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Toke Rammer Nielsen / Christian Anker Hviid / Steffen Petersen

BuildingCalc
LightCalc
BuildingCalc/LightCalc
iDbuild

Users guide for version 3.0

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Contents

1 Introduction

This is the user guide for a program package containing *BuildingCalc, LightCalc, BuildingCalc/LightCalc* and *iDbuild.* The individual programs can be used for analysis separately, even though they are integrated into the same graphical user interface.

BuildingCalc can handle multiple windows. At present time, *LightCalc, BuildingCalc/LightCalc* and *iDbuild* can only simulate office building with single sided rooms, meaning that there can be only one window in the simulation model. Furthermore only buildings of simple shapes, like quadrangular shape, can be evaluated.

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. For details about the calculation methods used in the program, see [Nielsen, 2005].

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. For details about the calculation methods used in the program, see [Hviid et. al., 2008].

BuildingCalc/LightCalc (BC/LC) is 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 extra heat gain from the electrical lighting. For details about the calculation methods, see [Hviid et. al., 2008].

iDbuild is a tool for systematic parameter variations and facilitation of integrated design process. The variations give building designers an overview of how different parameters affect the energy consumption and indoor environment of the room. The key philosophy of this module is that building designers, in an integrated design process, should make design decisions based on performance evaluations (consequence-conscious design decisions) – not make design decisions and then evaluating them.
The program is evaluating energy performance of rooms based on the methodology from EPBD [EPBD, 2002] and the specific Danish requirements from the Danish Building Code [Danish Building Code] and the SBi specification 213 [Aggerholm and Grau, 2005]. The indoor environment is evaluated according to DS/EN 15251 [DS/EN 15251:2007].

User guide updated: July 2008

2 General instructions

This section gives some general instructions on how to get started with the program package, how to run the program and how to set up some basic input for simulations.

2.1 Starting the program

The program is developed in MATLAB[1]. The program is available in a MATLAB version which requires MATLAB to run, and a runtime version which do not require MATLAB to run. The following descriptions explain how to set up and start up the two different versions of the program.

MATLAB version

Getting started – the first time

1. Download *iDbuild MATLAB Version* (**.rar)** from the webpage www.dtu.dk/centre/BFI/Fagomraader/energirigtigtbyggeri/integrateddesign.aspx
2. Unpack the downloaded **.rar** file using an appropriate archive manager, e.g. WinRaR (www.rarlab.com) or WinZip (www.winzip.com). Trial version of these archive managers will do.
3. Place the unpacked files in a folder with a name of your choice.
4. Place the folder *on a local disk on your work computer*. NB: Do NOT place the program on a network drive. Using the program on a network drive may cause simulation errors.

Starting the program

1. Start up MATLAB - *NB:* We can not ensure that the program works in MATLAB versions older than version 7.0.0.19920 (R14).
2. Browse to your *'current directory'* where the program 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'.
3. Run the file BuildingCalc.m in the MATLAB workspace as shown in Figure 1. This opens the graphical user interface (GUI) shown in Figure 2.

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

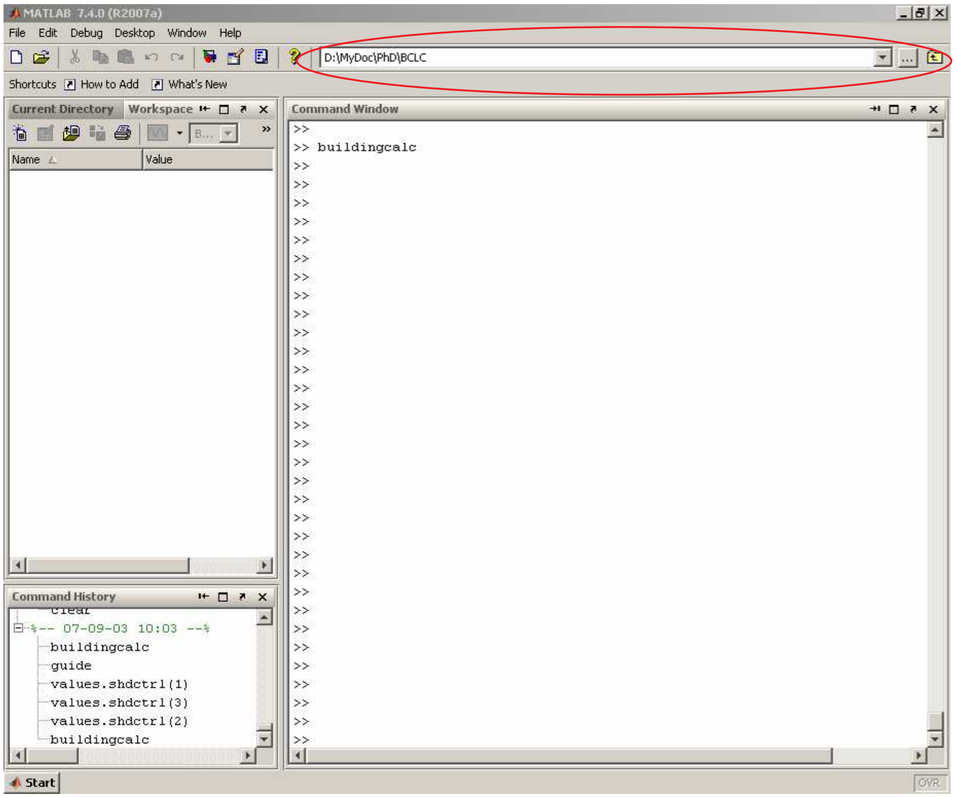


Figure 1. Starting BuildingCalc from Matlab.

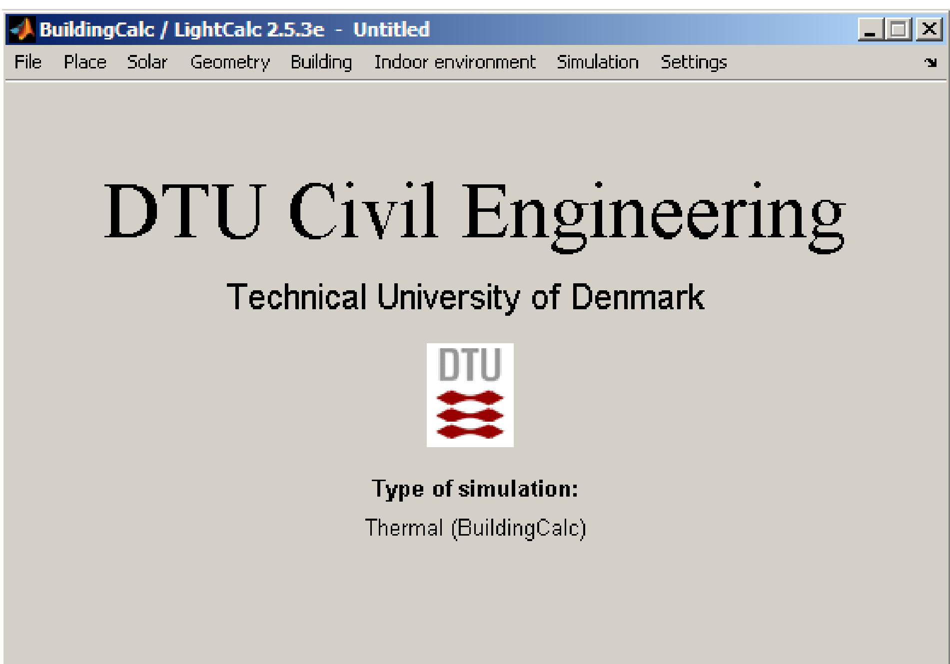


Figure 2. Opening GUI when running BuildingCalc.m

RUNTIME version

Getting started – the first time

1. You need to have *MATLAB Runtime Libraries* installed on your computer to run this program. We are not able to provide these directly on e.g. a web page due to copyrights. However, the libraries can be provided to you by request. Please contact *Steffen Petersen, stp@byg.dtu.dk*.
2. Install the *Matlab Runtime Libraries*.
3. Download *iDbuild Runtime Version* (**.rar**) from the webpage (www.dtu.dk/centre/BFI/Fagomraader/energirigtigtbyggeri/integrateddesign.aspx)
4. Unpack the downloaded **.rar** file using an appropriate archive manager, e.g. WinRaR (www.rarlab.com) or WinZip (www.winzip.com). Trial version of these archive managers will do.
5. Place the unpacked files in a folder with a name of your choice.
6. Place the folder *on a local disk on your work computer*. NB: Do NOT place the program on a network drive. Using the program on a network drive may cause simulation errors.

Starting the program

1. Open the folder with the program, double-click the file *buildingcalc.exe* and the program will start. It may take a little while the first time you start up the program.

2.2 File menu

The menu item *File* has seven options: *Type of project, Load, Save, Save as, Export to SketchUp, Import from SketchUp* and *Exit*.

2.2.1 Type of project

By default the program starts up with the stand-alone thermal simulation user interface (BuildingCalc). In order to change the type of project, go to the *file* menu and specify the desired type of project, see Figure 3. The GUI (graphical user interface) will adjust to comply with the input demands for the chosen type of project.

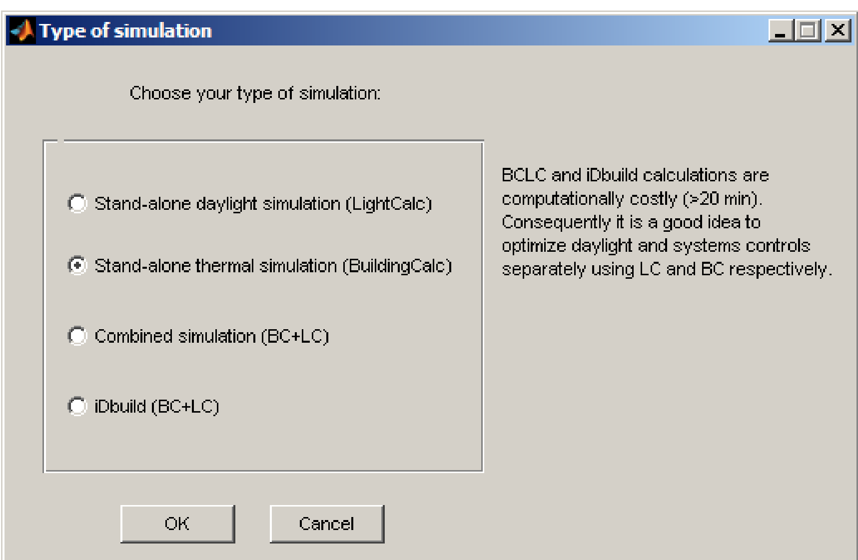


Figure 3. Type of Project

2.2.2 Load

The option *Load* enables the user to load previous saved projects.

2.2.3 Save

The option *Save* enables the user to save new projects.

2.2.4 Save as

The option *Save as* enables the user to save changes to the current project.

2.2.5 Export to SketchUp

The **Export to SketchUp** feature enables the user to export geometry from any of the programs in this package to Google SketchUp.

This export function creates a .txt file of the iDbuild model for import in Google SkecthUp. In order to import the .txt file in Sketchup, you need to have a copy of the file "idbuildcroom.rb" in the plugin folder of Sketchup (...Google\Google SketchUp 6\Plugins). The file "idbuildcroom.rb"' can be found in the program folder of iDbuild. To generate the model in SkecthUp, open SketchUp and go to the main menu "Plugins". A new submenu has appeared: "Import from iDbuild". Access this menu and browse the .txt file generated in iDbuild and click "Open".

NB: At present time, this feature only applies for iDbuild models with one window in one façade.

2.2.6 Import from SketchUp

The **Export to SketchUp** feature enables the user to import geometry from Google SketchUp.

This import function is able to read a .txt file of a room geometry generated in Google SkecthUp. In order to export room geometries as a .txt file in Sketchup, you need to have a copy of the file "expidbuild.rb" in the plugin folder of Sketchup (...Google\Google SketchUp 6\Plugins). The file "expidbuild.rb"' can be found in the program folder of iDbuild. To generate a file for import in iDbuild, open SketchUp, design your room, and go to the main menu "Plugins". A new submenu has appeared: "Export to iDbuild". Access this menu and save the generated .txt file.

NB: At present time, this feature only applies for SketchUp geometries with one window in one façade.

2.2.7 Exit

The option *Exit* close down the program.

2.3 Place

Before any calculations can be performed in any of the type of projects, a location and a 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 specify the location, see Figure 4. 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.

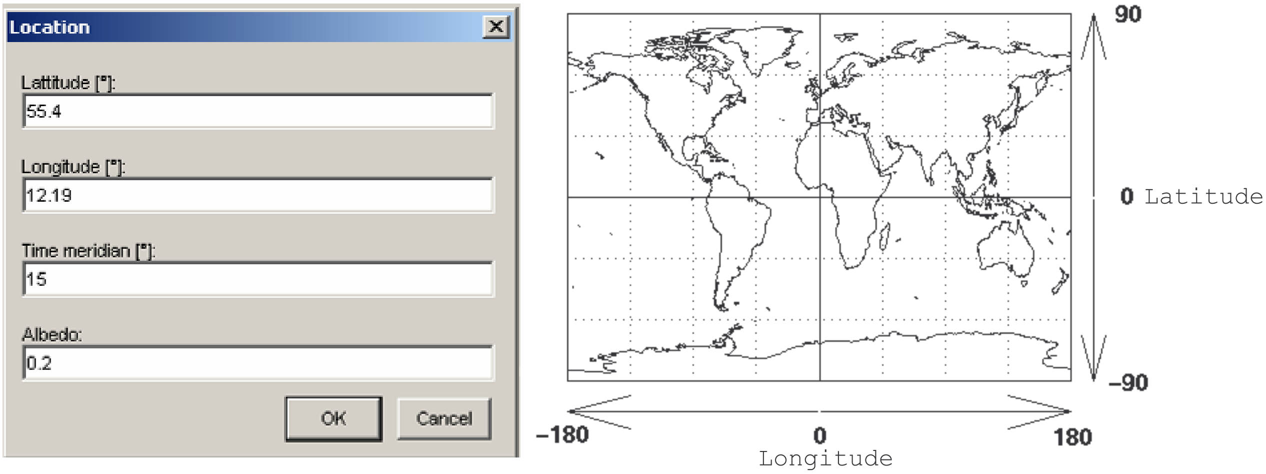


Figure 4. Input dialog for location.

For the given location a weather data file is chosen as shown in Figure 5 by choosing the option *Select weather data* under *Place*. Supplied with the program is the Danish design reference year “Denmark.mat”. Generating weather data for other locations than Denmark is possible in the MATLAB version of the program. You need to be confident with MATLAB programming to arrange the data. For data needed and data structure of the weather data file, see section 7.1.

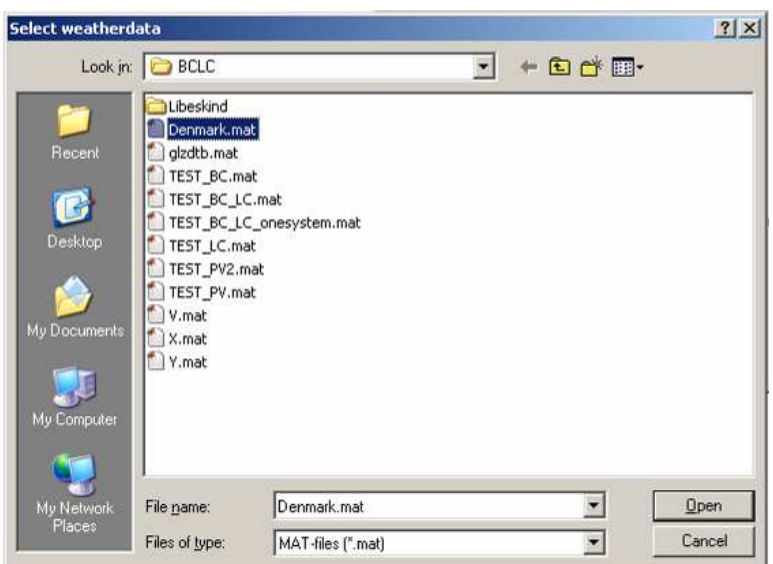


Figure 5. Select weather data file.

3 Calculation of solar radiation

The menu item *Solar* 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 internal menu item *File* the diagram shown in the GUI can be exported to a Matlab figure from which the diagram may be saved, printed and in other ways changed from the Matlab workspace.

The internal 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^o 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^o to local standard time meridian. Therefore during summer time changing the local time meridian for Copenhagen to 30^o instead of 15^o gives the right local time lines on the diagram.

Figure 6 shows the sun path for Copenhagen.

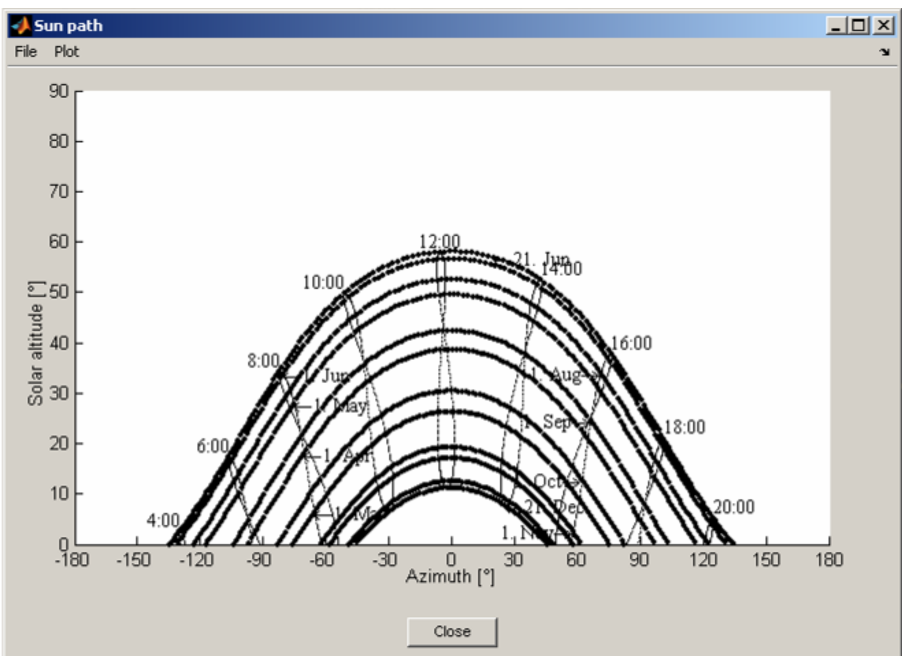


Figure 6. Sun path for all year in Copenhagen.

3.2 Solar radiation on surface

The option *Solar radiation on surface* starts the GUI used to calculate solar radiation on sloped surfaces. Figure 7 shows the GUI with solar data for a vertical surface facing south.

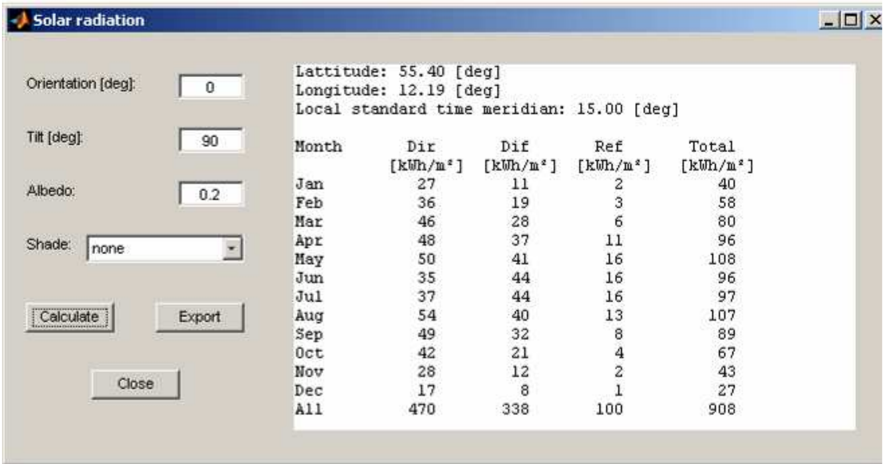


Figure 7. Solar radiation on vertical surface facing south.

The orientation of the surface is entered in degrees where 0^o is south, negative values are east of south and positive values are west of south. A surface facing west has an orientation of 90^o. The tilt of the surface is 0^o for a horizontal facing the sky, 90^o for a vertical surface and 180^o 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 7.2. 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* under the menu *Solar* starts the GUI used to enter shades for a reference point. Figure 8 show the GUI with two shades entered showing shade 1 in the diagram.

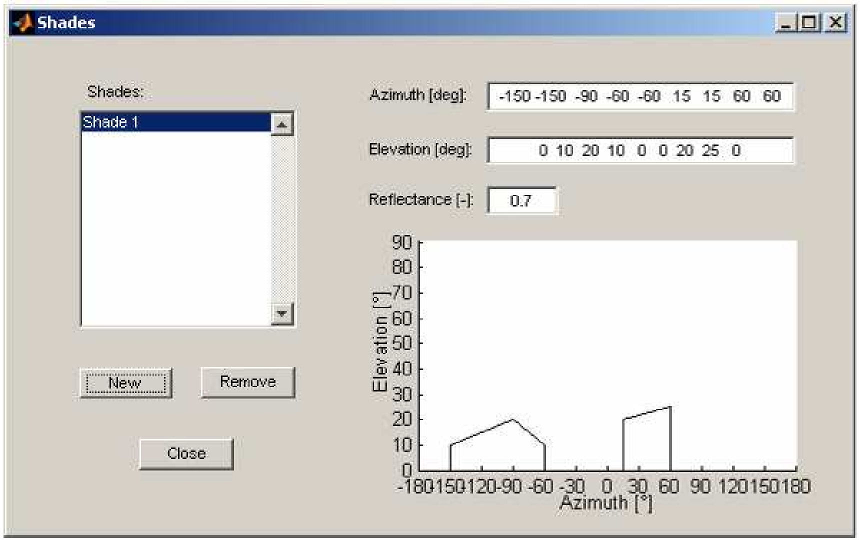


Figure 8. Shades.

Pressing "New" opens a shade dialog, see Figure 9. 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^o 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^o.

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 8 the input data for shade 1 is shown. Pressing "Remove" deletes the selected shade from the list of shades. However, the default shade profile called "No shade" can not be deleted. 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.

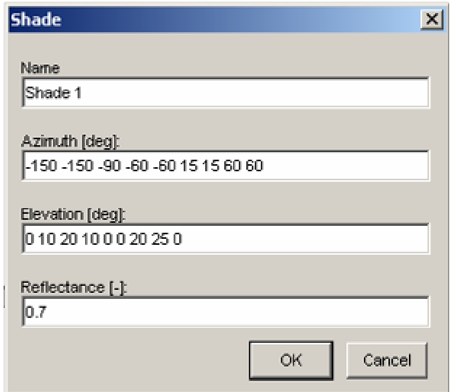


Figure 9. Shade dialog with data for shade 1.

4 Creating and simulating models of building/room

Defining a building/room for simulation is somewhat different dependent on the type of project (see section 2.2). This section is therefore divided in to the current 4 types of simulations: BuildingCalc, LightCalc, BuildingCalc/LightCalc and iDbuild.

4.1 BuildingCalc

The following headlines correspond to the name of the menu items for defining a building for simulation in BuildingCalc.

4.1.1 Geometry

The menu item *Geometry* gives the options *Dimensions* for defining the geometry of the room to be simulated. The dimensions of the simulated room are given in internal measures.

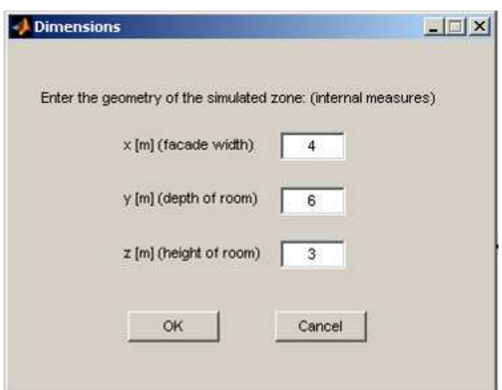


Figure 10. Dimensions dialog box.

4.1.2 Building

The menu item *Building* has four options: *Glazings*, *Windows*, *Constructions* and *Systems*.

4.1.2.1 Glazings

To define a new glazing fill out the input boxes and press “add”, see Figure 11. “Remove” deletes your highlighted entry.

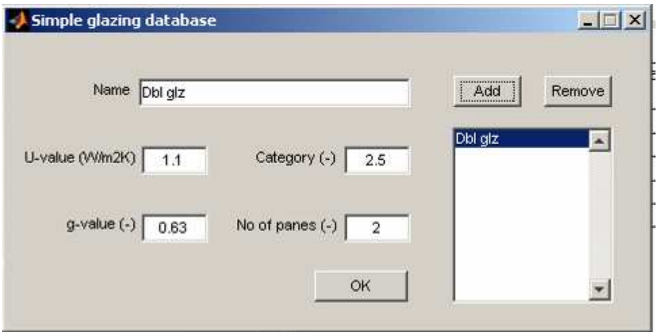


Figure 11. Simple glazing database

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). Values for typical glazings are given in
Table 2 (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

4.1.2.2 Windows

Multiple windows may be added in a BuildingCalc simulation. To add a window to the project fill out the input boxes and press "Add", see Figure 13. To remove a window from the list, select the window to remove and press "Remove". To change or update data for a window, select the window in the list, change the appropriate input box and press "Update".

The **orientation** is given in degrees between 0-180 according to the azimuth definition:

North	180
South	0
East	-90
West	90

Tilt angle is defined as the angle between window normal and the zenith vector.

The input includes **U-value for the frame**, **frame width** and **linear thermal transmittance**. Frame area and spacer length is calculated automatically.

Shades near the window may be added stating **wall depth**, **distance to overhang** and l**ength of overhang**. Figure 12 shows the definitions of the wall depth, *w*, frame width, *x*, distance to overhang, *d*, and length of overhang, *l*. Shades from surrounding obstructions may be added by choosing a shade from the list of shades (for definition of shades, see section 0).

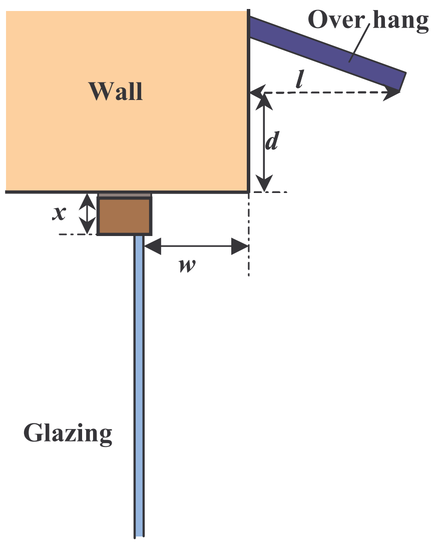


Figure 12. Definition of wall depth w, frame width x, distance to overhang d, and length of overhang l.

Only **glazings added to the project** in the glazing database will come up as glazing options (see section 4.1.2.1).

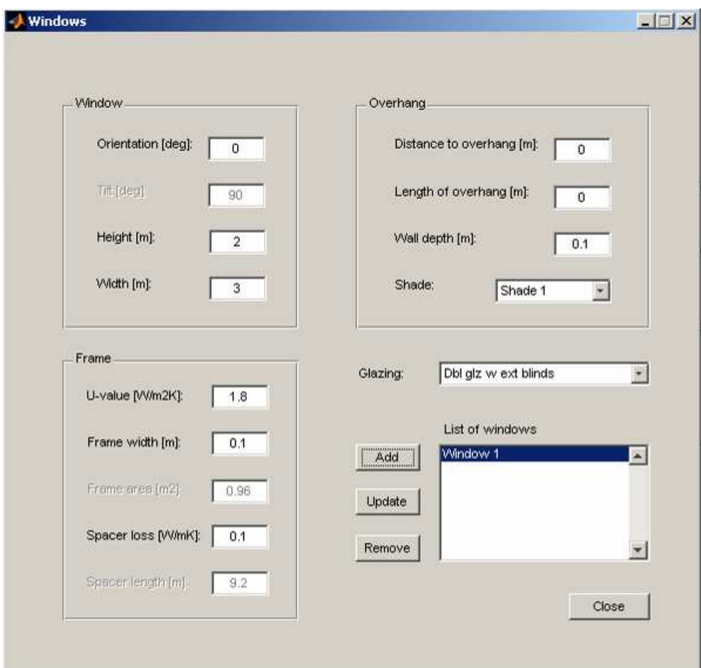


Figure 13. Window definitions.

4.1.2.3 Constructions

The option “Constructions” opens the GUI for defining the building constructions, see Figure 14.

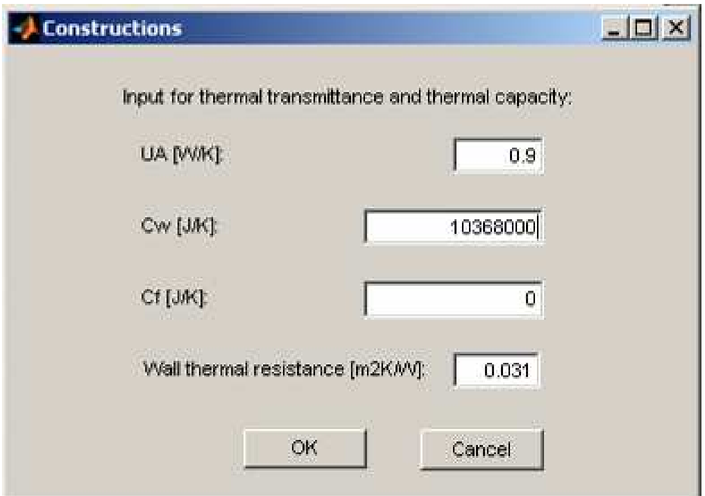


Figure 14. Thermal properties for the constructions.

The **UA value** in Figure 14 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/m^{2}K]
A: Surface area [m^2]
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 1. The effective heat capacity is calculated as:

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

with

c: Specific effective heat capacity from

If the heat capacity of the interior is unknown, the user may either neglect it or use estimate it. Example of estimation of Cf in a 18 m^2 office for 2 persons:

• 2xLabtop+Monitor+Keyboard:	15 kg
• 2x Chairs and desks:	75 kg
• 2x Cabinets/filing (w/books, etc):	200 kg
• 2x Misc stuff:	70 kg
• SUM:	360 kg = 20 kg/m^2

If the average specific heat capacity of the mass is set to 420 J/kgK (wood), then Cf = 20·420 = 8400 J/K per m^2 or 18·8400 = 151200.

Table 3

A_{floor}: The *floor* area of the room [m^2]

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 (automatically) as

$$Ca = 1.205 \cdot 1005 \cdot V + Cf \text{ [J/K]}$$

If the heat capacity of the interior is unknown, the user may either neglect it or use estimate it. Example of estimation of Cf in a 18 m^2 office for 2 persons:

- 2xLabtop+Monitor+Keyboard: 15 kg
- 2x Chairs and desks: 75 kg
- 2x Cabinets/filing (w/books, etc): 200 kg
- 2x Misc stuff: 70 kg
- SUM: 360 kg = 20 kg/m^2

If the average specific heat capacity of the mass is set to 420 J/kgK (wood), then Cf = 20·420 = 8400 J/K per m^2 or 18·8400 = 151200.

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

Description	Internal constructions	Specific effective heat capacity, c [J/m^2K]	Wall thermal resistance, R_w [m^2K/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

4.1.2.4 Systems

The option *Systems* opens the GUI for defining the systems in the building, see Figure 1.

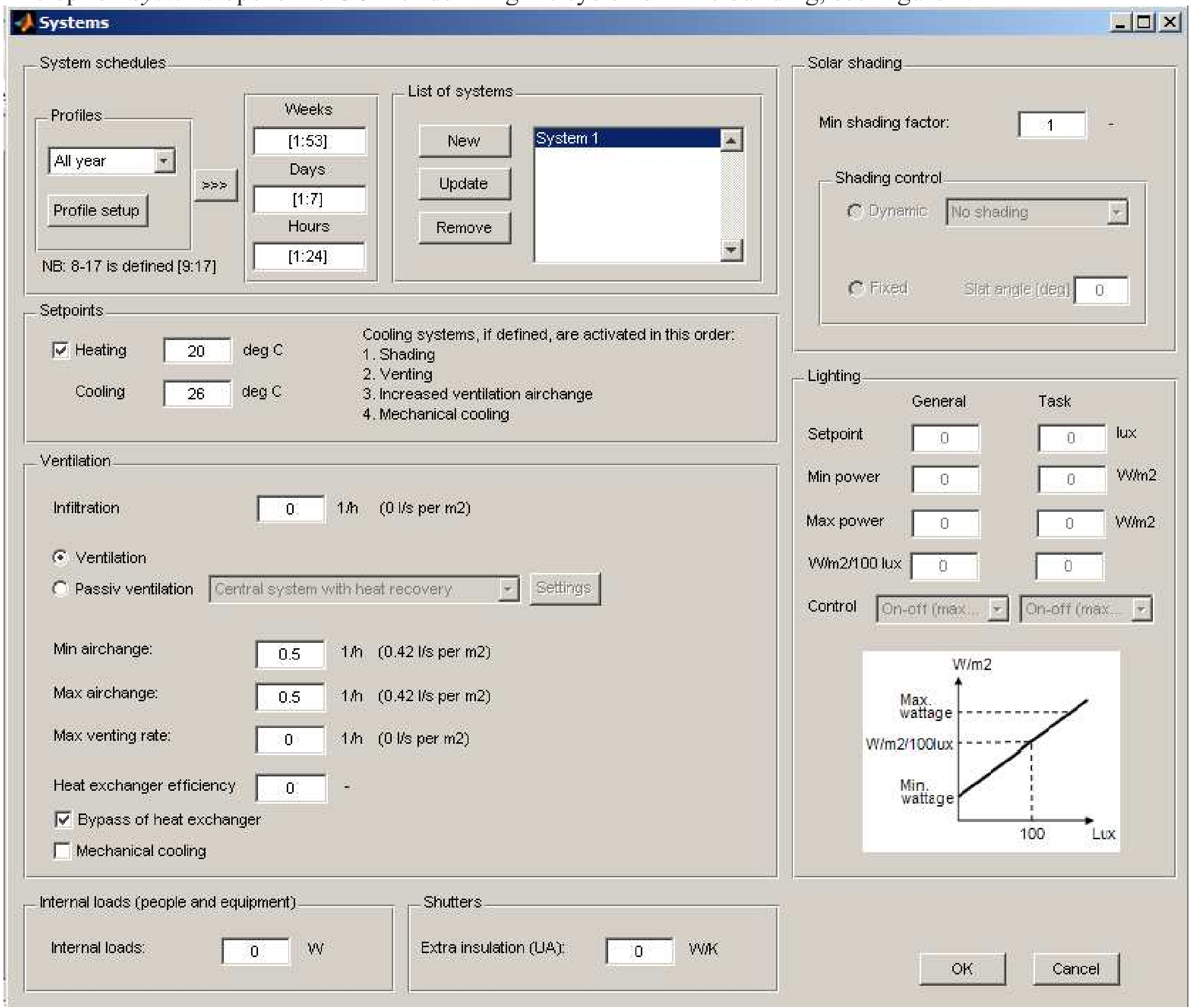


Figure 15 Input data for systems

System schedules is where to define the time periods the systems are in use. They must be defined in the fields for weeks, days and hours. The statement in Figure 15 means that the system is active the whole year.

The values must be entered as a Matlab vector in square brackets. **Be sure to define the systems so that all hours of the year are covered.** Numerous systems with different controls may be defined.

Using the "Add new" button adds a new system with the given weeks, days and hours values to the model.
The "Update" button updates the selected system with the stated values.
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

An alternative to defining Matlab vectors describing the time period is to select a profile from the drop-down menu in "Time profiles". There are five default time profiles: *All year*, *Heating season*, *Outside heating season*, *Office hours 8-17 heating season* and *Office hours 8-17 outside heating season*. Select one of these and press the button ">>>" to create the Matlab vectors. **Remember to press "Update" at the list of systems to store the new time period in highlighted system.**

You can add your own profiles to the default list by pressing "Profile setup". This is also a more graphical way of setting up time periods, see Figure 16.

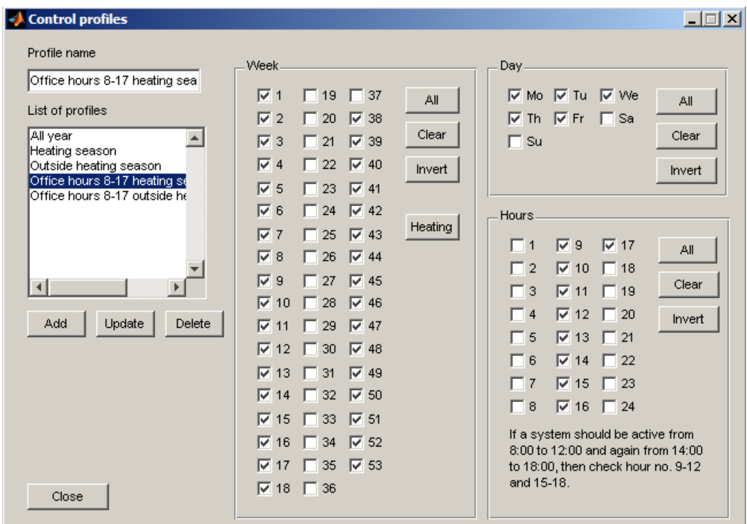


Figure 16. Profile setup – a more graphical way of setting up time profiles

Set points for heating and cooling system for the highlighted system in "System list" are defined in "Set points". To activate heating for the highlighted system the check box must be marked. BuildingCalc will try to uphold the defined cooling set point by activating systems (if they are defined by the user) in the following order:

1. shading
2. venting
3. increased mechanical ventilation air change
4. mechanical cooling

Remember to press "Update" at the list of systems to store new or adjusted set points in the highlighted system.

Infiltration, ventilation (mechanical/natural or passive) and **venting rates** must be given in h^{-1}. **Infiltration** is defined as a constant air change. It is then possible to either define a mechanical/natural ventilation system or a passive ventilation system.

<u>Mechanical ventilation system:</u> The **minimum** and **maximum air change rates** state the interval in which the mechanical ventilation airflow may be controlled. The indoor air temperature controls how much extra

air change rate is needed (up to "maximum air change"). Opening windows or doors performs **venting**. The maximum obtainable venting rate is specified.
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. If **mechanical cooling** is to be a part of the design, then check the "Mechanical cooling" check box.

Remember to press "Update" at the list of systems to store new or adjusted ventilation input.

<u>Natural ventilation system:</u> A natural ventilation system is defined as a mechanical in terms of air change rates. External programs may be used to verify that the **minimum** and **maximum air change rates** are obtainable in the design.
Venting is always 0. There is no **heat exchanger efficiency** or **bypass**. **Mechanical cooling** must be unchecked.

Remember to press "Update" at the list of systems to store new or adjusted ventilation input.

<u>Passive ventilation:</u> Passive ventilation is driven by natural driving forces like pressure differences and stack effect. The program has a small feature for calculating simple systems. The input settings GUI is seen in Figure 17. Two examples of passive ventilation are given in Figure 18.

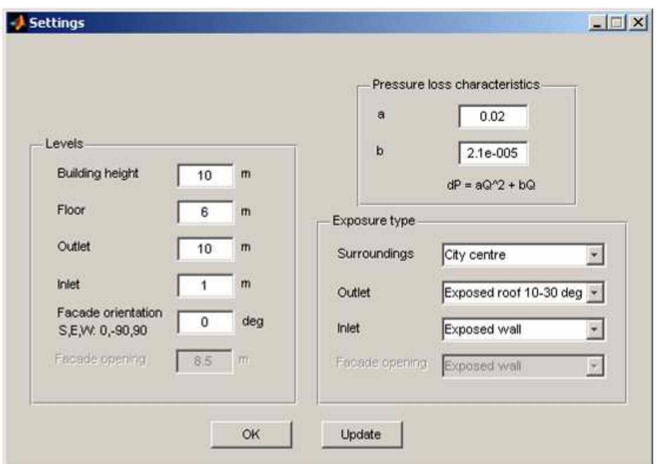


Figure 17. Settings for passive ventilation system

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

System A **System B**

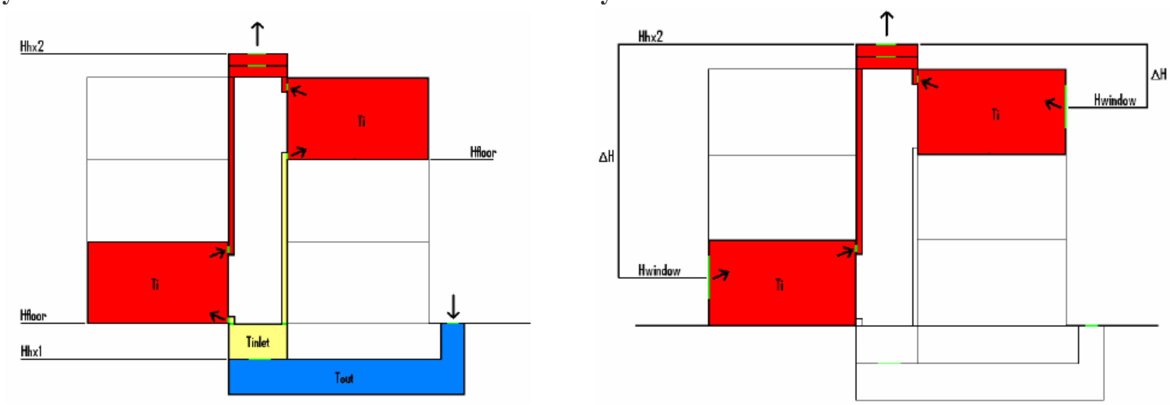


Figure 18. A) Example of passive system with central intake. B) Example of passive system with intake through façade openings (windows)

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 fulfil the min requirement a warning is issued and the user should investigate the result to assess the severity of the warning.

Remember to press "Update" at the list of systems to store new or adjusted ventilation input.

Internal loads may be entered in Watts. Internal loads include *electrical lighting*, *people* and *equipment*.

Remember to press "Update" at the list of systems to store new or adjusted internal load input.

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 (see section 4.1.2.3) 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 to press "Update" at the list of systems to store new or adjusted extra insulation.

The **shading definitions** are different for thermal (BC) and combined (BC/LC) simulations. In a BC 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.

Remember to press "Update" at the list of systems to store new or adjusted shading factor.

Sophisticated controls of the **electrical lighting systems** based on daylight levels are not available in BuildingCalc.

4.1.3 Indoor environment

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 19. 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

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

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

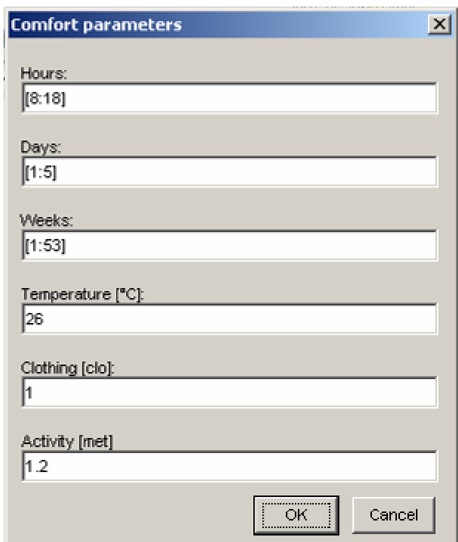


Figure 19. Comfort settings dialog.

4.1.4 Settings

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

Selecting the option *Properties* opens the dialog shown in *Figure 20*. 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 (**Solar energy to air**). The transmitted solar energy that is not absorbed directly in the air is absorbed on the internal surfaces.

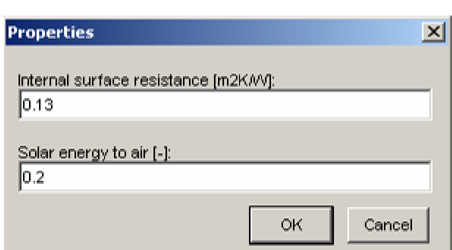


Figure 20. Properties dialog.

4.1.5 Simulation

The menu item *Simulation* has two options: *Calculate* and *Results*.

4.1.5.1 Calculate

The option *Calculate* executes the thermal simulation the instance it is pressed by the user.

4.1.5.2 Results

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. The results can be plotted as hourly value curves or duration curves. Figure 21 shows the hourly value curve of the indoor air temperatures for a test case.

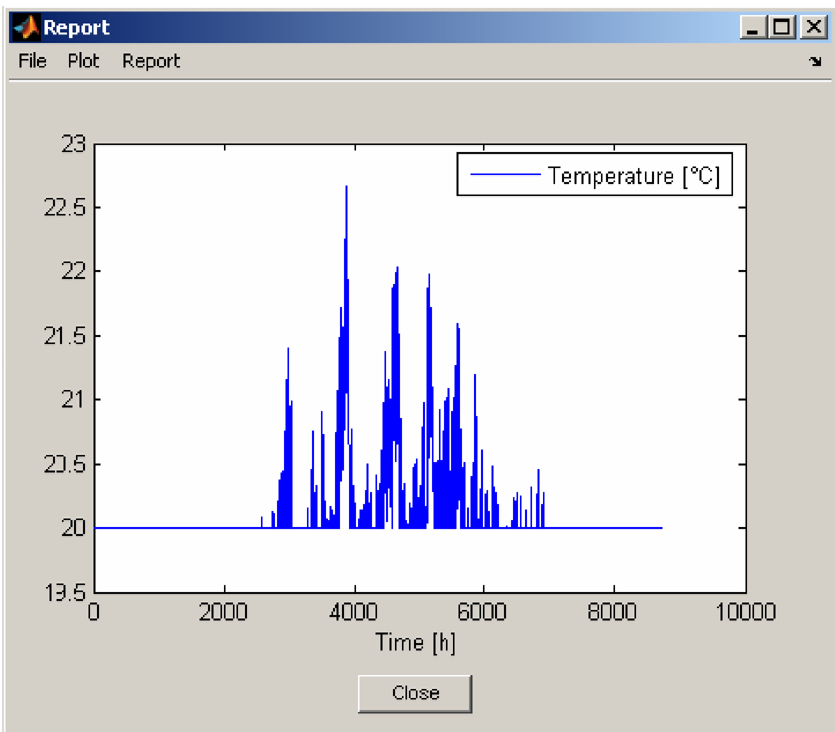


Figure 21. Temperature of room air.

The menu item *Report* 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 *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 7.3.

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 7.4.

4.2 LightCalc

The following headlines correspond to the name of the menu items for defining a building for simulation in LightCalc. Some of menu items in LightCalc are the same as for BuildingCalc.

At the moment, only one window in one facade can be simulated. Window tilt is not an option for daylight simulations: only vertical windows are handled.

4.2.1 Geometry

The option *Dimensions* for definition of room geometry is the same as in BuildingCalc, see section 4.1.1.

The option *Window offset* opens the GUI in Figure 22. The user must define the **offset from floor** and the **offset from right wall (looking out)** according to Figure 23. The values cannot be exact zero.

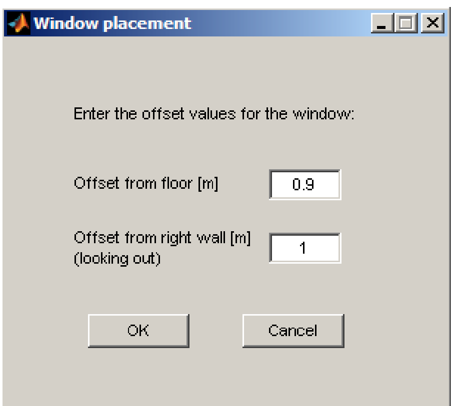


Figure 22. Window offset definition

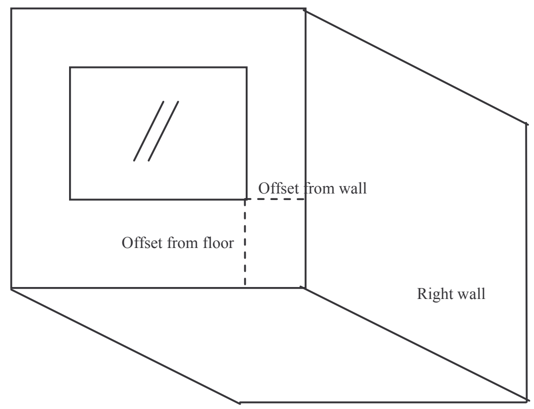


Figure 23. Definition of offsets in external facade

4.2.2 Building

Compared to BuildingCalc, only the two options *Glazings* and *Window*s is available in the menu item *Building* of LightCalc: information about the construction and systems is not needed for a stand-alone daylight calculation.

4.2.2.1 Glazings

For a simulation involving daylight simulations, the input for glazing is somewhat more complex than for BuildingCalc. The GUI with the advanced glazing and shading devices database can be loaded by selecting the option *Glazings*. The GUI is shown Figure 26.

A default glazing database called ‘glzdtb’ can be loaded through the menu item *Load database*. Glazings in the database are described layer-by-layer from the outside (left) to the inside (right). An example is shown in Figure 24.

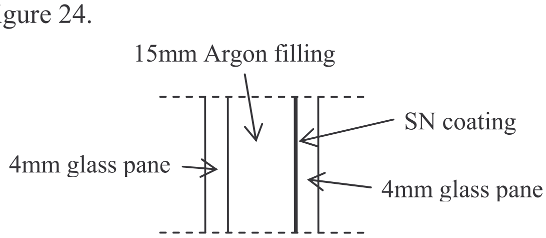


Figure 24. Illustration of how to interpret glazings in ’glzdtb’. Example used: 4-15Ar-SN4

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 26 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.

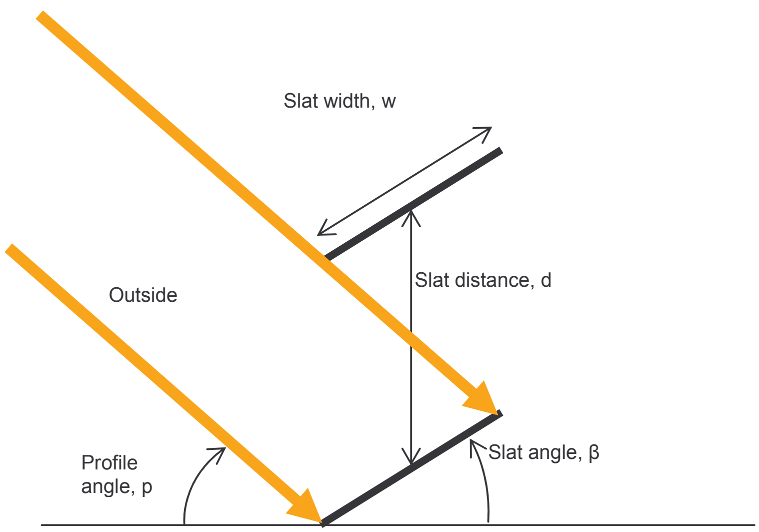


Figure 25. Slat dimensions

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.

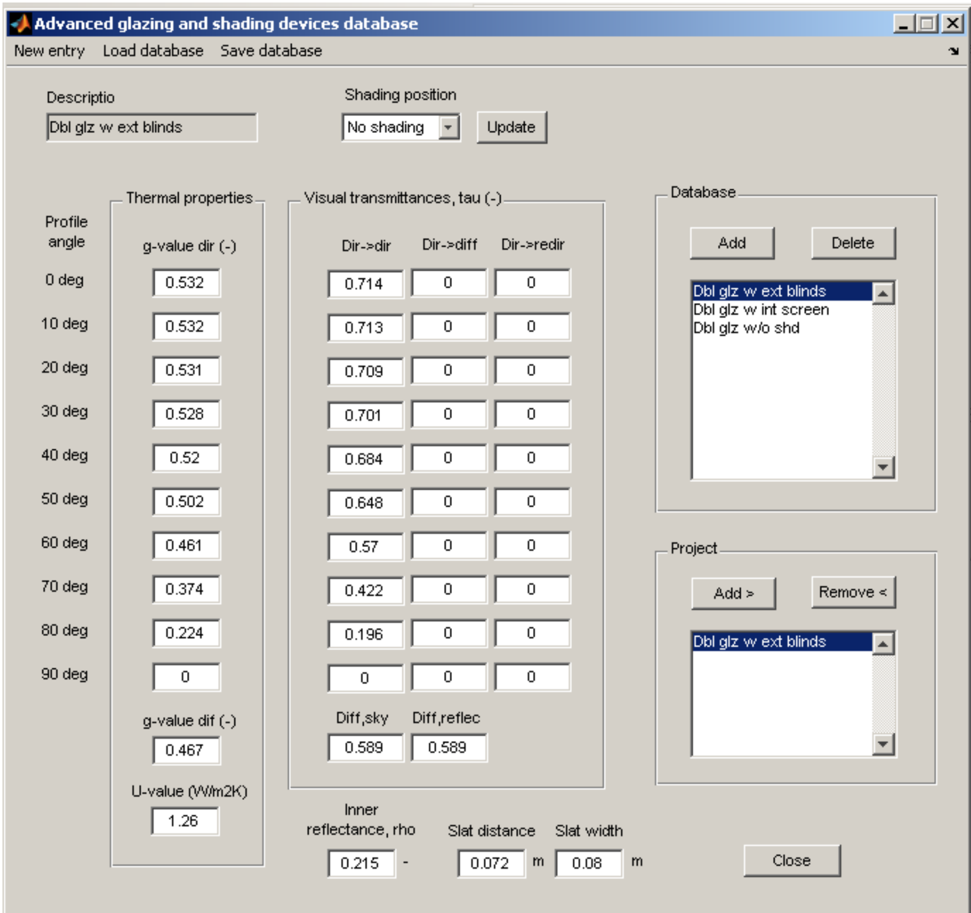


Figure 26. Advanced glazing and shading database

If the user wants to make a new entry, press “New entry”. The GUI in Figure 27 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.

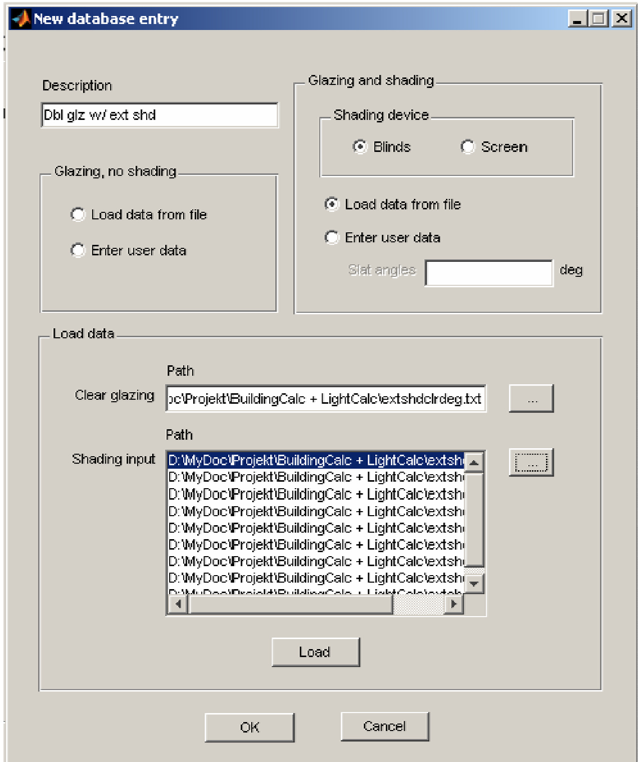


Figure 27. New database entry.

When “OK” in Figure 27 is pressed, the data is moved to the GUI in Figure 26, 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

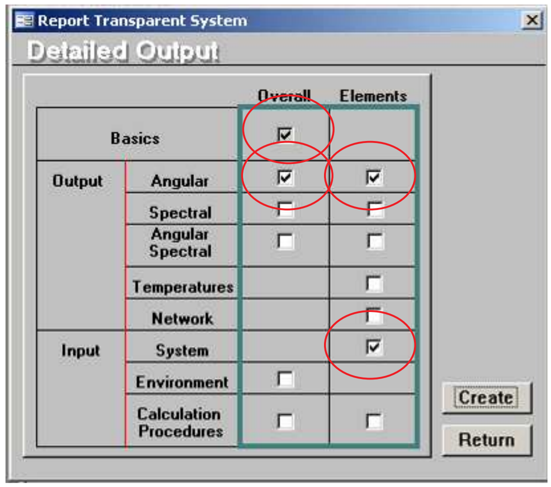


Figure 28. The WIS report dialog box

4.2.2.2 Windows

A window is defined in the same way as in BuildingCalc, see section 4.1.2.2. However, U-value and linear transmittance is not needed for daylight calculations, and tilt angle is fixed to 90°C.

4.2.3 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 29. Here the user can specify the reflectance of all internal surfaces.

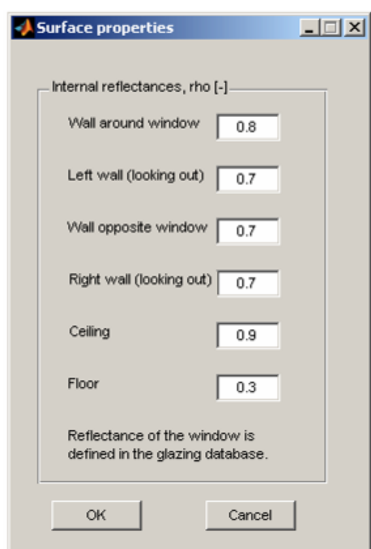


Figure 29. Surface properties dialog box.

4.2.4 Simulation

The menu item *Simulation* has two options: *Calculate* and *Results*.

4.2.4.1 Calculate

Selecting the option *Calculate* opens a dialog box as in Figure 30.

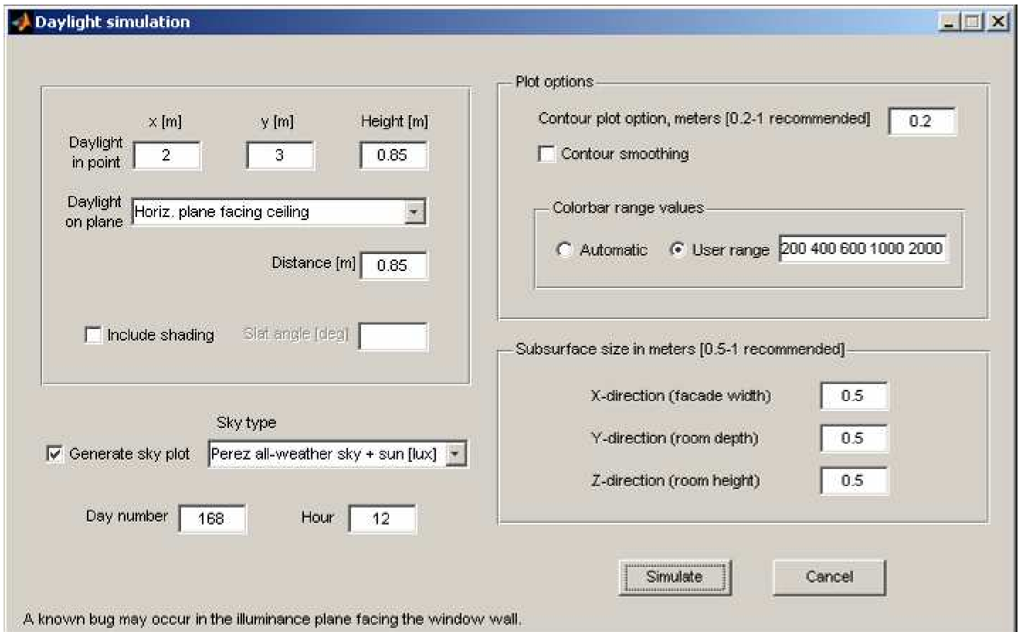


Figure 30. Final input for daylight simulation.

It is then possible to specify options for the output e.g. a specific value in a **point** or **plane** of interest. **Daylight in point** is the illuminance in a specific point. **Daylight on plane** is the illuminance on a fictive plane.

Distance is used to place the fictive plane and refers to the perpendicular distance from the backside of the plane to nearest parallel internal surface.

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

It is possible to select different **sky luminance distribution models** and to generate a luminance distribution plot (2D and 3D overview of the sky) 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 in general 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 a uniform sky which gives 10000 lux on an external horizontal plane. It is independent of *day* and *hour*.

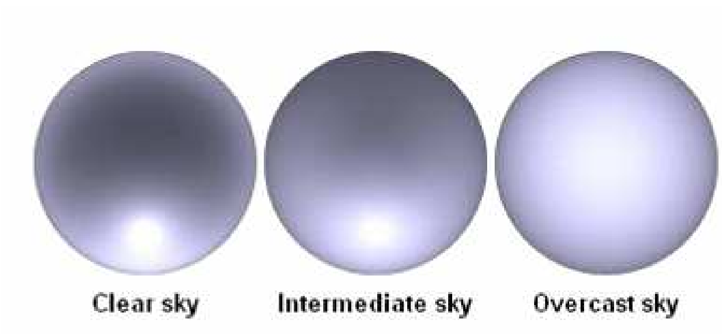


Figure 31. Illustrations of different sky types.

Day number and **hour** is specified in the following manner: 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).

The **Contour plot option** sets the distance between evaluated points (in meters). Advice: Should be smaller for small windows.

The **Contour smoothing** option smoothes the isolines in the contour plot. (Feature needs more development).

The **Colorbar ranges** option adjusts isolines in the contour plot. Very useful when comparing plots.

The **Subsurface size** option specifies the number of room dividing subsurfaces and is linked to the accuracy of the calculation as well as the computational time. Decreasing the subsurface size to less than 0.5 will increase the computational time drastically. Measured in meters.

4.2.4.2 Result

The option *Results* opens the result dialogues in Figure 32(if specified by user) and Figure 33.

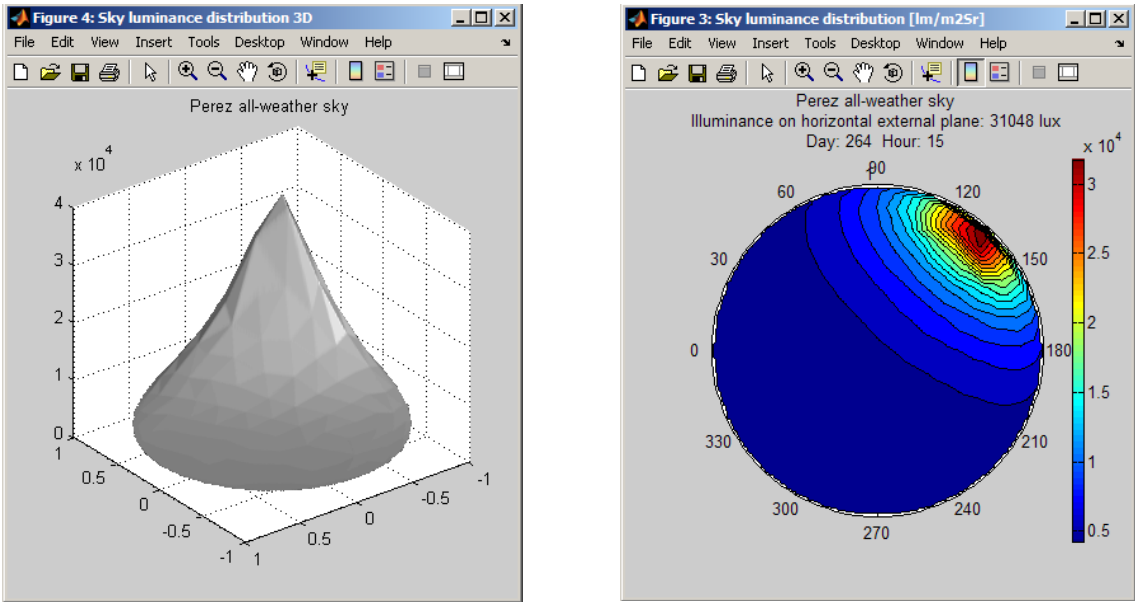


Figure 32. Sky luminance distribution. In this case Perez sky.

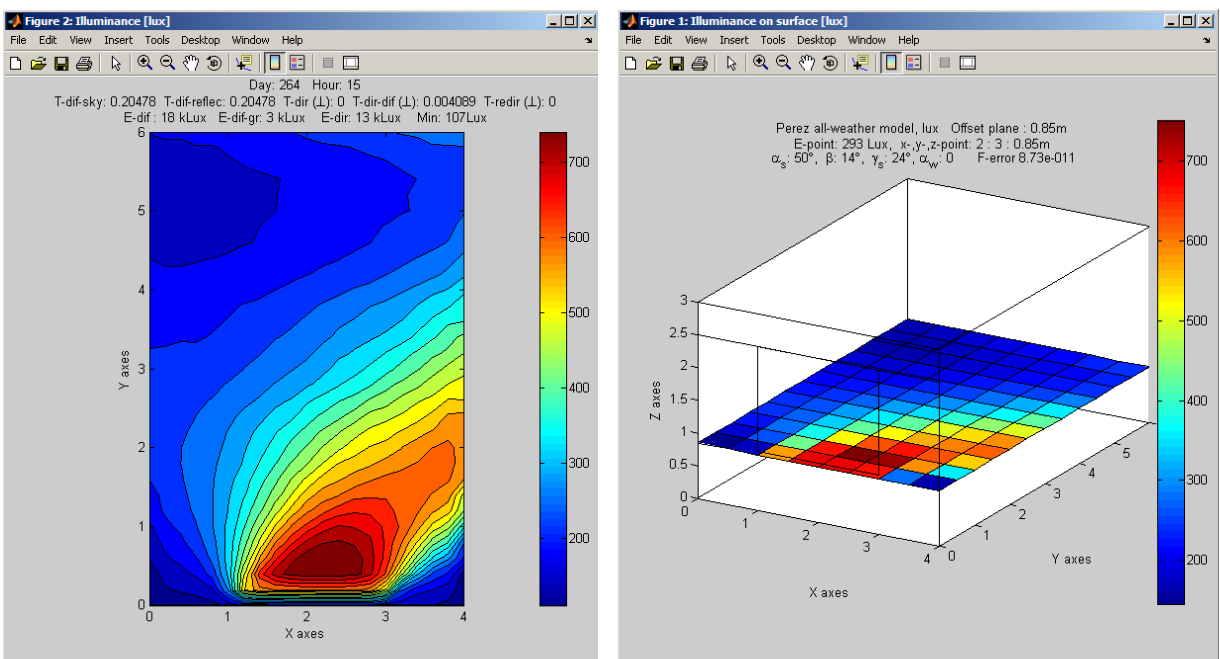


Figure 33. Lux levels on a virtual surface in room.

4.3 BuildingCalc/LightCalc

4.3.1 Geometry

Geometry is defined as in LightCalc, see section 4.2.1.

4.3.2 Building

BuildingCalc/LightCalc (BC/LC) is sharing input GUIs with both BuildingCalc and LightCalc: this is the integrated thermal and daylight simulation tool of the program package.

4.3.2.1 Glazings

The option *Glazings* for definition of glazing systems is the same as in LightCalc, see section 4.2.2.1.

4.3.2.2 Windows

The option *Windows* for definition of windows is the same as in BuildingCalc, see section 4.1.2.2. However, at present time, it is only possible to define one window in one façade.

4.3.2.3 Constructions

The option *Constructions* for definition of the thermal properties of the construction is the same as for BuildingCalc, see section 4.1.2.3.

4.3.2.4 Systems

The option *Systems* for definition of all building service systems is the same as for BuildingCalc, see section 0. However, since this is the combined thermal and daylight calculation the user now has the possibility of 1) defining dynamic shading control dependent of different predefined shading strategies, and 2) to control the electrical lighting system with respect to daylight levels in the room.

Shading control: 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. Only the latter applies if the solar shading is a screen.
The shading positions and consequently the different U-values, g-values and light transmittances are automatically taken into account in the simulations.

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.

Remember to press "Update" at the list of systems to store new or adjusted shading control settings..

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

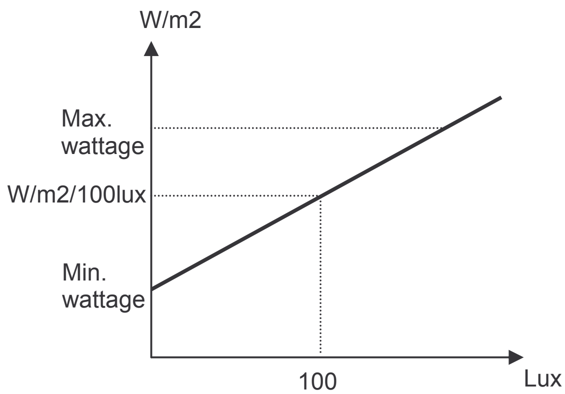


Figure 34. Continuous linear dimming control of the electrical lighting.

4.3.3 Indoor environment

The option *Comfort settings* is the same as for BuildingCalc, see section 4.1.3.

4.3.4 Settings

The menu item *Settings* is the entry to setting some values used in the simulation. Selecting the option *Properties* opens the dialog shown in *Figure 20*, see section 4.1.4. Selecting the option *Surface properties* opens the dialog in Figure 29, see section 4.1.4.

4.3.5 Simulation

The menu item *Simulation* has two options: *Calculate* and *Results*.

4.3.5.1 Calculate

Selecting the option *Calculate* opens a dialog box as in Figure 35.

The **General daylight reference point** is the point for daylight control of all general electrical lighting settings specified in the option *Systems* under the menu item *Building*. Default coordinates are in the middle of the room.

The **Task lighting reference point** can be specified separately. Default coordinates are in the middle of the room.
Unchecking the checkbox "Different from general" means the daylight will only be evaluated in one point (the general reference point) with certain implications: the light level set point is the highest one of the two reference point, general and task, as defined in *Systems*. The general system will try to achieve this set point up to the defined max power and then, if needed, the task lighting system takes over.

The **Vertical eye illuminance** for glare control is specified as a point (like in **General** and **Task**), an indication of which direction the occupant is facing, and a glare threshold.

The subsurface option is described in section 4.2.4.1. It is generally recommended that all subsurfaces are set to be 2 (speed) except for your very last simulation as this parameter heavily influences the computational time (by many minutes).

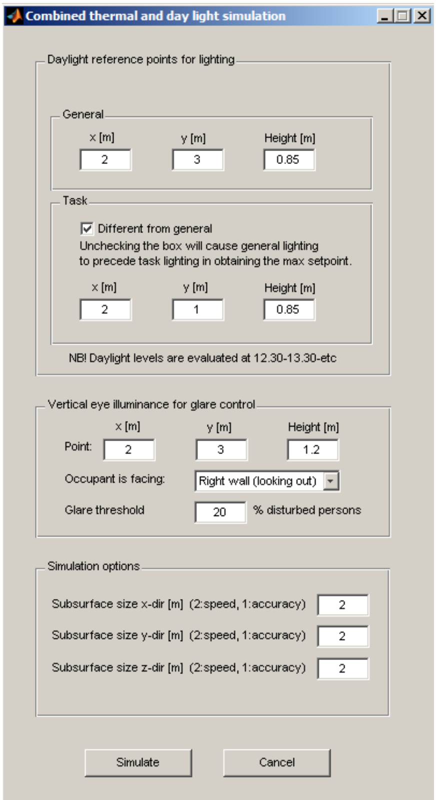


Figure 35. Final input for a combined thermal and daylight simulation.

4.3.5.2 Results

Choosing the option *Result* accesses the same result GUI as in BuildingCalc, see section 4.1.5.2.

4.4 *iDbuild*

iDbuild uses BC/LC as a calculation engine for parameter variations of all input parameters to give building designers an overview of how different parameters affect the energy consumption and indoor environment of the room. The program is evaluating energy performance of rooms based on the methodology from EPBD [EPBD, 2002] and the specific Danish requirements from the Danish Building Code and SBi specification 213 [Aggerholm and Grau, 2005]. The indoor environment is evaluated according to DS/EN 15251 [DS/EN 15251:2007].

Defining a room is practically done the same way as in BC/LC. However, there are implemented some features in certain GUIs to smoothen setup and facilitation of the parameter variations. These deviations from BC/LC are explained in the following sections. First is a general description of how to set up parameter variations.

4.4.1 Setting up parameter variations

In general, a parameter variation is based on the reference value of a performance-decisive parameter and two variations: either a lower and a higher value compared to the reference value, or a var.1 and var.2 value. The lower/higher parameter variation indicates that the parameter is scalable, e.g. room height, construction U-value, etc. The var.1/var.2 parameter variation indicates that the parameter is non-scalable, e.g. glazing component.

The designer decides which performance-decisive parameters to vary. Parameter variations can be performed in two different ways:

1. As variation of the single performance decisive parameters (default)
2. As bundles of performance decisive parameters (elective)

Figure 36 is a graphical overview of the two possible options for parameter variations.

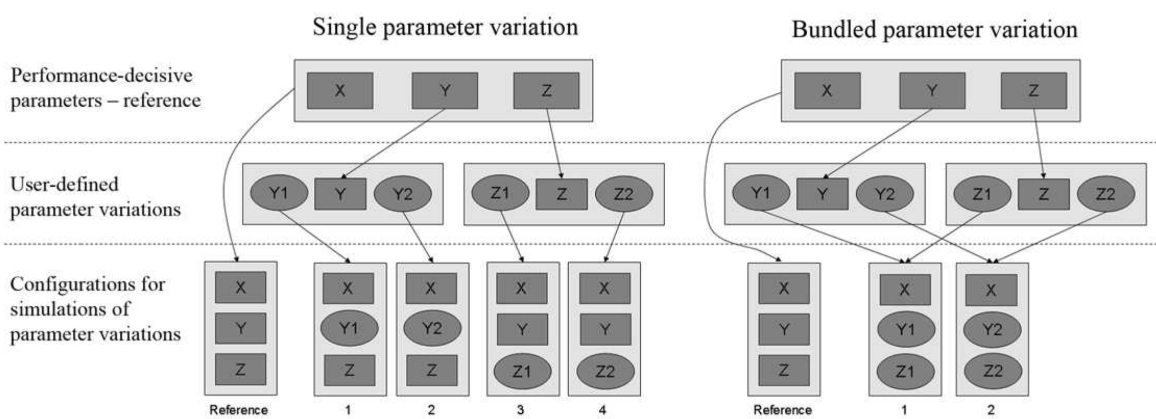


Figure 36. Principle of the two possible ways of setting up parameter variations in iDbuild.

The two options are described separately in the following sections.

4.4.1.1 Single parameter variation

In this option, the program will first calculate the performance of the established reference room. Then the program will calculate each defined parameter variation separately, meaning that all other parameters than the performance parameter in question is fixed. This gives the designer an overview of the performance impact of the single performance decisive parameter. If no parameter variations are defined, the program will just calculate the performance of the reference.

In order to set up a parameter variation, the checkbox next to the performance-decisive parameter in question is checked, and a “var.1/lower” and “var.2/higher” value is filled in. In Figure 37, the variation of window height is used as an example of the setting of a single parameter variation (option *Windows* in the menu item *Building*).

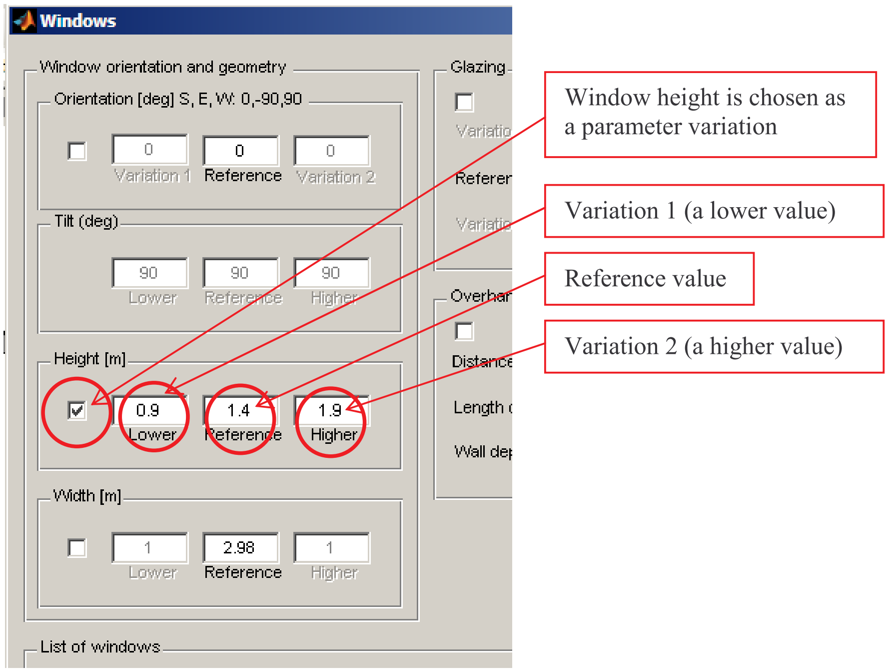


Figure 37: Setting up a parameter variation in iDbuild. The window height is varied with +/- 0.5 m

Using the default option of single parameter variations, the program will take all defined reference values and then do the following: 1) chance the selected parameter to the lower value of the single parameter and make a new performance simulation, then 2) chance the selected parameter to the higher value of the single parameter variation and make new performance a simulation. See Figure 36 for graphical overview.

*The program performs one simulation for **each** of the defined parameter variations.*

If the user sets up two single parameter variations, the program will perform: 1 performance simulation of the reference + 4 individual parameter variations = 5 simulations. The user may set up as many single parameter variations as found necessary. Be aware that the time consumption for simulations will increase with the number of parameter variations. The time consumption for simulation may also increase/decrease with the room size and the controls set up in *Systems*.

4.4.1.2 Bundle parameter variation

Choosing this option, the program will first calculate the performance of the established reference room. Then the program will calculate the performance of 1) the reference including all defined “lower/var.1” values and 2) the reference including all defined “higher/var.2” values. The parameter variations are set up as in “Single parameter variation” but are bundled into two parameter variations (one “lower/var.1” and one higher/var.2). The distinction between “lower/higher” values is not as important for this simulation option as for single parameter variations. See Figure 36 for graphical overview of the bundled parameter variation.

*The program performs one simulation for **all** of the defined parameter variations.*

If the user sets up two parameter variations, the program will perform: 1 performance simulation of the reference + 2 bundled parameter variations = 3 simulations. However, the 2 parameter variations may, as mentioned earlier, contain the variation of several parameters. An example when to use "Bundle parameter variation" is that if the user wants to vary the room height but at the same time wants the window height to be correspondingly "lower/higher".

In order to activate the bundle parameter variation option go to the menu item *Calculate* and click the option *Simulation settings*. Check the box next to **Bundle parameter variations**, see Figure 38.

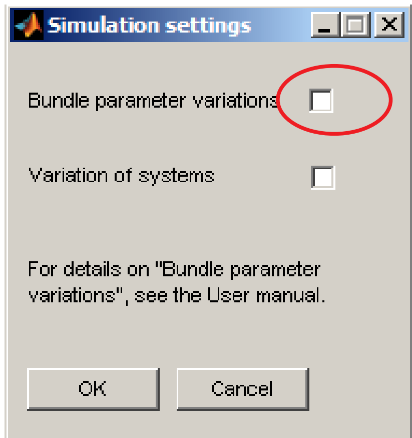


Figure 38: If the check box next to "Bundle parameter variations" is checked, the program is bundling parameter variations as described above.

4.4.2 Geometry

Geometry is defined as in BC/LC and LightCalc, see section 4.2.1. Parameter variations are defined as in the example in section 4.4.1.1.

4.4.3 Building

iDbuild is sharing input GUIs with BC/LC. However, there are implemented some features in some of the GUIs to smoothen the setup of the parameter variations.

4.4.3.1 Glazings

The option *Glazings* for definition of glazing systems is the same as in BC/LC and LightCalc, see section 4.2.2.1.

4.4.3.2 Windows

The option *Windows* for definition of windows is in principle the same as in BC/LC and BuildingCalc, see section 4.1.2.2. However, the GUI is arranged in a different way to facilitate the parameter variation, see Figure 39.

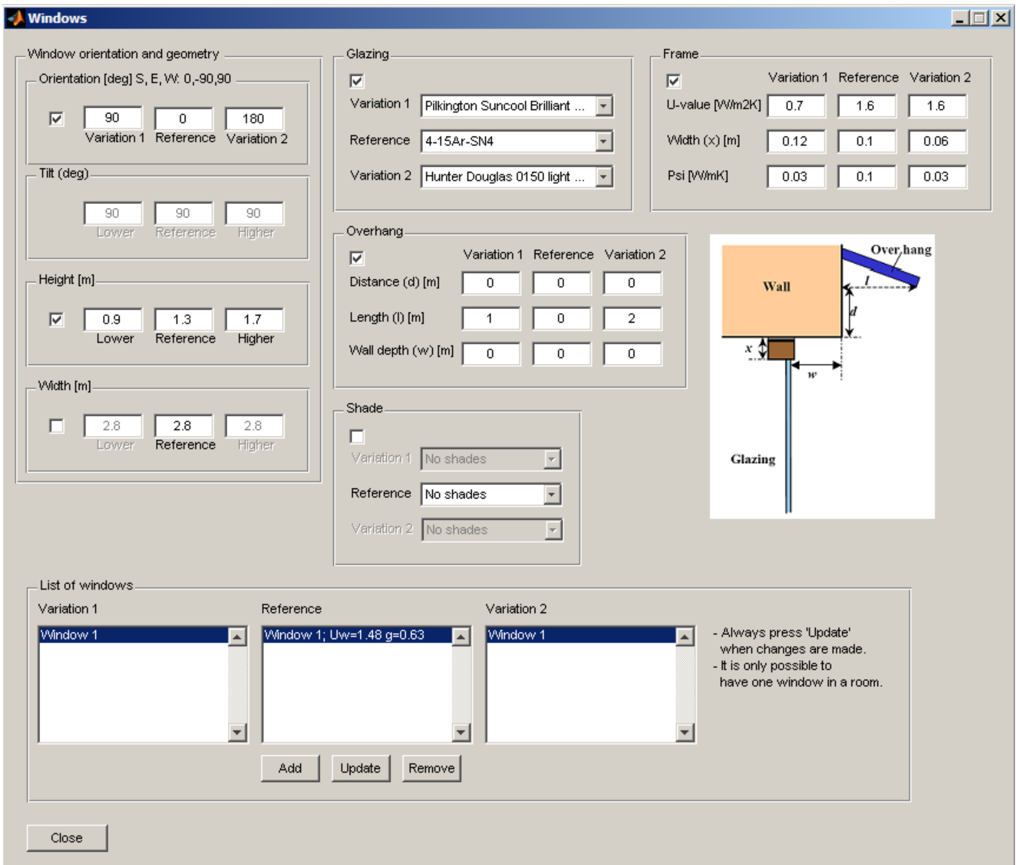


Figure 39. Window definition in iDbuild.

4.4.3.3 Constructions

The option *Constructions* for definition of the thermal properties of the construction is in principle the same as for BC/LC and BuildingCalc, see section 4.1.2.3. However, some extra features are implemented to smoothen the set up of the simulation model, see Figure 40.

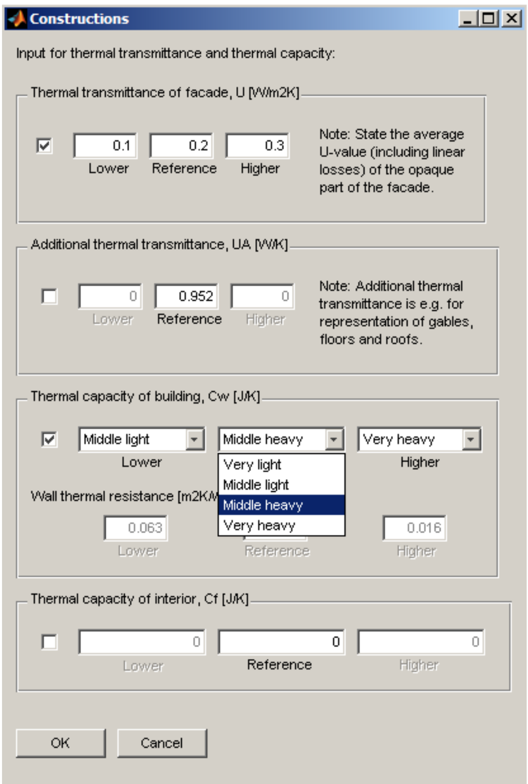


Figure 40. Construction properties in Dbuild

<u>Thermal transmittance</u>
In iDbuild the user specify the "U-value of the façade". If there is some additional heat loss due to e.g. roof or floor, it should be specified as an UA value in "Additional thermal transmittance, UA". For details on UA value, see section 4.1.2.3.

<u>Thermal capacity of building</u>
In iDbuild the user can choose between 4 categories of thermal capacity of the building. The four categories correspond to those in

If the heat capacity of the interior is unknown, the user may either neglect it or use estimate it. Example of estimation of Cf in a 18 m^2 office for 2 persons:

- 2xLabtop+Monitor+Keyboard: 15 kg
- 2x Chairs and desks: 75 kg
- 2x Cabinets/filing (w/books, etc): 200 kg
- 2x Misc stuff: 70 kg
- SUM: 360 kg = 20 kg/m^2

4.4.3.4 Systems (reference, variation 1, variation 2)

In the menu item *Building* there is three system options: *System, reference* ; *System, variation 1* and *System, variation 2*. The user should set up the system for the *System, reference* first. The user then has to open option *System, variation 1* and *System, variation 2*, respectively, and press the button "**Copy data from reference**", see Figure 41.

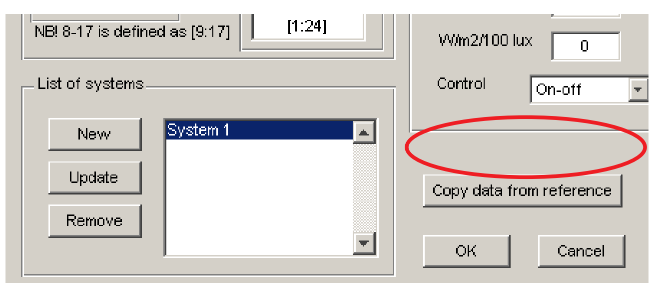


Figure 41: If the user wants the same system settings for all parameter variations, go to "System, variation 1" and "System, variation 2", and press "Copy data from reference".

When “Copy data from reference” is pressed, an information dialogue box appears, see Figure 42. This message is the reason why systems for reference, variation 1 and variation 2 in principle should be defined separately; the control of shading systems might differ if the user has different glazings as parameter variation.

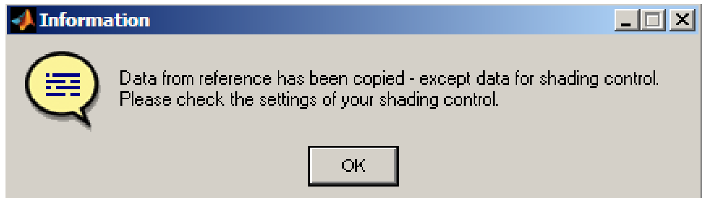


Figure 42: Information box regarding the control of shadings appears when ”Copy data from reference” is pressed.

The dialogue closes when “OK” is pressed and all data from the reference – except the shading control, is copied. The user must then set up shading control for variation 1 and 2, if necessary. In general, all defined parameter variations will use *System, variation 1* for the performance calculations of ***all*** **“lower/var.1”** variations and *System, variation 2* for the performance calculations of ***all*** **“higher/var.2”**.

NB: It is recommended that parameter variations of any settings in *Systems* should be performed in a separate copy of a iDbuild file. If the user wants to see the output of a variation of a certain setting in the *Systems* separate from all other parameter variations, go to the menu item *Simulation* and choose the option *Simulation settings*. Check the box next to “Include variation of systems”, see Figure 43.

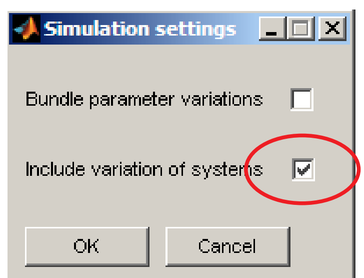
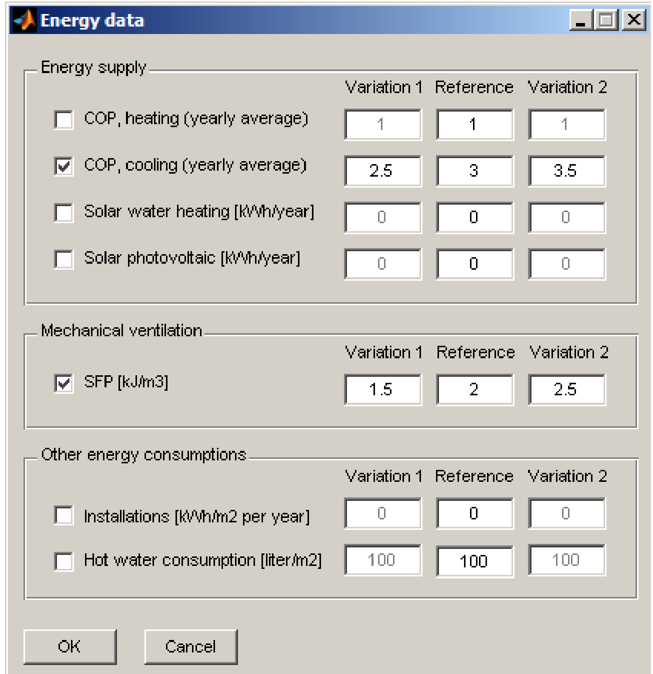


Figure 43: If the user wants a parameter variation simulation of different system settings, check the box as shown in the figure.

The setting will make a parameter variation simulation where all parameters except the three system settings are fixed.

4.4.3.5 Energy data

First of all: **All parameters in the option *Energy data* in the menu “Building” do not require extra simulations time.**
The program needs, as minimum, to calculate the performance of the reference. After this simulation, the user can – without additional simulation time – specify parameter variations for all parameters in the options *Energy data*.
This is because the parameters in *Energy data* are merely factors used, together with the output data of the simulation, for calculation of the energy performance. The user may therefore add *Energy data* variations after simulations without additional simulation time. An explanation of the energy data needed for calculating the energy performance is given next to



COP, heating: The yearly average (NOT peak, seasonal, etc) coefficient of performance for the heating system. Primary energy factor for heating is defined in section 4.4.5.

COP, Cooling: The yearly average (NOT peak, seasonal, etc) coefficient of performance for cooling system. Primary energy factor for electricity is defined in section 4.4.5.

Solar water heating: The amount of heat energy (kWh/year) generated by a solar water heating system on the building. Is subtracted from the overall energy consumption according to EPBD.

Solar photovoltaic: The amount of electrical energy (kWh/year) generated by a PV system on the building. Is subtracted from the overall energy consumption according to EPBD. Primary energy factor for electricity is defined in section 4.4.5.

SFP: Specific Fan Power of mechanical ventilation system (= 0 if natural ventilation).

Installations: Energy for all other building services which according to EPBD has to be included in the calculation of energy performance. Heat gains due to these services may be subtracted.

Hot water: Included as a part of EPBD. Details on the calculation of energy for hot water can be seen in section 4.4.5.

4.4.4 Indoor environment

The option *Evaluation settings* in the menu item *Indoor environment* is essential to the evaluation of the output data in terms of the quality of indoor environment. Figure 44 shows the GUI together with explanations of the input data fields. The settings are closely linked to the definitions in DS/EN 15251. It is recommended that the values in *Evaluation settings* correspond to the settings in *Systems* or vice versa.

NB: Data specified in *Evaluation settings* has no influence on other data in the program than the simulation output data. There is no direct link between what is specified here and in what is specified in the option *Systems* in the menu item *Buildings*.

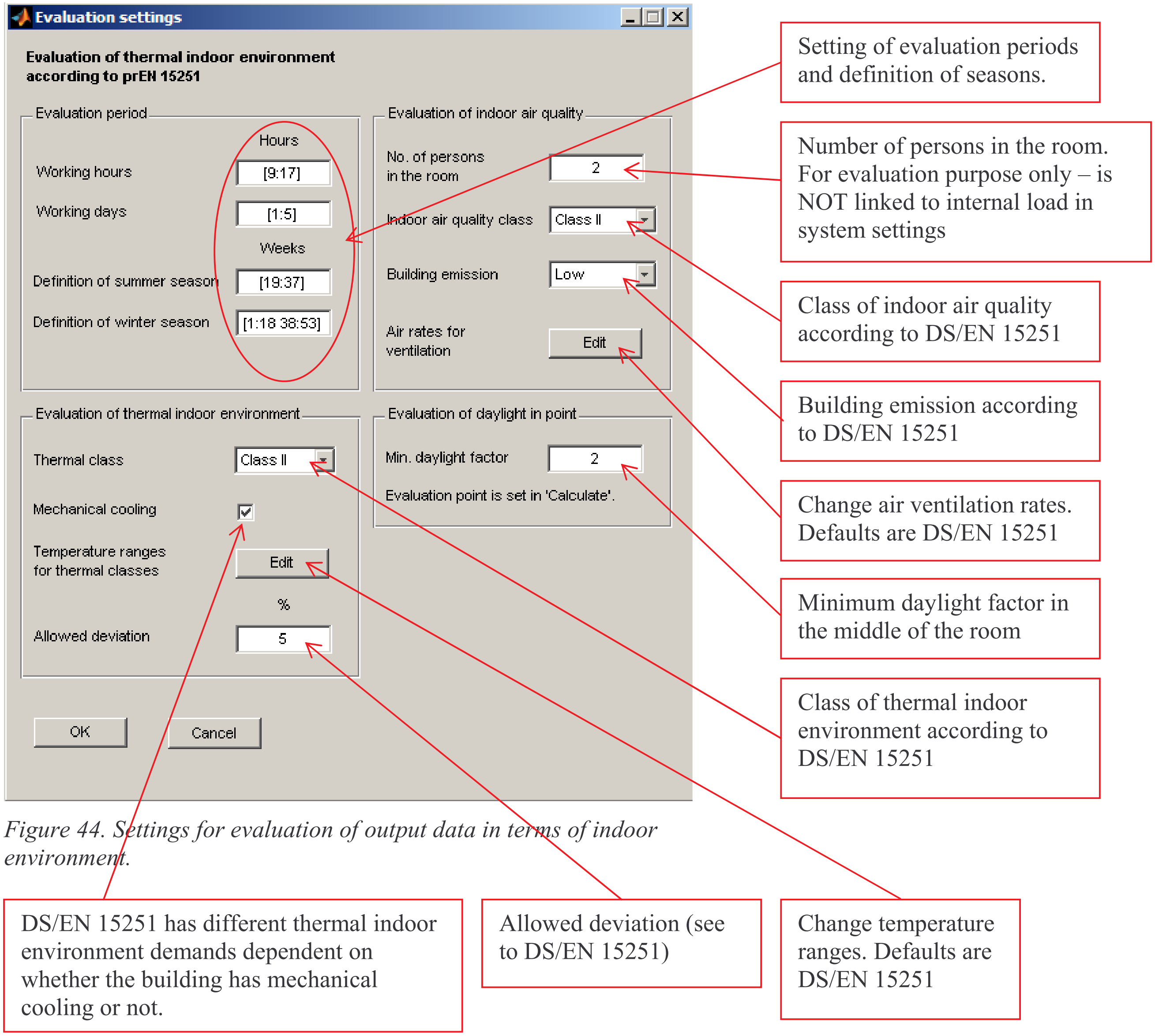


Figure 44. Settings for evaluation of output data in terms of indoor environment.

Note: Default temperature ranges from DS/EN 15251 are based on the values in table A.3. The allowed deviation for yearly deviation only (section G.2).

Note: Default ventilation rates from DS/EN 15251 are based on the description in section B.1.3 and the values in table B.3.

4.4.5 Settings

The menu item *Settings* is the entry to setting some values used in the simulation. Selecting the option *Properties* opens the dialog shown in *Figure 20*, see section 4.1.4. Selecting the option *Surface properties* opens the dialog in Figure 29, see section 4.1.4. The option *Energy properties* opens the dialog in Figure 45.

Primary heating source: The primary energy factor of the primary energy source.

Electricity: The primary energy factor of electricity (secondary energy source).

Heating data: Data for simple way of calculating heating energy (primary energy) for hot water consumption.

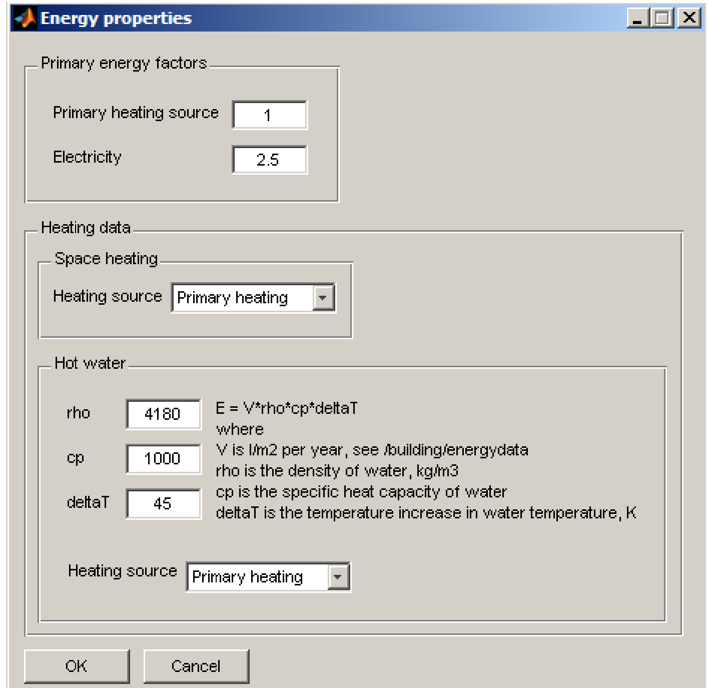


Figure 45. Energy properties

4.4.6 Simulation

The menu item *Simulation* has three options: *Simulation settings*, *Calculate* and *Results*.

4.4.6.1 Simulation settings

The option “Bundle parameter variations” is explained in section 4.4.1.2. The option “Variation of systems” is explained in section 4.4.3.4.

4.4.6.2 Calculate

Selecting the option *Calculate* opens a dialog box as in Figure 46. The settings which can be defined here is the same as described in section 4.3.5.1. However, there is an additional setting for the user to consider. In the top of the GUI there is an option for either “Automatically adjusted” or “Fixed” daylight reference points. This refers to how iDbuild would handle the daylight reference points in case of a parameter variation of the *room width* and/or *room depth*. The two options are explained in *Figure 47*

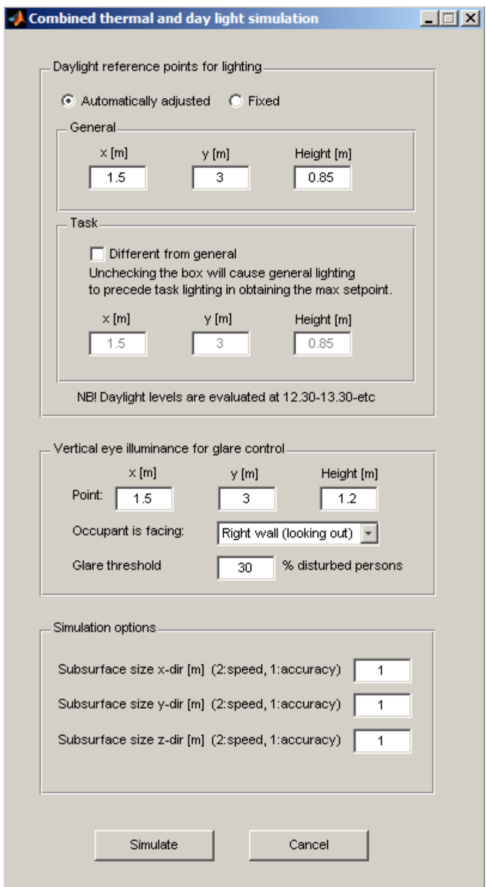


Figure 46. Final input for an iDbuild simulation.

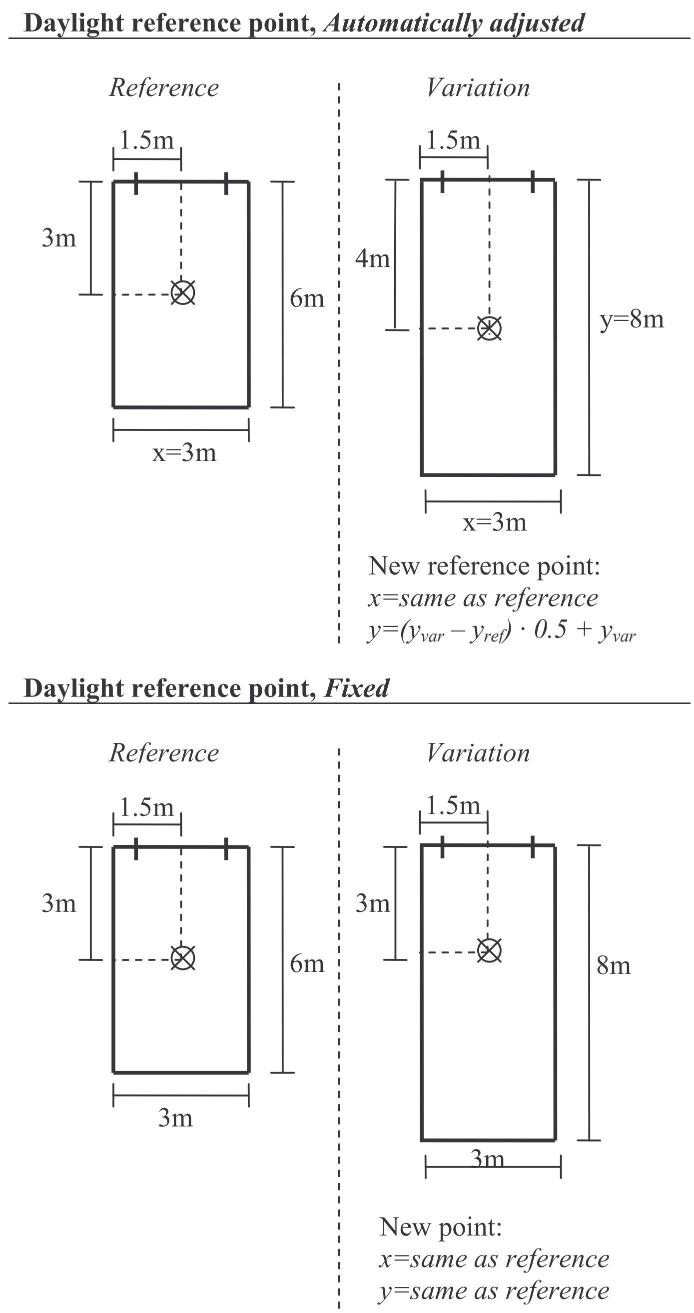


Figure 47. Definition of how iDbuild is handling daylight reference points if room width and/or lenght is variated.

4.4.6.3 Results

Then simulations are performed, the option *Results* can be accessed. The dialogue in Figure 48 will pop up.

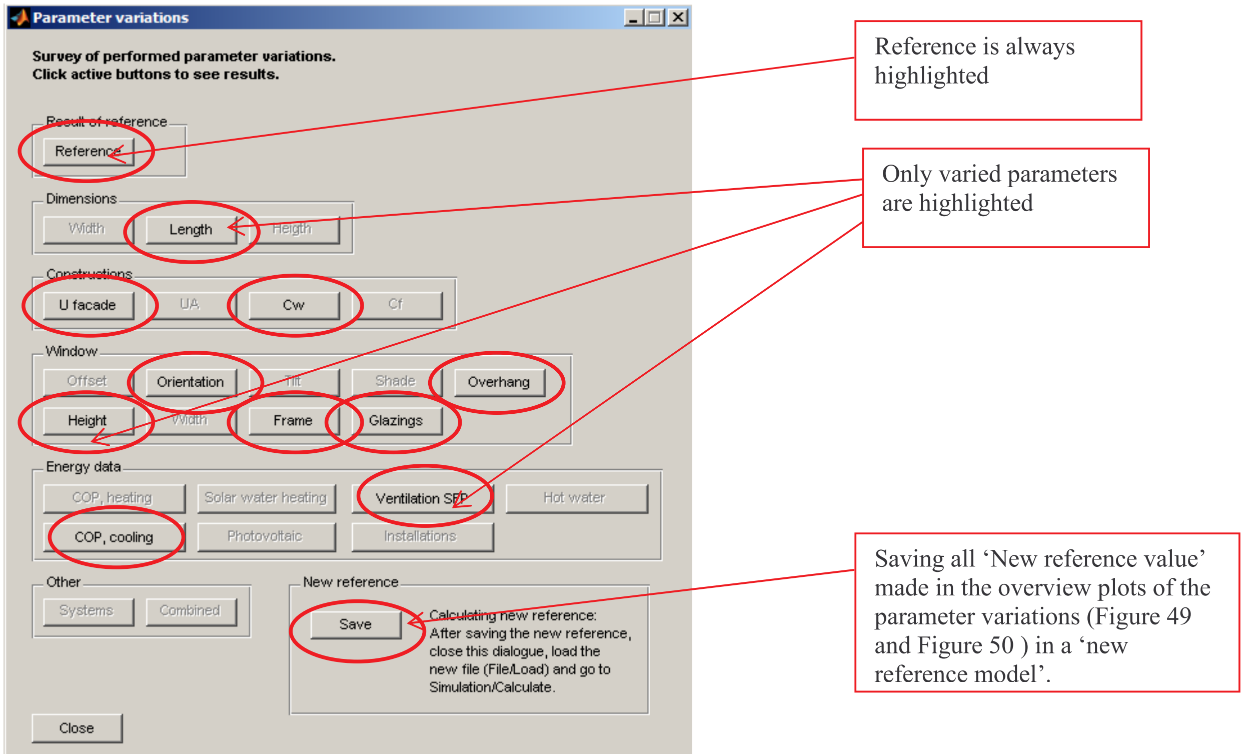


Figure 48: Overview of parameter variations.

Push the button of the varied parameter, and an overview of the output of the parameter variation in terms of energy consumption and indoor environment will show. The program is distinguishing between scalable and non-scalable parameters in the presentation of the results. The following examples of the presentation of results are for variation of glazing, which is a non-scalable parameter and the variation of window height, which is a scalable parameter.

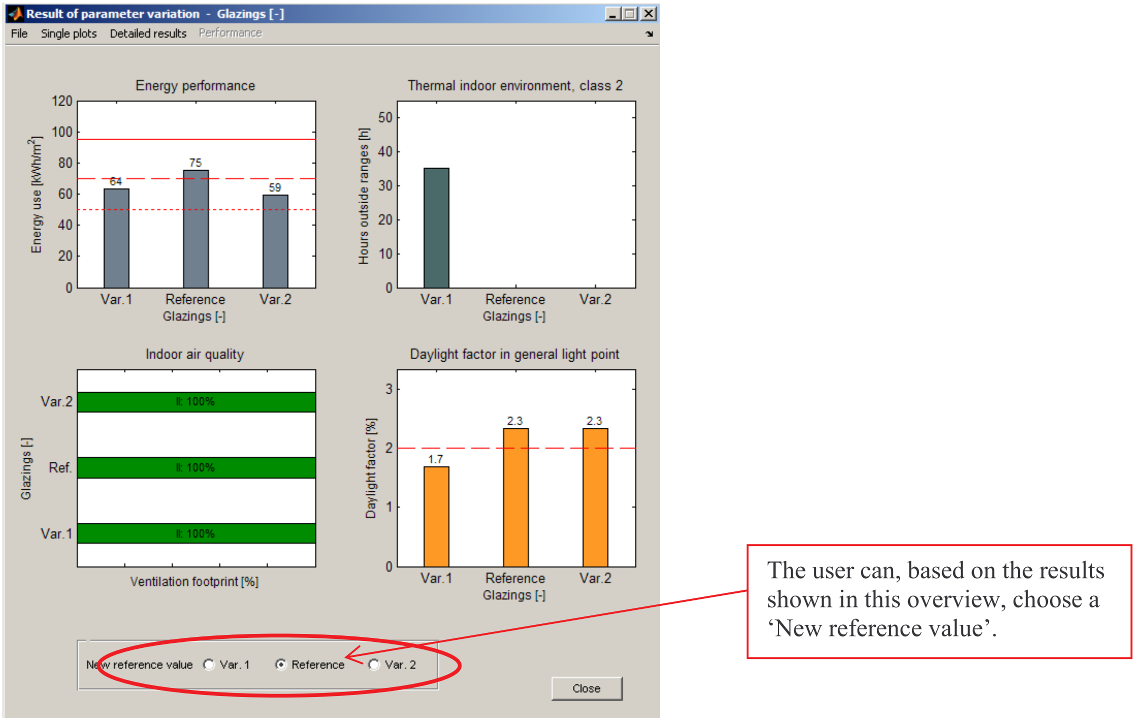


Figure 49: Result overview of a parameter variation of glazings – a non-scalable parameter: results of variations for energy and daylight are shown as bars. Var.1: solar dbl glz, ref: dbl glz w/o shd, var.2: dbl glz w/ shd.

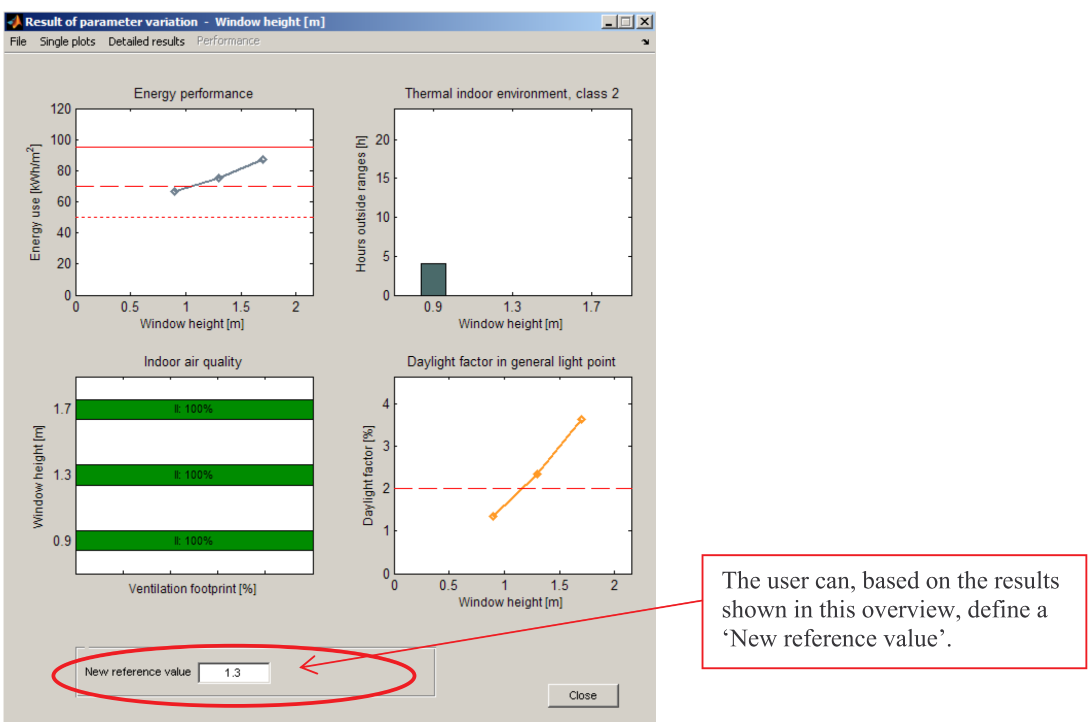


Figure 50: Result overview of a parameter variation of window height – a scalable parameter: results of variations for energy and daylight are seen as a continuing line.

This overview can be saved by clicking menu item *File*, choosing the option *Export*. In the Export dialogue, go to *File* then *Save*.

The button *Save* under 'New reference' in Figure 48 is for saving a new .mat file containing the values stated in the button of the parameter variation overviews (see Figure 49 and Figure 50). The value of the input parameter is the same as the current reference value for parameters where no variation is performed. The same goes for parameters where the user has not changed the parameter in the variation overview. All defined parameter variations are reset in the saved 'New reference' and the designer can now load this new file and simulate its performance. The designer may then define new parameter variations and repeat the analysis based on the new (hopefully improved) reference.

In the menu item *Detailed plots*, the initial results shown in Figure 49 and Figure 50 can be accessed for more detailed analysis of the output. As an example, the detailed plots from the variation of window heights are shown in Figure 51-Figure 55. For saving and/or editing of these plots, click *File* in the single plot dialogue and choose *Export*.

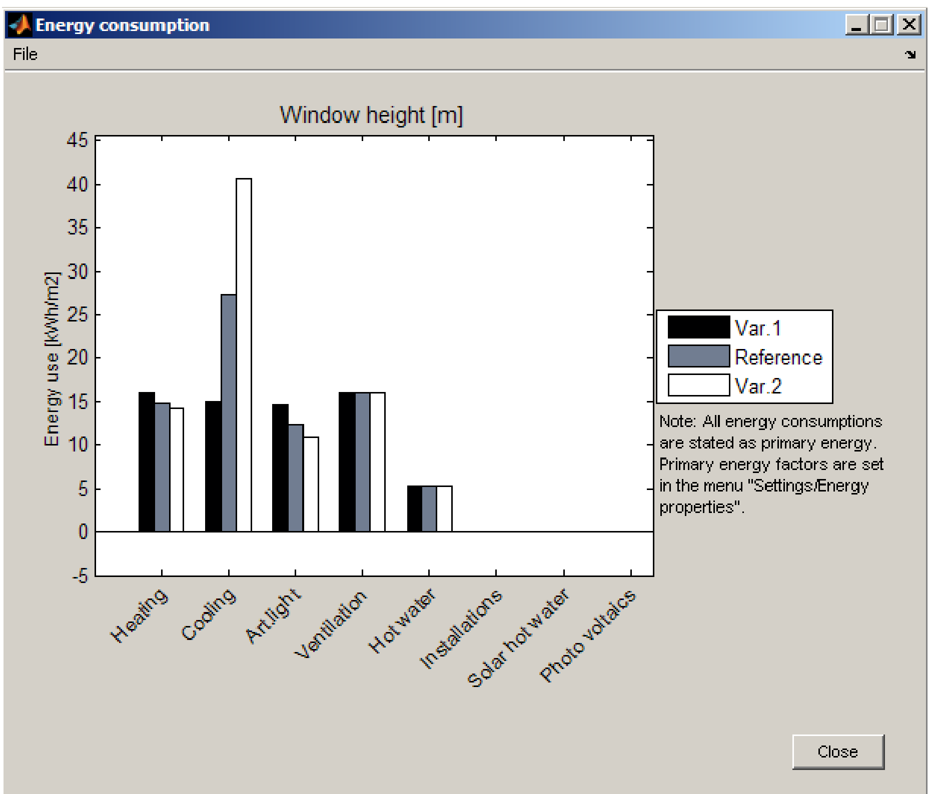


Figure 51: Energy consumtion of the reference and variation 1 and 2 distributed on the different types of energy consumption according to EPBD.

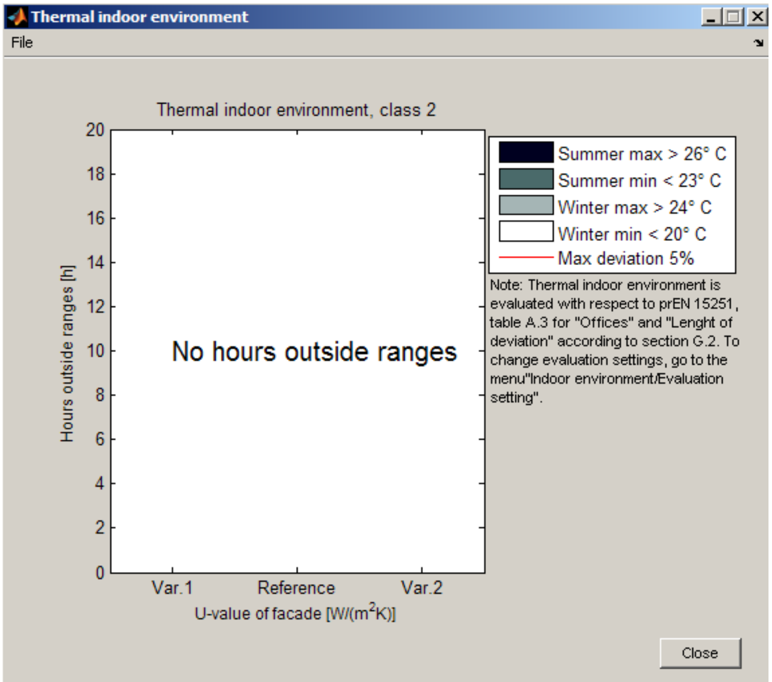


Figure 52: If there are no oversteppings of temperatures according to DS/EN 15251, then "No hours outside ranges" will appear in the graph. If there are oversteppings – see Figure 53.

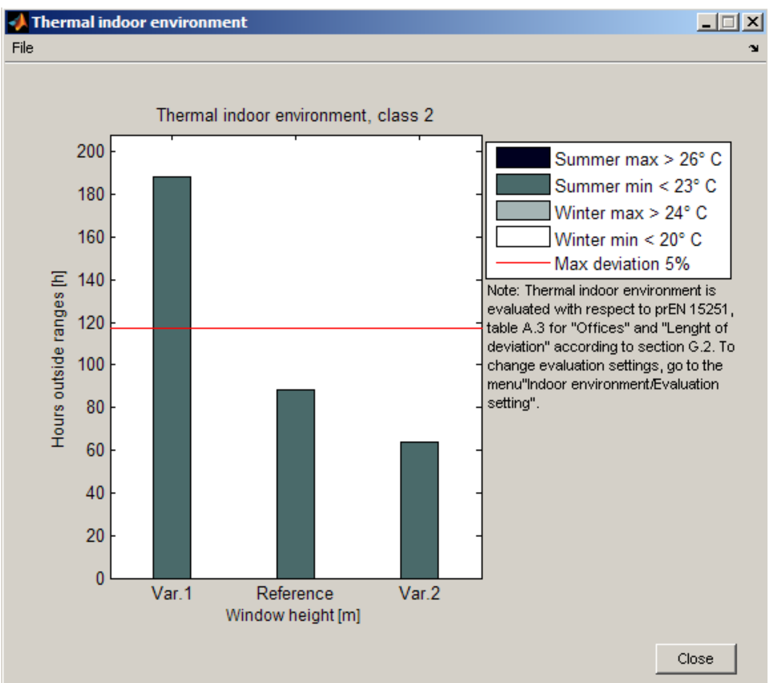


Figure 53: If there are oversteppings of temperatures according to DS/EN 15251, they will be presented as above. The read horizontals line is the "Allowed deviation in working hours" from the menu "Evaluation settings". The graph shows the number of hours outside every min/max set points (see legend) and stack them up for compliance control of the "Allowed deviation in working hours". If there are no oversteppings – see Figure 52.

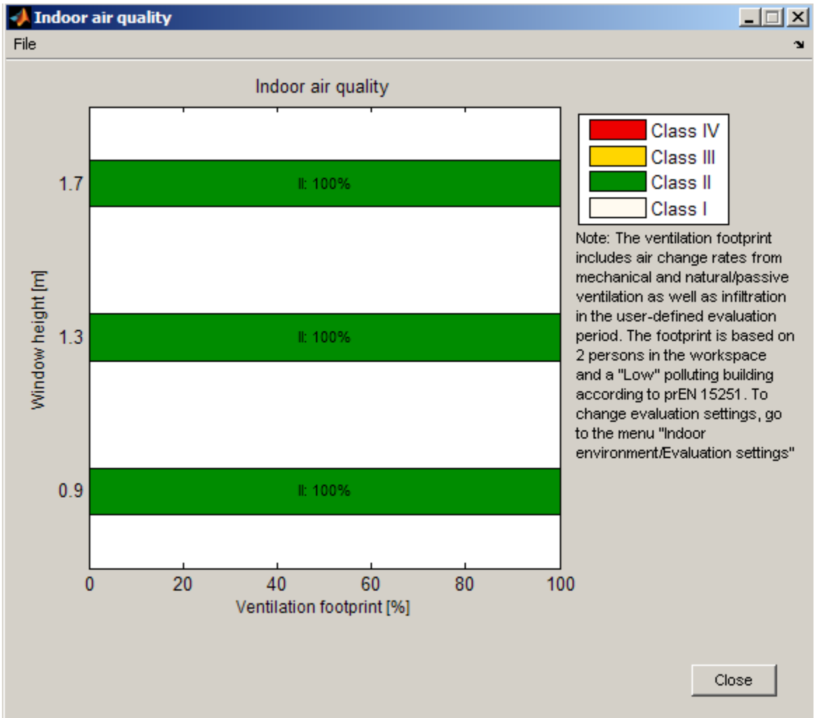


Figure 54: The result in terms of indoor air quality is plotted as suggested in DS/EN 15215 Annex I.2.The ventilation does not change when the window height is varied. All three simulations is fulfilling class II according to DS/EN 15251.

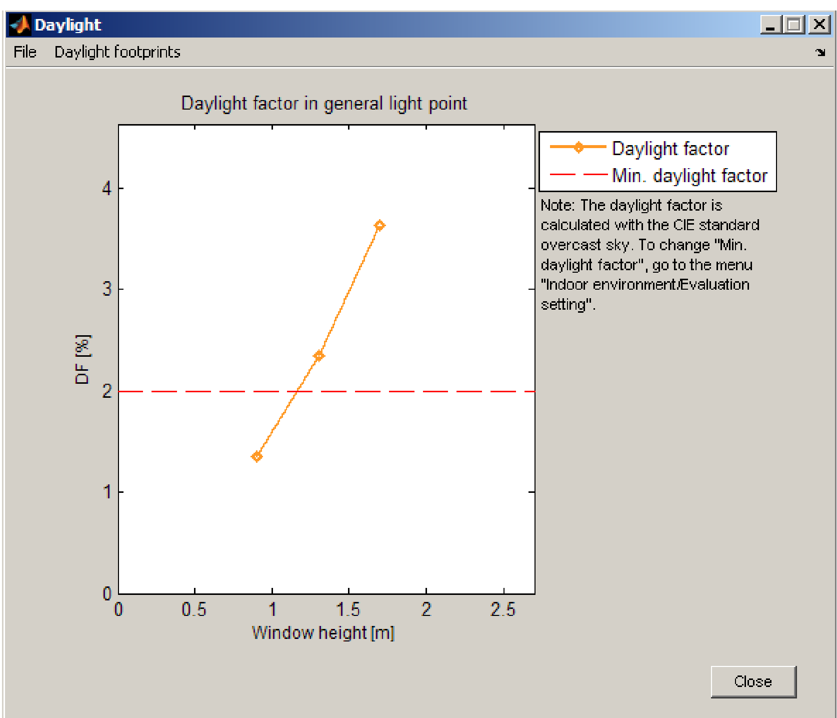


Figure 55: Plot of daylight factor in general set point.

The option *Detailed daylight analysis* in the daylight GUI enables the user to make further investigations of the daylight conditions in the room, see Figure 56.

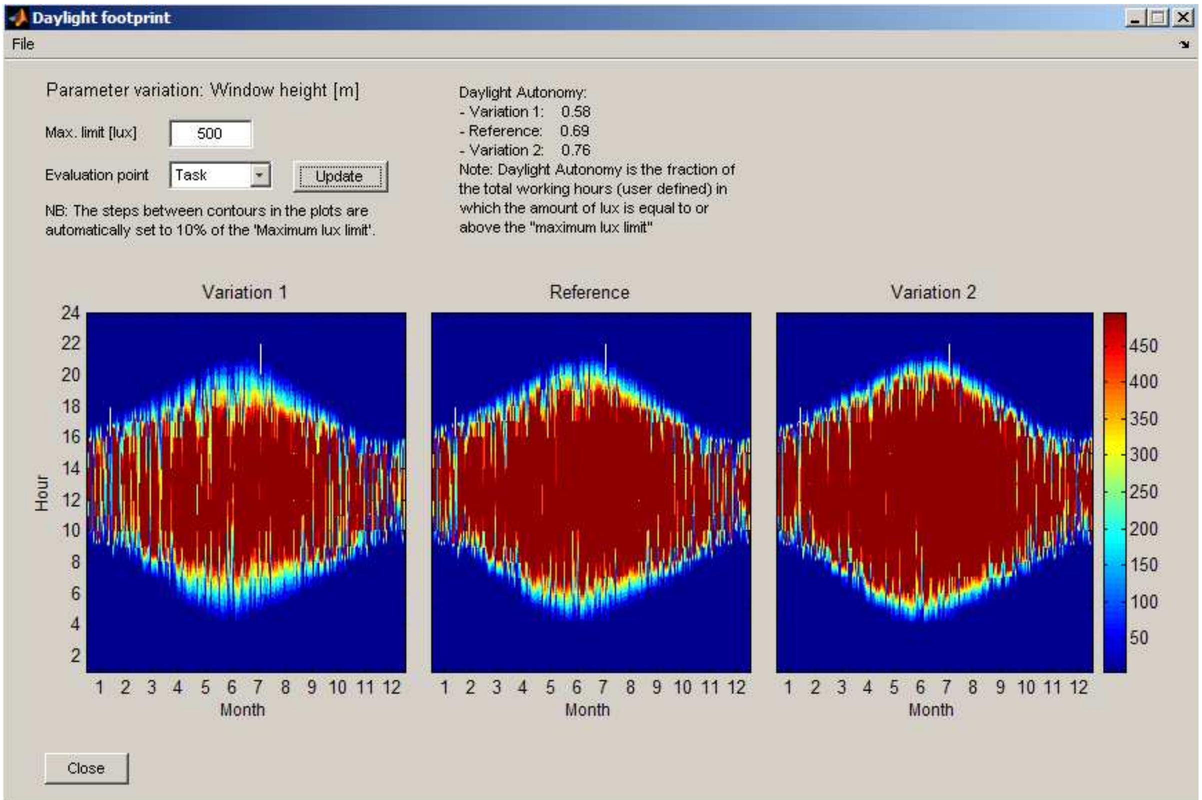


Figure 56. Data for detailed analysis of daylight conditions in the room.

Max. limit refers to the maximum value of the colour scale. *Tip:* Set max. limit to the respective lighting set point. All the “area” with the deep red colour is then the hours of the year where there is enough daylight with respect to the set point. This will also give you **Daylight autonomy** with respect to the daylight set point.

In **Evaluation point** the user can choose between the three daylight evaluation points from the simulation: *General, Task* and *Glare*.

Press **Update** to see results with respect to new settings of Max. limit and/or Evaluation point.

The plots can be exported in *File/Export.*

5 Tips and tricks

- Summer and winter in Denmark is usually defined as:
  - Winter: 1. October – 30. April. In BC/LC this is written as [1:16 41:53]
  - Summer: 1. May – 30. September. In BC/LC this is written as [17:40]

- Name all your model files so they are easily recognized – also a week later.

- Windows – use the standard solutions in BC/LC (database called "glzdtb.mat" in the BC/LC library). These are known products on the market. Alternatively, generate your own glazing systems with WIS.

- If the user wants to change "Type of simulation", it is recommended to close BC/LC and start it again, and then choose type of simulation, and make the model. This maintains consistency in the program package.

- Keep all files related to the program in the BC/LC folder – do NOT make subfolders or folders with files somewhere else on your computer.

- Using the program remote on a network drive may cause simulation errors. Always work with the program *locally* on your work station (e.g. C:/xx/yy…). Do NOT move the program around once you have set up a model for simulation situated in a specific folder with a specific path.
  If you *have* to remove the program, e.g. save it on a network drive, be sure that the program is located in the *exact* same path *locally* on a computer where you initially defined your models when you want to work on the models again. Otherwise data corruptions will occur.

- Enquiries for weather data for other locations than Denmark are welcome at stp@byg.dtu.dk or trn@byg.dtu.dk. You might be lucky… Otherwise, see section 2.3 for generation of weather data.

6 Special cases

6.1 How to simulate multiple windows 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

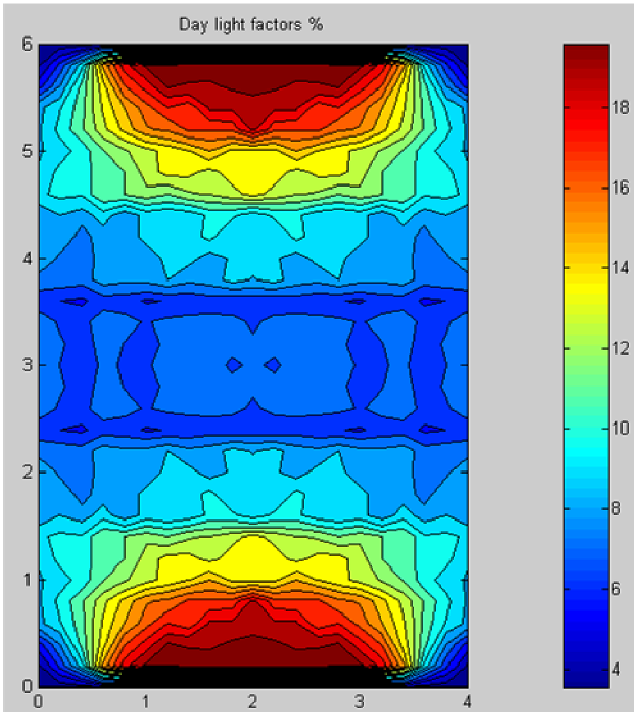
To simulate windows in the same façade, erase the lines marked with a % and replace V_prelim with VE.

Multiwin.m:

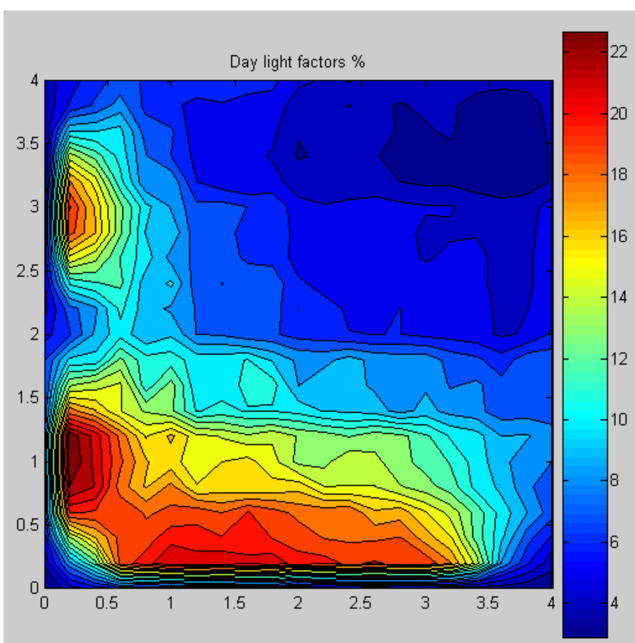
```
load('X');
load('Y');
load('VE');
VE = V;
load('VW');
VW = V;

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`



7 Data formats

7.1 Input weather data

Denmark.mat contains weather data from dry12.cop. Only the yellow marked data (hourly values) 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

7.2 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 ^{o}C
2	Outdoor dew point temperature	0.1 ^{o}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	^{o}
8	Horisontal shadow angle	^{o}
9	Vertical shadow angle	^{o}

7.3 Building documentation

--- Combined thermal and daylight simulation ---

Results:

Month	Heating [kWh]	Cooling [kWh]	Lighting [kWh]	Overheat [h]	Min PPD [%]	Mean PPD [%]	Max PPD [%]
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]

7.4 *Output format for Export results*

Description of the contents of the Export result structure. Generated .txt file can be copy/pasted in to e.g. Excel for better overview.

Field	Description, hourly values of	Unit
result.SPM	Time, hour numbers of the year	-
result.Qsun	Transmitted solar energy	W
result.heat	Heating power	W
result.cool	Cooling power	W
result.temp	Operative temperature	°C
result.outtemp	Outdoor temperature	°C
result.shading	Shading factor	-
result.mvent	Mechanical ventilation rate	h^{-1}
result.nvent	Ventilation rate due to venting	h^{-1}
result.pvent	Ventilation rate due to passive system	h^{-1}
result.Load_int	Internal heat load	W
result.deltaUA	Extra insulation UA-value	W/K
result.E_point	Daylight in general lighting point	lux
result.E_point2	Daylight in task lighting point	lux
result.E_glare	Vertical eye illuminance	lux
result.light_gen	Load from general lighting	W
result.light_task	Load from task lighting	W
result.artlight_gen	Artificial light output from general lighting	lux
result.artlight_task	Artificial light output from task lighting	lux
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.pmv	PMV	-
result.ppd	PPD	%
result.width	Width of room	m
result.depth	Depth of room	m
result.height	Height of room	m
result.winheight	Height of window	m
result.transloss	Transmission loss through façade	W
result.mventloss	Ventilation loss due to mechanical ventilation	W
result.nventloss	Ventilation loss due to venting *and* passive ventilation	W
result.infiltration	Ventilation rate due to infiltration	h^{-1}
result.Umet	Meteorological wind speed (not in text file output)	m/s
result.Umet	Wind direction, north 0° (not in text file output)	°

8 Revision history

Known issues 27.02.2008 in version 2.5.4

- 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
- The detailed report in combined simulation should contain monthly ventilation rates and/or ventilation heat loss
- Loading the same file twice causes the menubar to contain the file name twice
- Daylight calculation of the diffuse part is flawed for overhangs. The error is largest to the back of the room
- Save as does not function correctly when file was just saved
- Bug in evaluation point for daylight (z-direction)

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 usability

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 wall depth 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 (iDbuild) corrected
- Numerous changes to user interface and code optimization/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

Version 2.5.3

- An extra daylight evaluation point has been added, so general and task light may be evaluated in two different places in the room.
- Control algorithm for lighting systems rewritten because it was ambiguous.
- Sunlight was not excluded from the calculation when obstructed by an external shade. Bug corrected.
- Frame width was not included when calculating the size of the glazing. Bug corrected.

Version 3.0

- In iDbuild: U-value for façade in separate input box. Additional UA value can also be defined.
- Rearrangement of 'system' interface for better intuitive understanding.
- Help notes added throughout the input interfaces in iDbuild.
- In iDbuild: Facilitation of design decisions based on parameter variations (creation of 'new' reference model) implemented in iDbuild for better and smoother ID process.
- Duration curves for output handling implemented (for all type of projects).
- Export of BC/LC geometry to Google SketchUp implemented.
- Import of room geometry from Google SketchUp to iDbuild implemented.
- Outputs in iDbuild improved. Better alignment with DS/EN 15251.
- Extra output regarding yearly daylight performance now available in iDbuild.
- Bug in performance calculation when simulating parameter variations corrected (correction of UA and Cw when necessary).
- Numerical values added to graphs regarding energy performance and DF.

9 References

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