illuminance level: stronger daylight at noon than at 3 pm. There are some designers who believe that the CIE Overcast Sky has a fixed brightness (they usually quote 10,000 Lux), this is not the case, as the zenith brightness of the CIE Overcast Sky varies by site latitude, by season and by the time of the day.
- CIE intermediate sky, lux
  - Sky type in between clear and overcast sky. Day and hour has an influence on the results in terms of the position of the sun.
- CIE clear sky, lux
  - For modelling clear blue skies with no clouds. Day and hour has an influence on the results in terms of the position of the sun.
- CIE 10k lux overcast sky, lux
  - Mostly for testing purposes. Produces an overcast sky which gives 10000 lux on an external horizontal plane. It is independent of day and hour.
- CIE 10k uniform sky, lux
  - Only for testing purposes. Produces an uniform sky which gives 10000 lux on an external horizontal plane. It is independent of day and hour.

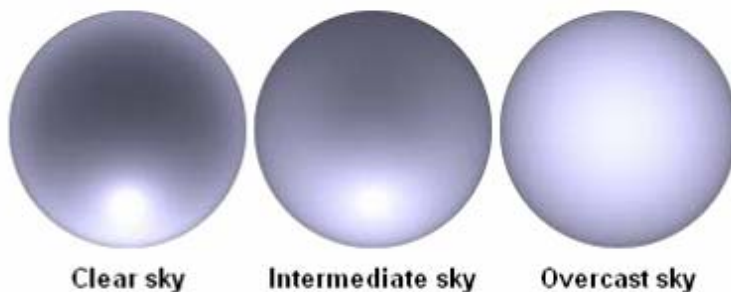Clear sky   Intermediate sky   Overcast sky

Figure 24. Illustrations of different sky types.

In Figure 25 we see different options.

- Daylight in point: illuminance in a specific point
- Daylight on plane: illuminance on a fictive plane
- Distance: used to place the fictive plane. Is the length from the backside of the plane to nearest parallel wall
- Include shading + slat angle: if a glazing+shading combination has been specified it is possible to remove and/or adjust slat angles.
- Generate sky plot: 2D and 3D overview of the sky
- Sky type: different sky models are available for different analysis
- Day + hour: 1st of january is day 1. 8 am is hour 8. In combined BC/LC mode this corresponds to solar height at 7.30 am.
- Contour plot option: distance between evaluated points in meters. Should be smaller for small windows.
- Contour smoothing: smooths the isolines in the contour plot. Need more work.
- Colorbar ranges: adjust isolines in the contour plot. Very usefull when comparing plots.
- Subsurface size: specifies the number of room dividing subsurfaces and is linked to the accuracy of the calculation as well as the computational time. Decreasing the subsurf size to less than 0.5 will increase the computational time drastically. Measured in meters.
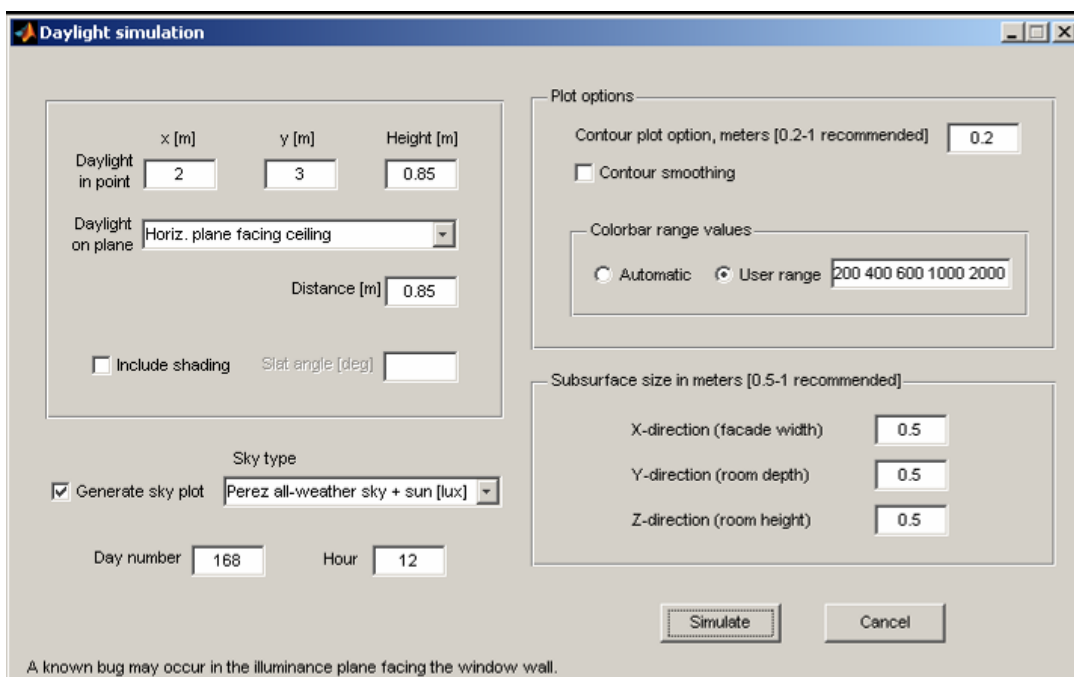
Figure 25. Final input for daylight simulation.

Figure 26 shows the combined BC/LC mode. For a combined simulation the options are reduced to the reference point for the electrical lighting systems and the subsurface option. The *subsurf* size option is described above, but should not be less than 1 (2 is probably better) unless for your very last simulation as this parameter heavily influences the computational time (many minutes).

Remember that for stand-alone LightCalc simulations a value of 0.5 is more relevant.

Figure 26. Final input for a combined thermal and daylight simulation.

7   Output

Depending on the type of simulation the output is either Figure 27 or Figure 28 and Figure 29.

Selecting the option "Results" opens the results GUI. The menu item "Plot" in the results GUI selects what to plot and the period to plot in the diagram. Figure 27 shows the indoor air temperatures for a test case. The period to be plotted can be a given month or a series of days ([1:365] gives all year).

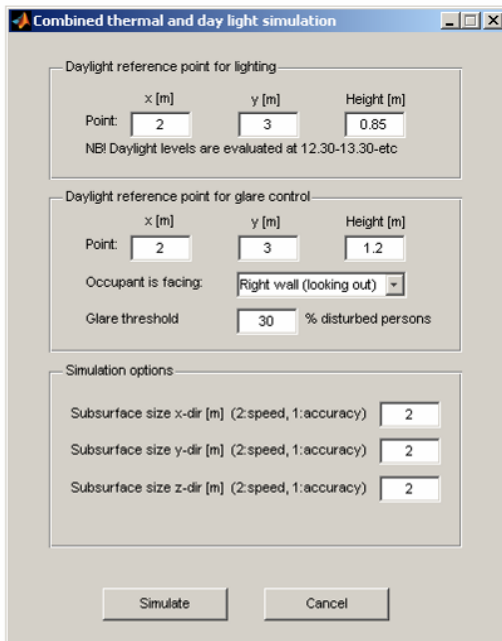The menu item "Results" in the results GUI may be used to show the monthly heating and cooling demands on the screen via the "Show report" option. Also the hours the indoor temperature exceeds the temperature in the indoor comfort settings and values for minimum, mean and maximum predicted percentage dissatisfied are stated for the time period specified in the comfort settings.

The menu item "File" in the results GUI is useful for documenting the building and exporting plots and results. The "Document building" option exports a text file with monthly the heating and cooling loads. Also the hours the indoor temperature exceeds the temperature in the indoor comfort settings and values for minimum, mean and maximum predicted percentage dissatisfied are stated for the time period specified in the comfort settings. After this the building input data is listed. An example is shown in section 10.3. The "Export plot" option exports the diagram in the GUI to a Matlab figure from where it may be saved, printed and modified. The "Export results" exports the results as the structured Matlab variable result in the chosen file name. The results may be loaded into the Matlab workspace. The format of the results is stated in section 10.4.
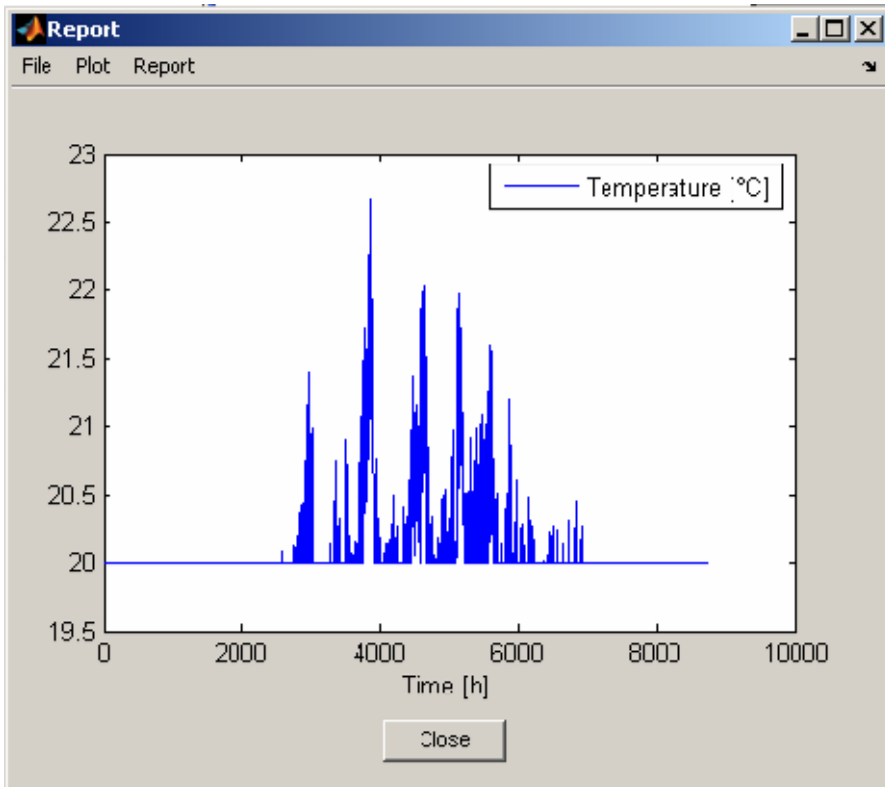
Figure 27. Temperature of room air.
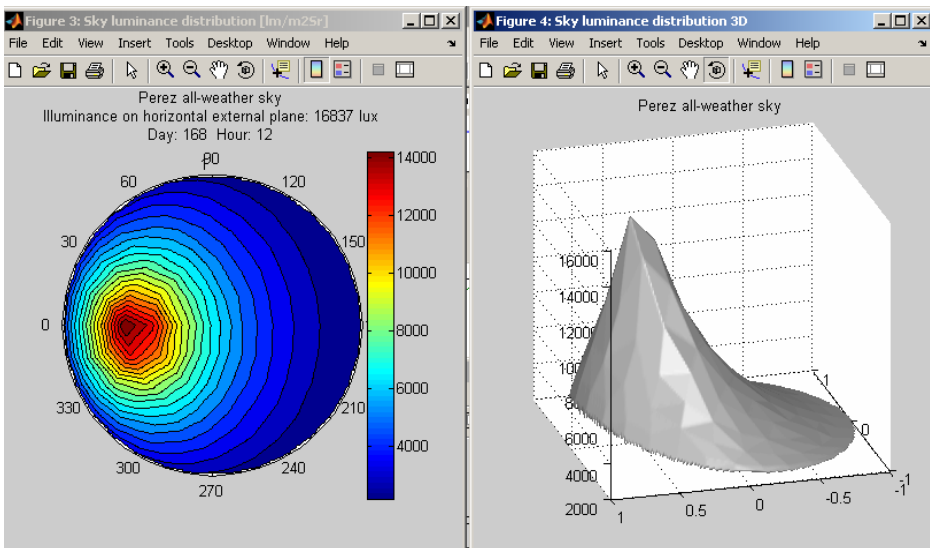
Figure 28. Sky luminance distribution. In this case Perez sky.
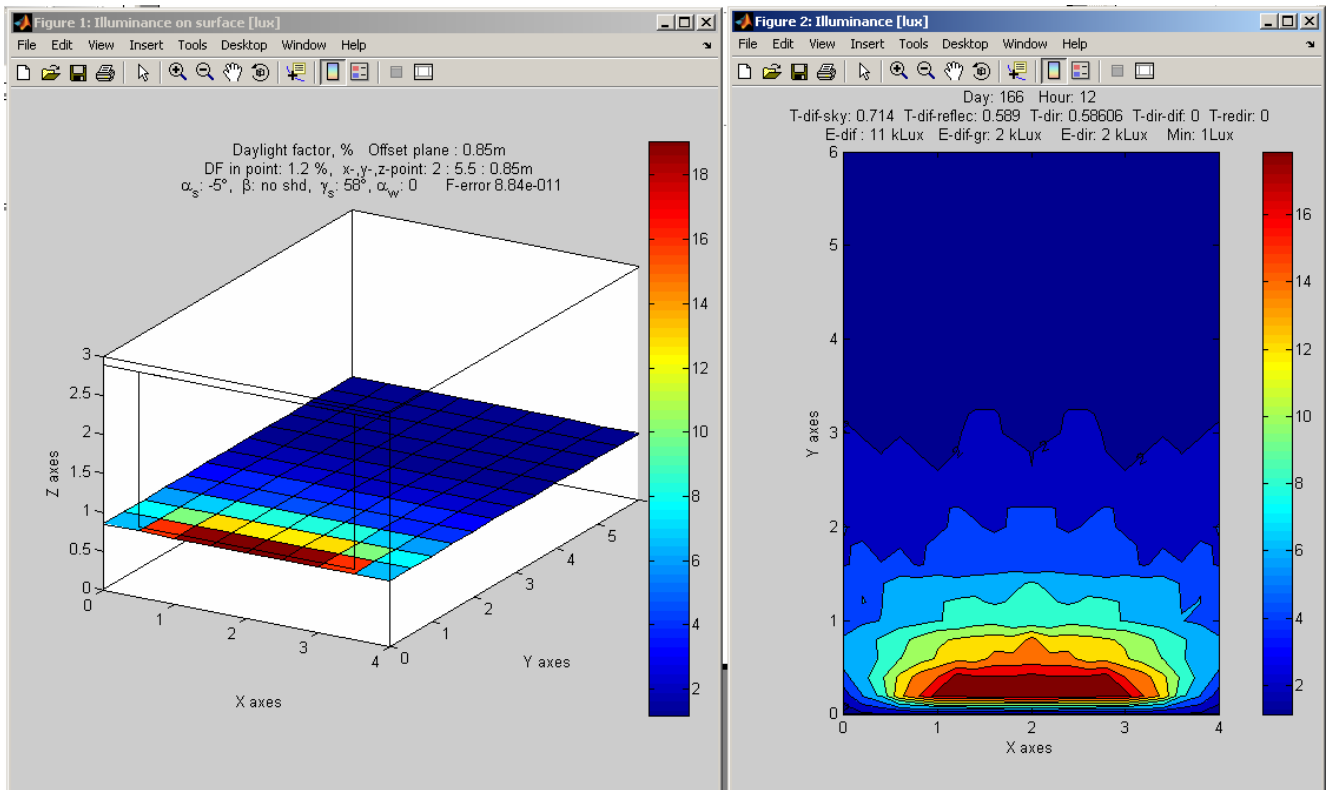
Figure 29. Daylight factors on surfaces in room.

8   Settings

The menu item "Settings" is the entry to setting some values used in the simulation.

Selecting the option surface properties opens the dialog in Figure 30. This is used for daylight simulations.
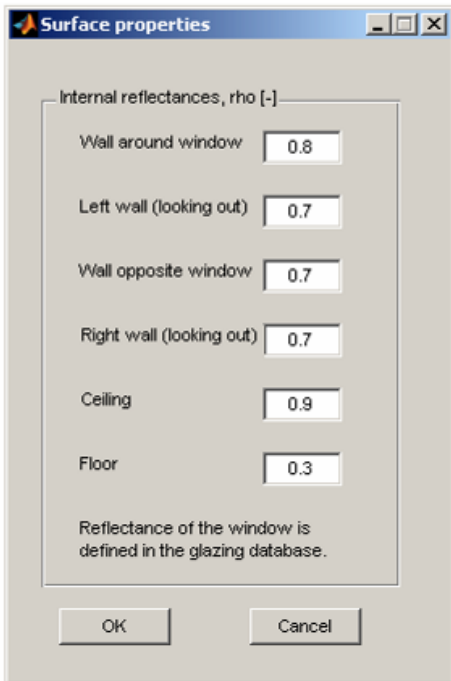
Figure 30. Surface properties dialog box.

Selecting the option "Properties" opens the dialog shown in Figure 31. This dialog is used to define the internal surface resistance between the air and surfaces and to define the fraction of the transmitted solar energy absorbed directly in the air. The transmitted solar energy that is not absorbed directly in the air is absorbed on the internal surfaces.
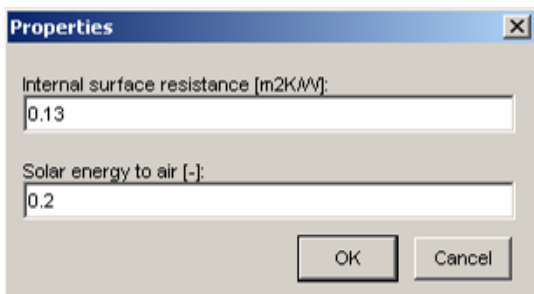
Figure 31. Properties dialog.

9   How to simulate windows in opposing facades in LightCalc

When the user selects "Results" in the LightCalc interface, three files are automatically stored in the current directory. The names of the files are X.mat, Y.mat and V.mat. They contain the data that is necessary to plot the contour plot for the daylight levels.

It is a bit tricky to sum the daylight levels from two simulations, but the following procedure should help.

To simulate a room with windows in east and west façade, do the following.

- Make sure your room covers the entire area of interest from the east to the west façade.
- Define the window in the east façade.
- Run a LightCalc simulation.
- Select "Results"
- Browse to your current directory (work directury) and rename the V-file to reflect your simulation, e.g. VE.mat.
- Erase the window in the east façade and define a new one in the west façade (e.g. by changing the orientation of the window).
- Run another LightCalc simulation.
- Select "Results"
- Rename the V-file again to reflect your simulation, e.g. VW.mat.
- Run the script below by copying it into a new matlab file, save the file and run it from the command prompt. The script is bundled with the BuildingCalc program and is named multiwin.m

To simulate windows in the same façade, erase the lines marked with a % and replace V_prelim with VE.

Multiwin.m:

```
load('X');
load('Y');
load('VE');
VE = V;
load('VW');
VW = V;

j = size(VE,1); %
for i = 1:size(VE,1) %
    V_prelim(j,:) = VE(i,:); %
    j = j-1; %
end %

V = V_prelim + VW; %replace V_prelim with VE if necessary

figure
contourf(X,Y,V,20);
colorbar
axis equal
axis tight
title('Bla bla bla')
```

Opposite windows
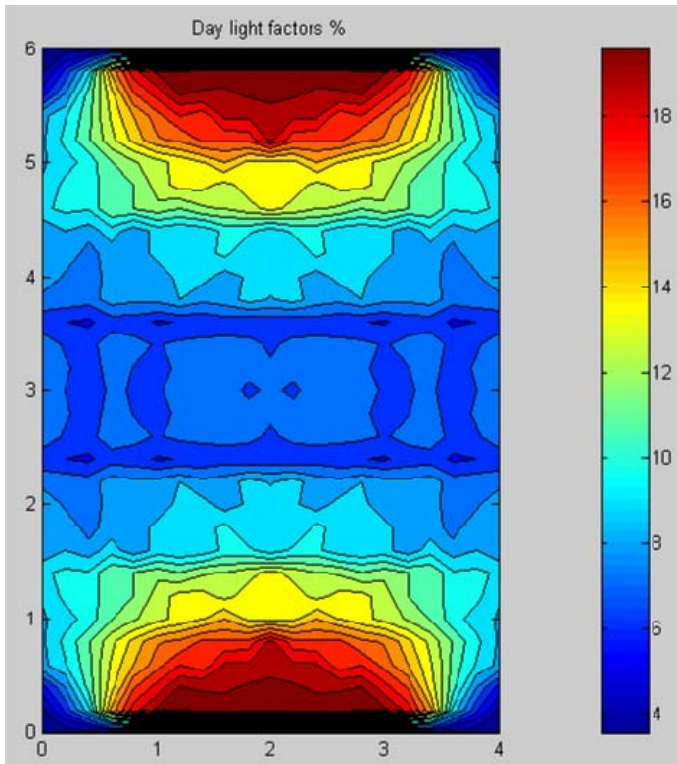
Example of two small windows to the east and a bigger one to the north. Only applicable for quadratic rooms! Requires non-trivial coding, but there is help in `multiwin.m`
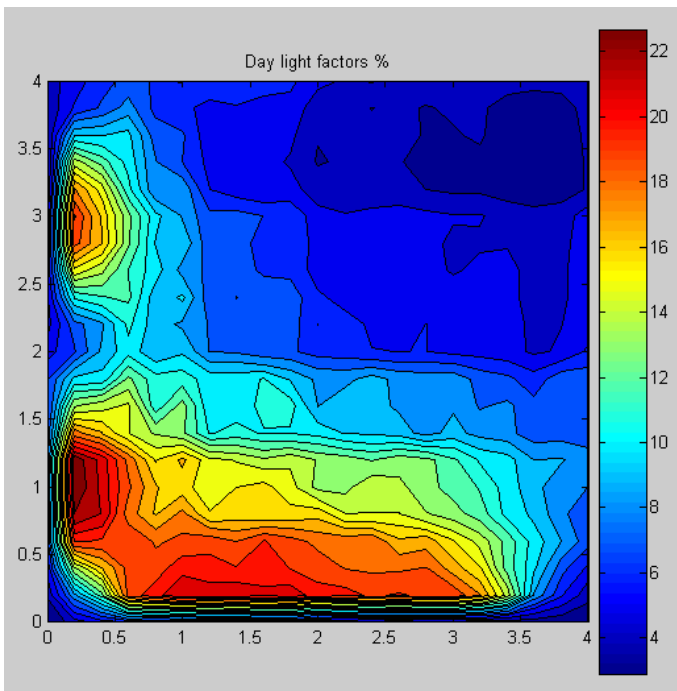
10 Data formats

10.1 Input weather data

Denmark.mat contains weather data from dry12.cop. Only the yellow marked data is actually necessary for the code.

Column:	Description	Unit
1	Time	s
2	Outdoor air temperature	0,1 °C
3	Outdoor dew point temperature	0,1 °C
4	Global solar radiation	W/m^2
5	Diffuse solar radiation on horizontal	W/m^2
6	Direct solar beam radiation	W/m^2
7	Long wave sky radiation	W/m^2
8	Illuminans, global	lux
9	Illuminans, diffuse	lux
10	Illuminans, direct	lux
11	Total observed cloud cover	0..80
12	"Equivalent opaque" cloud cover	0..80
13	Sun shine time	min
14	Wind direction	deka deg
15	Wind speed	0,1 m/s^2
16	Indikator for speciel data	
17	Maks temperature, max. at 7 & 19 o'clock	0,1 °C
18	Min temperature , min. at kl. 7 & 19 o'clock	0,1 °C
19	Air pressure (every 3 hours)	hPa
20	Precipitation, 1, 7, 13 & 19 o'clock	0,1 mm
21	Observed weather, ww (hver 3. time)	0..99
22	Weather since last observation, ww1 (every 3 hours)	0..9
23	Weather since last observation, ww2 (every 3 hours)	0..9
24	Empty (0)	
25	Relative air humidity	%
26	Solar elevation	0,1 deg

10.2 Output weather data format

The weather data is given in rows for each hour of the year with the following data in columns. The first row in the weather data is for the first hour Jan 1st.

Column	Description	Unit
1	Outdoor air temperature	0.1 °C
2	Outdoor dew point temperature	0.1 °C
3	Total solar radiation on the surface	Wh/m^2
4	Direct solar radiation on the surface	Wh/m^2
5	Diffuse solar radiation on the surface	Wh/m^2
6	Reflected solar radiation on the surface	Wh/m^2
7	Incidence angle	°
8	Horisontal shadow angle	°
9	Vertical shadow angle	°

10.3 Building documentation


```
--- Combined thermal and daylight simulation ---

Results:
Month   Heating  Cooling  Lighting  Overheat  Min PPD  Mean PPD  Max PPD
        [kWh]    [kWh]    [kWh]     [h]       [%]      [%]       [%]
Jan       381        0        0        0        5        11        12
Feb       301        0        0        0        5        11        12
Mar       237        0        0        0        5        10        12
Apr       132        0        0        0        5         9        11
May        28        0        0        3        5         8        28
Jun         0        0        0       21        5         8        35
Jul         0        0        0       20        5         8        32
Aug         0        0        0       19        5         8        38
Sep        11        0        0        0        5         7        20
Oct        91        0        0        0        5         9        12
Nov       238        0        0        0        5        11        12
Dec       366        0        0        0        5        11        12
All      1785        0        0       63        5         9        38


Settings:
Internal surface resistance: 0.1300 m²K/W
Solar energy to air: 0.20
Solar energy to surfaces: 0.80

Comfort parameters:
Temperature: 26.00 °C
clothing: 1.00 clo
Activity: 1.20 met
Hours: [1:24]
Days: [1:7]
Weeks: [1:53]

Zone dimensions:
Facade width (X-axis): 4.00 m
Zone depth (Y-axis): 6.00 m
Facade height (Z-axis): 3.00 m

Description of building constructions:
UA-value: 12.00 W/K
Cw-value: 12000000 J/K
Cf-value: 0 J/K
Wall thermal resistance: 0.1000 m²K/W

Description of windows:
Window number 1
Name of glazing: Dbl glz w/ ext blinds
Orientation: 0.0°
Tilt: 90.0°
Height: 2.00 m
Width: 3.00
Frame width: 0.10 m
Frame U-value: 1.50 W/m²K
```

```
Psi: 0.050 W/mK
Wall depth: 0.00 m
Distance to overhang: 0.00 m
Length of overhang: 0.00 m
Shade name: none

Description of systems:
System number 1
Heating:
      Heating system: On
      Heating setpoint: 20.00 °C
      Extra insulation: 0.00 W/K

Cooling:
      Cooling system: Off
      Cooling setpoint: 24.00 °C

      Venting: 4.00 1/h

      Shading factor: 1.00

Mechanical ventilation:
      Minimal air change: 0.50 1/h
      Maximal air change: 0.50 1/h
      Heat exchanger efficiency: 0.00
      Bypass: Yes

Infiltration: 0.00 1/h

Load: 0.00 W

General lighting setpoint: 0 lux
      Min wattage:  0.00 W/m²
      Max wattage: 0.00 W/m²
      Lighting control: 1 (1:on-off,2:dimming,3:always on,4:always off)

Task lighting setpoint: 0 lux
      Min wattage: 0.00 W/m²
      Max wattage: 0.00 W/m²
      Lighting control: 1 (1:on-off,2:dimming,3:always on,4:always off)

Period:
      Hours: [1:24]
      Days: [1:7]
      Weeks: [1:53]
```

10.4 Output format for results

Description of the contents of the result structure.

Table not updated for version 2.4.2

Field	Description	Unit
result.heating	The yearly heating demand	kWh
result.cooling	The yearly cooling demand	kWh
result.heat	The hourly heating power	W
result.cool	The hourly cooling power	W
result.temp	The hourly indoor air temperature	^{o}C
result.shading	The hourly shading factor	-
result.mvent	The hourly mechanical ventilation rate	m^3/s
result.nvent	The hourly natural ventilation rate	m^3/s
result.hoursabove	Vector stating if the indoor air temperature exceeds the cooling setpoint. The value in the vector is one when the indoor air temperature exceeds the cooling setpoint for the given hour otherwise the value is zero.	-
result.Load	The hourly internal loads	W
result.deltaUA	The hourly extra insulation UA-value	W/K
result.Qsun	The hourly transmitted solar energy	W

11 Revision history

Known issues 18.12.2007 in version 2.5.2
- About button not implemented yet
- Passive ventilation systems does not have a fan check box and in iDbuild passive ventilation systems does not have a SEL-value
- Frequency histograms are not yet a feature
- The report should contain monthly ventilation rates and/or ventilation heat loss
- Loading the same file twice causes the menubar to contain the file name twice

History
Version 1
- BuildingCalc in Toke Rammer Nielsens implementation
Version 2
- BuildingCalc and LightCalc by Tryggvi Nielsen conflated. Feature for importing WIS data implemented
Version 2.3
- Many smaller and larger bugs corrected
Version 2.4
- some smaller bugs in the LightCalc algorithm is corrected
- glare control feature implemented
Version 2.4.1
- first version with iDbuild
- bug causing screens to be incorrectly imported is corrected
- interpolation algorithm for light transmittances has been refined to exclude all direct sunlight for the exact cut-off angle. This improved LightCalc agreement with Radiance significantly.
Version 2.4.2
- second version of iDbuild. Numerous errors corrected.
- bug in electrical lighting corrected. It caused any value in systems->min wattage apart from zero to be discarded
- major bug in LightCalc fixed. It caused LC to exclude half of the daylight for other orientations than south
- execution speed increased trough code optimization
- many other minor changes to look and useability
Version 2.5
- Much more precise daylight calculation, now with nice smooth contour lines and same DF for different directions
- Serious bug in overhang and walldepth corrected
- Bug in copy glazing corrected
Version 2.5.1
- Problem with running on older versions of Matlab corrected
- Bug in copy data from reference corrected
- Numerous changes to user interface and code adjustments in iDbuild
Version 2.5.2
- Bug in direct-diffuse contribution corrected
- For clear glazings the solar incidence angle is now calculated directly and is no longer derived from profile angle calculations
- Bug caused the skyplots to be visible only in the taskbar. This has been corrected.
- Predefined glazings and shading database has been extended and sorted

12 References

Hansen, H. E., Kjerulf-Jensen, P. and Stampe, O. B. (1992) Varme- og klimateknik. Grundbog. danvak.

Karlsson, J. and Roos, A. (2000) Modelling the angular behaviour of the total solar energy transmittance of windows. Solar Energy, Vol. 69, No. 4, pp. 321-329.

Karlsson, J., Rubin, M. and Roos, A. (2001) Evaluation of predictive models for the angle-dependent total solar energy transmittance of glazing materials. Solar Energy, Vol. 71, No. 1, pp. 23-31.

Perez, R., Seals, R., Michalsky, J., 1993. All-weather model for sky luminance distribution - preliminary configuration and validation. Solar Energy 50 (3), 235-245.

Wienold, J., Christoffersen, J., 2006. Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. Energy and Buildings 38 (7), 743-757.