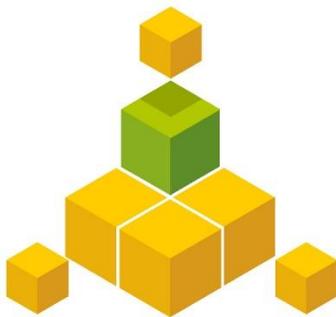


# TRNSYS 18

a TRaNsient SYstem Simulation program

## Updates in Version 18



**TRNSYS 18**



Solar Energy Laboratory, Univ. of Wisconsin-Madison  
<http://sel.me.wisc.edu/trnsys>



TRANSSOLAR Energietechnik GmbH  
<http://www.trnsys.de>



CSTB – Centre Scientifique et Technique du Bâtiment  
<http://software.cstb.fr>



TESS – Thermal Energy Systems Specialists  
<http://www.tess-inc.com>

# TABLE OF CONTENTS

<b>1. INTRODUCTION</b>	<b>1–4</b>
1.1. New Features at a glance	1–4
1.2. Updating from TRNSYS 17 to TRNSYS 18	1–6
<b>2. PACKAGE</b>	<b>2–6</b>
2.1. Documentation emphasis on learning to better use TRNSYS	2–6
2.2. Integrated TRNSYS-Dedicated Fortran Type Compiler (TypeStudio)	2–6
<b>3. TRNSYS SIMULATION STUDIO</b>	<b>3–7</b>
3.1. Parametric runs	3–7
3.2. Updated 3D building project type including daylighting	3–8
3.3. Better interoperability	3–8
3.4. Generated FORTRAN code updated for FORTRAN 90	3–9
3.5. Various other improvements	3–10
<b>4. TRNBUILD/TRNSYS MULTIZONE BUILDING (TYPE 56)</b>	<b>4–10</b>
4.1. TRNBuild - Multizone building interface	4–10
4.1.1. Navigator	4–11
4.1.2. Construction Types	4–11
4.1.3. Glazing library	4–12
4.1.4. Schedule Types	4–13
4.1.5. Regime Types	4–14
4.1.6. Airnode – Gains	4–17
4.2. Integrated daylight simulation	4–18
4.2.1. Definition of radiance materials	4–18
4.2.2. Definition of daylight mode of thermal zone	4–20
4.2.3. Definition of daylight sensor points	4–21
4.2.4. Generation of radiance files	4–21
4.2.5. Daylight related outputs	4–24
4.3. Extended comfort calculation	4–24
4.4. Integrated Supply air conditioning	4–25
<b>5. TRNSYS ENGINE</b>	<b>5–27</b>

5.1. Improved solar radiation interpolation	5–27
5.2. Updated psychrometric properties	5–27
5.3. Automatic report generation	5–27
<b>6. NEW COMPONENTS</b>	<b>6–28</b>
6.1. New Controller Components	6–28
6.2. New Electrical Components	6–28
6.3. New HVAC Components	6–28
6.4. New Hydronics Components	6–29
6.5. New Loads and Structures Components	6–29
6.6. New Thermal Storage Components	6–29
6.7. New Utility Components	6–29
<b>7. ADD-ONS (NOT INCLUDED IN PACKAGE)</b>	<b>7–30</b>
7.1. TRNSYS3d (free of charge)	7–30
7.2. TRNLizard (free of charge)	7–32
7.3. Complex fenestration model (Type 56)	7–34

# 1. INTRODUCTION

TRNSYS, the transient systems simulation program that has been commercially available since 1975, continues to develop by the international collaboration of the United States, France, and Germany. TRNSYS remains one of the most flexible energy simulation software packages by facilitating the addition of mathematical models, the available add-on components, the capabilities of the multizone building model, and the ability to interface with other simulation programs.

The following document explains the updates for the new TRNSYS version 18. Updates include improvements to the TRNSYS Simulation Studio, the addition of new capabilities to the TRNSYS multizone building model, developments for the TRNSYS engine, and new components to the TRNSYS standard library.

## 1.1. *New Features at a glance*

### Package

- Documentation emphasis on learning to better use TRNSYS
- Hints and Tips documentation
- Parameter / Input / Output reference documentation
- Documented HVAC system examples
- Detailed building / HVAC modeling introduction tutorial
- Additional documented examples
- Integrated TRNSYS-Dedicated Fortran Type Compiler (TypeStudio)

### Simulation Studio

- Parametric runs
- Updated 3D building project type including daylighting
- Better interoperability: TMF files in XML, style information in the deck file
- generated FORTRAN code updated for FORTRAN 90
- Simplified dialogs: unused tabs are hidden, keyboard shortcuts
- Improved connection window: sort variables by name, click on inbound variables first, delete key removes the selected connection, new keyboard shortcuts and map
- Improved error report: opens automatically if there are errors, new design with tabs, improved filters (notice/warning/errors)
- Simulation summary report activation
- Numerous simplifications and bug fixes

**TRNSYS Multizone Building (Type 56)**

- Daylight depending control type
- Dynamic daylight simulation for sensor points based on DaySIM
- Comfort calculation extended to elevated air speed acc. ASHRAE Standard 55-2013, Appendix G
- Energy demand for supply air conditioning including heat recovery
- Restructuring source code

**TRNBuild (User interface of the multizone building model)**

- TRNBuild Navigator extended to regime data (heating, cooling, ventilation, gains) and constructions data (layers, surfaces, windows) and schedules
- Use of longer names of airnodes and zones, construction types, etc. possible
- Use of small letters for names of airnodes and zones, construction types, etc. possible
- Added opaque surface types (wall, floor, ceiling, roof)
- Rename wall types to construction types
- Added total renewable primary energy and total non-renewable primary energy for opaque layers and windows
- New glazing library
- New schedule library
- Added annual schedules
- New gain library
- New gain categories: lights, people, equipment, misc, thermal bridge
- Reference area as a new parameter for each airnode
- Area related definition of regime data types (heating, cooling, ventilation, gains) possible
- Electric fraction to regime types
- Extended regime coupling of airnodes from 2 to 6
- Several new outputs (NTypes)
- Description & unit for user-defined inputs

**TRNSYS Engine**

- Improved solar radiation interpolation
- Updated psychrometric properties
- Automatic report generation

**New Components**

- 8 new controller components
- 20 new HVAC air-side components
- 3 new links to other programs (Mathis, Python, CoolProp)
- 11 new hydronics components
- 2 new utility components
- 2 new electrical components

**TRNSYS-add-ons** (not included in the package)

- Complex fenestration model (Integrated in Multizone Building)
- TRNSYS3d
- TRNLizard
  - New plugin for Rhino/Grasshopper
  - Parametric geometry modelling
  - Intuitive interface for building simulations
  - 3D-visualization

## ***1.2. Updating from TRNSYS 17 to TRNSYS 18***

The new version of TRNSYS is capable of opening and simulating version 17 Simulation Studio project files (\*.tpf). However, once the file is saved as a TRNSYS 18 project, it may not be re-opened in TRNSYS 17.

For multizone building projects TRNBuild updates the BUI file automatically from 17 to the new 18 format. However, files can be saved into a TRNBuild 18 format only. **Note: BUI files of TRNSYS 18 can NOT be opened correctly in previous versions of TRNSYS.**

# **2. PACKAGE**

## ***2.1. Documentation emphasis on learning to better use TRNSYS***

Many portions of the manual set have been rewritten with an emphasis on better helping beginning users get started using TRNSYS. The changes include moving the tutorials into a separate volume of the documentation set and adding new tutorials including a detailed building/HVAC project. More examples have been created and moved to a separate volume which includes detailed documentation for many of the examples. The mathematical reference volume has been updated to include full Parameter/Input/Output documentation and hints and tips for using the individual components.

## ***2.2. Integrated TRNSYS-Dedicated Fortran Type Compiler (TypeStudio)***

The TypeStudio is a graphical interface and Fortran compiler that have been set up to facilitate creating new Types for use with TRNSYS. The TypeStudio creates and manages workspaces that can contain

one or more TRNSYS Types. It allows the user to compile the Type(s) into a dynamic link library (dll) that will be placed in the proper location for the TRNSYS engine to load them during a simulation.

```

Type Studio
File Edit View Workspace Build Help
Type138.f90
39 timestep = getSimulationTimestep()
40 !-----
41
42 !-----
43 !Set the Version Number for This Type
44 If (getIsVersionSigningTime()) Then
45   Call SetTypeVersion(17)
46   Return
47 Endif
48 !-----
49
50 !-----
51 !Do All of the Last Call Manipulations Here
52 If (getIsLastCallOfSimulation()) Then
53   Return
54 Endif
55 !-----
56
57 !-----
58 !Perform Any "End of Timestep" Manipulations That May Be Required
59 If (getIsEndOfTimestep()) Then
60   If (getIsIncludedInSSR()) Then
61     Call updateReportIntegral(1,getOutputValue(3))
62     Call updateReportIntegral(2,getOutputValue(4))
63     Call updateReportMinMax(1,tset)
64     Call updateReportMinMax(2,getOutputValue(1))
65     Call updateReportMinMax(3,getOutputValue(2))
66   Endif
67

```

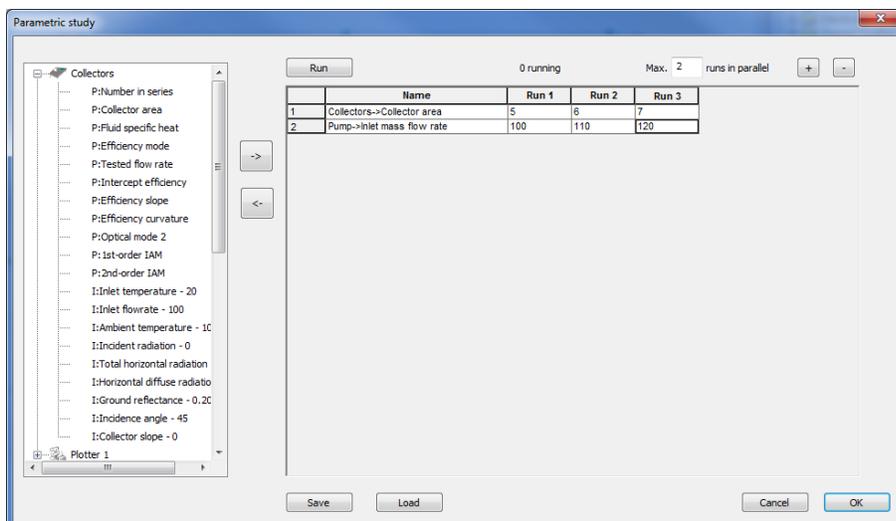
## 3. TRNSYS SIMULATION STUDIO

### 3.1. Parametric runs

The new parametric runs features allows users to launch a set of simulations based on a table with variable values. The table can be created interactively directly in Simulation Studio: the user first chooses the component, then the desired variable (parameter, input or equation) to be varied. It is possible to add runs by clicking the '+' button.

The number of runs in parallel can also be specified; this allows launching several simulations in parallel, to take advantage of multi-core architectures. If the user wishes to continue to work with his computer while the simulation is running, he can choose to allow for only one run in parallel, to keep the load at a reasonable level; interactions with the computer will be more fluent.

Limiting parallel runs to one is also useful if some project components used do not support parallel treatment (e.g. because they create temporary files with constant names, etc.).



## 3.2. Updated 3D building project type including daylighting

The new version of the 3D Building assistant (wizard) implements the features of Type 56 described in paragraph 1.3 of this document. It has been simplified to one dialog window, which now allows to define the static distribution factor of solar direct radiation and boundary temperature for the ground model. The wizard automatically reads IDF files made with SketchUp and translates them to TRNSYS projects, including both project and building description. The building description is ready for use with the new daylighting features.

## 3.3. Better interoperability

TRNSYS Model Files (.TMF files) can now be stored in the universally used XML format. This opens Simulation Studio to third-party software for importing and exporting model descriptions. It is also possible to author models directly in XML.

The traditional .TMF format is still available – both formats can be used interchangeably.

```

<?xml version="1.0" encoding="UTF-8"?>
<TrnsysModel>
  <object>Solar Collector; Quadratic Efficiency, 2nd Order Incidence Angle
  Modifiers</object>
  <author>Contributors are listed in manuals</author>
  <organization>Solar Energy Laboratory, University of Wisconsin - Madison</organization>
  <editor>CMR, MKU</editor>
  <creationDate>TRNSYS v7.5</creationDate>
  <modificationDate>May 2011</modificationDate>
  <mode>1</mode>
  <validation>16</validation>
  <icon>C:\tmp\type1b.bmp</icon>
  <type>1</type>
  <maxInstance>9999</maxInstance>
  <keywords/>
  <details>This component models the thermal performance of a flat-plate solar collector.
  The solar collector array may consist of collectors connected in series and in
  parallel. The thermal performance of the collector array is determined by the
  number of modules in series and the characteristics of each module. The user must
  provide results from standard tests of collector efficiency versus a ratio of fluid
  temperature minus ambient temperature to solar radiation. The fluid temperature
  may be the inlet temperature, the average temperature, or the outlet temperature.
  In type1, there are 5 possibilities for considering the effects of off-normal solar
  incidence. In this instance of Type1, a second order quadratic function is used to
  compute the incidence angle modifier. The coefficients of the function are supplied
  by an ASHRAE or equivalent test (see manual).</details>
  <variables>
  <variable>
    <!--input-1-->
    <order>1</order>
    <name>inlet temperature</name>
    <role>input</role>
    <dimension>Temperature</dimension>
    <unit>C</unit>
    <type>real</type>
    <min>-Inf</min>
    <max>+Inf</max>
    <boundaries>[ ; ]</boundaries>
    <default>20.0</default>
    <symbol>SN</symbol>
    <definition>The temperature of the fluid entering the the solar
    collector.</definition>
  </variable>
  <variable>
    <!--input-2-->
  
```

The meta-commands in the generated simulation input files (decks) have also been extended: it is now possible to store information about link styles / connection ports.

All links connecting UNIT 19 to UNIT 14

Properties of one link (a set of connections) in the project window

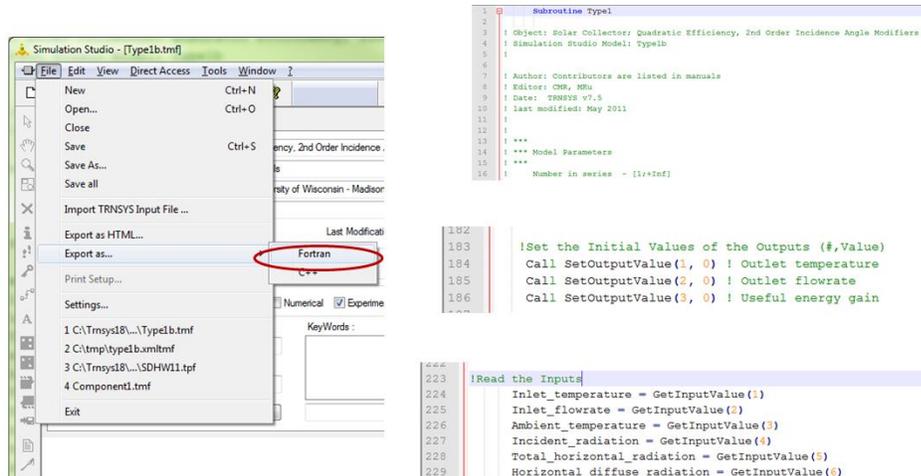
```

*!LINK_STYLE
*!LINK 19:14
*!CONNECTION_SET 0:20:0:17:1:32896:2:0:1:165,76:89,76:89,612:155,612
*!LINK 19:13
*!CONNECTION_SET 0:40:0:0:1:32896:2:0:1:165,96:111,96:111,520:162,520
  
```

This feature is exploited by the 3D building wizard to create more visually attractive, professional looking project schemes.

### 3.4. **Generated FORTRAN code updated for FORTRAN 90**

The FORTRAN generator has been updated to produce more modern code templates, compatible with the FORTRAN 90 coding standards.



This also includes systematic use of access functions instead of directly using IN / OUT / PAR arrays.

## 3.5. Various other improvements

Many more enhancements have been implemented in Simulation Studio, such as:

- Simplified dialogs: unused tabs are hidden, keyboard shortcuts
- Improved connection window: sort variables by name, click on inbound variables first, delete key removes the selected connection, new keyboard shortcuts and map
- Improved error report: opens automatically if there are errors, new design with tabs, improved filters (notice/warning/errors)
- Simulation summary report activation
- Numerous simplifications and bug fixes

# 4. TRNBUILD/TRNSYS MULTIZONE BUILDING (TYPE 56)

## 4.1. TRNBuild - Multizone building interface

This section provides an overview of improvements related to the interface TRNBuild.

### 4.1.1. Navigator

For providing a better overview of defined construction types (layers, surfaces, windows), schedules and regime data (heating, cooling, ventilation, gains) were added to the TRNBuild navigator. With a right click on an existing type the data associated with this type is displayed. New data can be added, existing data can be deleted, renamed and saved.

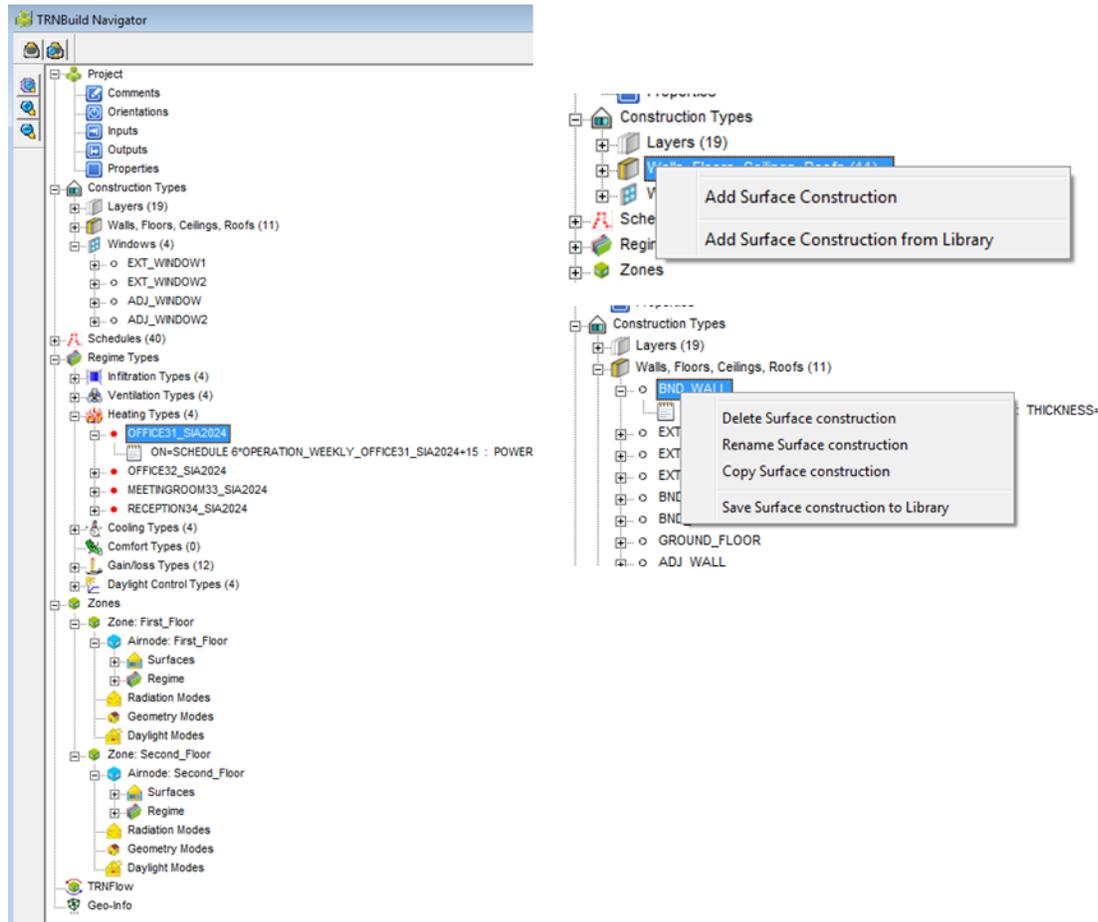


Figure 1: Extended TRNBuild navigator

### 4.1.2. Construction Types

Opaque surface constructions are no longer called WALL type. For being clearer they are now called CONSTRUCTION because they could define a construction for a floor, ceiling, roof or wall.

For opaque layers and windows optional data related to embodied energy, the total renewable primary energy and total non-renewable primary energy can be specified. An overview table of integrated numbers of the project of the surface area and the embodied energy for each construction type is provided at the end of the INF file.

### 4.1.3. Glazing library

The TRNSYS 18 package includes now a glazing systems library based on the “add-on” library of TRNSYS 17. The glazing data base contains over 230 different glazing systems (e.g. heat or solar protection glazing, double or triple glazing) based on detailed spectral provided by manufactures.

**Note:** TRANSSOLAR Energietechnik GmbH makes any warranty, expressed or implied, or assumes any liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

The glazing systems library was generated with the program Window 7.4.6.0 of the Lawrence Berkeley National Laboratory (<http://windows.lbl.gov/>). Therefore, the new standard files of TRNSYS 18 (TRNSYS18.std and TRNSYS18\_evis.ssp) were used. In these files, the integral characteristic of transmittance and reflectance for the visible range is based on the energy spectrum required by the 2 band solar radiation model of Type 56. For most other standard files available for the program Window, these integral characteristics for the visible wave lengths do not represent the entire visible range, owing to spectral sensitivity of the human eye.

For the new glazing data base the syntax of the glazing property data is extended to include the used standard file and the visible transmittance owing to spectral sensitivity of the human eye which can be helpful for selecting the radiance material for daylight simulation.

```

BERKELEY LAB WINDOW v7.4.6.0 DOE-2 Data File : Multi Band Calculation : generated with TRNSYS18.std
Unit System : SI
Name       : DOE-2 WINDOW LIB
Desc      : GU_ClimaGuard_N_#3_Ar90
Window ID : 3201
Tilt      : 90.0
Glazings  : 2
...
SHGC      0.660  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A  N/A
Vis_daylight: 0.800
Layer ID# 33000  33009  0      0      0      0
    
```

Figure 2: Glazing system property data syntax

It is possible to use data from glazing data bases which weren't created with the TRNSYS18 standard. However, using two glazing properties which were generated with different standards in one zone isn't allowed. The reason for introducing a TRNSYS18 standard file is to allow a more accurate simulation of solar radiation of two windows with high selective glazing properties (e.g. sun protection glazing) in series.

The “Description” of a glazing system (e.g. GU\_ClimaGuard\_N\_#3\_Ar90 in Figure 2) in the library is made up of the following composition:

YY\_name\_NN\_filling

- YY - Manufacturer code  
(GU...Guardian, IP...Interpane, SG...SaintGobain, GT Glas Trösch)
- name - Glazing system name
- NN - Coating position e.g #3 (numeration starts on the outer face)
- filling - Filling between glass panels

### 4.1.4. Schedule Types

For TRNSYS 18, a visualisation of the schedule data is integrated. In addition, a new schedule category is available now: an annual schedule. The annual schedule is especially helpful for scaling gains. (see section 4.1.6 )

Also, the library handling of schedules is improved and for the German and French library many schedules based on the SIA 2004 (2015) for different categories like residential, hotel, office, school, retail and restaurant have been added. For providing a better overview they are organized in one library file for each category.



Figure 3: Schedule types and library

### 4.1.5. Regime Types

For a more general definition of regime types, a floor reference area of an airnode is introduced. Regime data types like heating, cooling, ventilation and gains offer the option to define the power or airflow related to the reference area of an airnode. This makes it easier to use one regime type for several different airnodes and data is often given area related. The reference floor area is automatically calculated when importing an TRNSYS3d file and is available as output (NType 150).

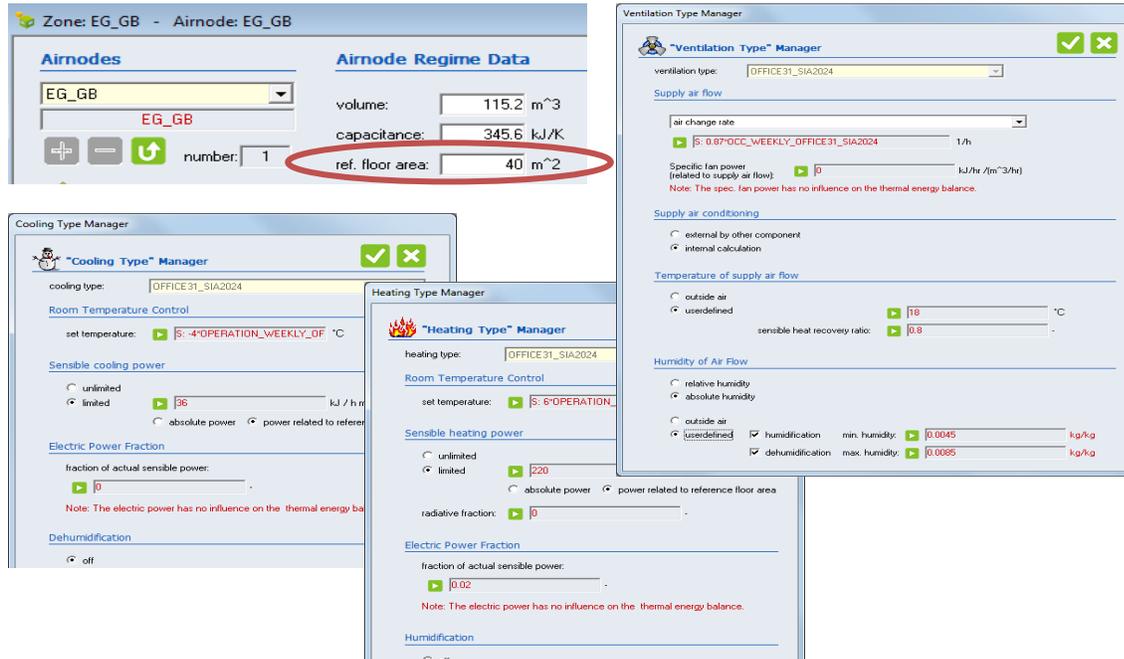


Figure 4: Regime types

In addition, regime types have been extended to allow taking the electricity demand into account by adding an electric power fraction and a specific fan power, respectively. Therefore, new outputs have been implemented (see NType 155 – 162).

The ventilation type has been extended to calculate the supply air-conditioning from outdoor air including sensible heat recovery, humidification below and dehumidification above a user-defined set point (see section 4.4 for further details). The effort compared to connecting an external component is small and with the additional outputs a more complete overview of the energy demand is provided. (see NType 170 – 189)

For providing a better subdivision of gains the following gain categories have been added:

- people
- lights
- electrical equipment
- miscellaneous
- thermal bridge

The new outputs according to these categories are NType 151 – 154 and NType 163- 164.

The category “thermal bridge” allows to take into account a thermal bridge effect of the envelope without adding a surfaces to the model. This is especially convenient for models with 3D where surfaces can’t be added. The thermal bridge effect can be defined as an absolute gain/loss or a specific gain/loss related to the envelope area of an airnode (The envelope area consists of external and boundary surfaces). For the thermal bridge calculation, the loss coefficients have to be entered as positive values. The direction of the resulting heat flux (gain or loss) depends on the actual temperature difference (Toutside – Tinside).

In addition, the gain library has been updated and extended. The German library contains now data based on different standards like DIN 13779, VDI 2078 and SIA 2024.

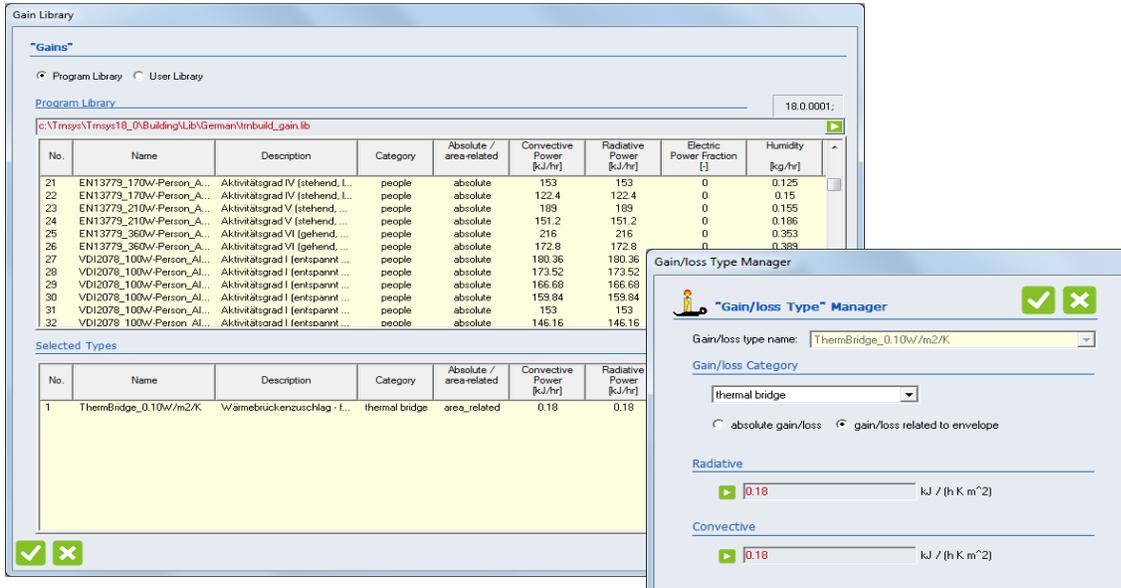


Figure 5: Gain library and gain type manager

In TRNSYS 18, the capability to control artificial lighting by daylight availability is added to the building model. Therefore, a new regime type is added. The data for this type is structured in three parts: lighting control type, illuminance set points and daylight illuminance on the sensor.

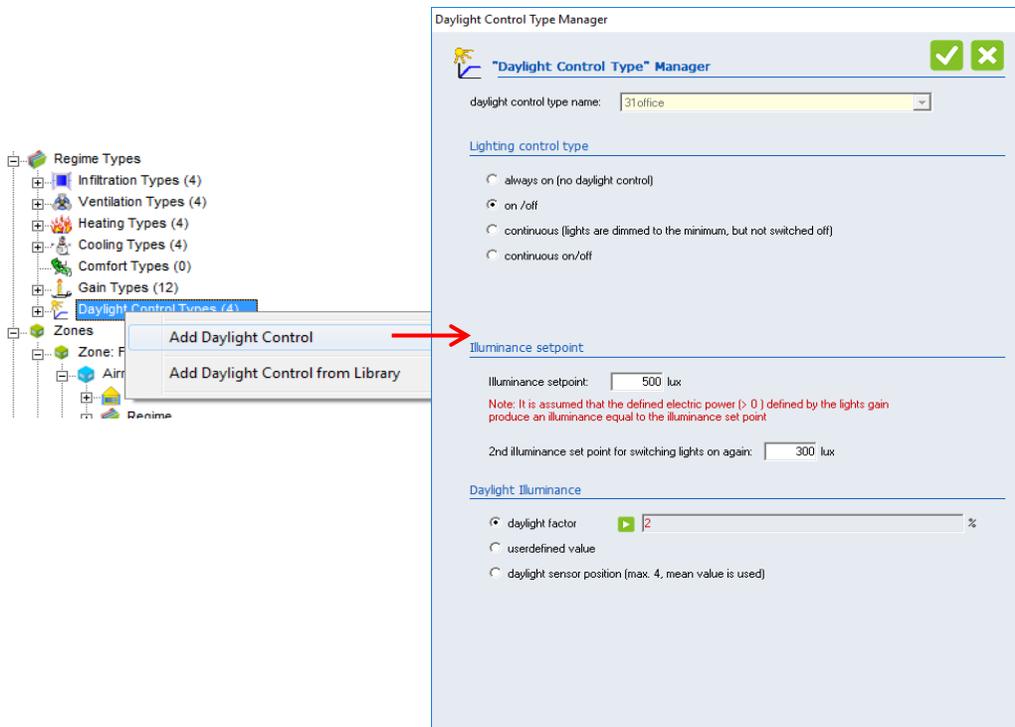


Figure 6: Daylight depending control type

Different modes of artificial lighting control are implemented in the TRNSYS building model:

- always on (no daylight control)
- A hysteresis control, where an upper threshold and a lower threshold are defined by the user. This control provides only control signals of 0 or 1.
- A linear dimmer, where the artificial lighting contribution ideally compensates insufficient daylight availability to match the set illuminance. A minimum operation ratio has to be provided by the user, the value never drops below this ratio during operation time.
- A combination of mode 2 and 3. This control allows turning off the artificial lighting during operation

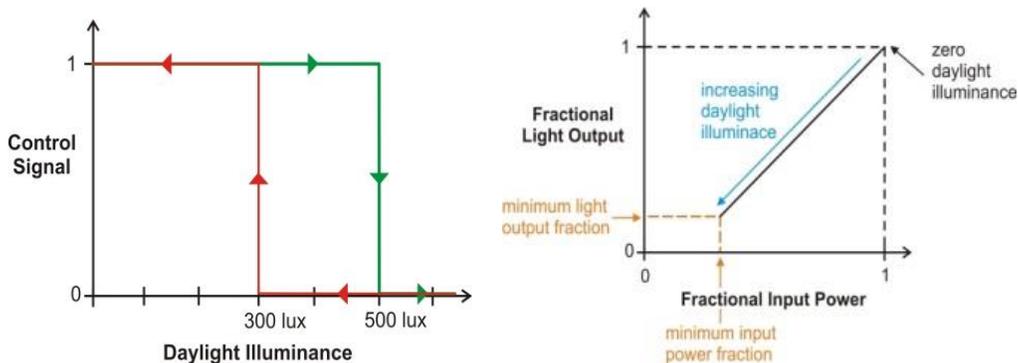


Figure 7: Artificial lighting control, hysteresis control (left), dimming control (right)

The determination of the illuminance by using a daylight factor  $D$  is a very rough method, but the simplest option. The illuminance for control  $E_i(t)$  is calculated by multiplication of the horizontal outdoor illuminance

$E_a(t)$  with the daylight factor. The outdoor illuminance is calculated within Type 56 using new kernel routines.

A second option is passing illuminance values by reading in values obtained by other programs, measurements and calculated by other TYPES, respectively.

The third option applies the integrated daylight simulation based on the DaySIM method. The mean illuminance of up to four geometric defined sensor positions is used for control. The integrated DaySIM method is presented in section 4.2.

Several outputs have been added related to daylight depending control (NType 405 – 432) such as daylight illuminance, daylight autonomy, etc.

### 4.1.6. Airnode – Gains

The gain definition dialog of airnodes has been revised and provides a good overview of the defined gains.

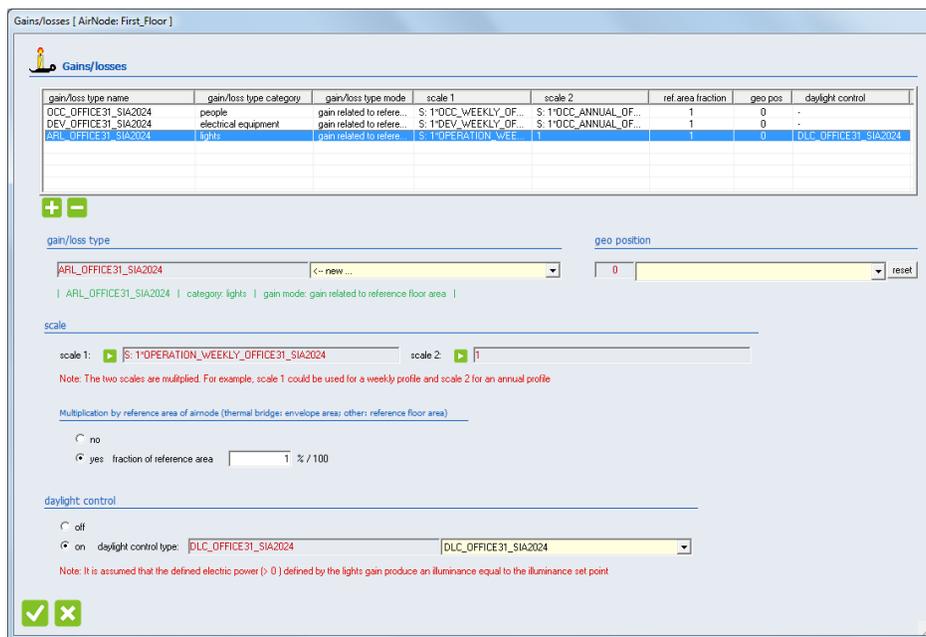


Figure 8: Gain/losses dialog of airnodes

A second scale can now be defined for each gain. For example, a weekly schedule for occupation can be defined as scale1 and annual schedule containing a reduction to 50% in vacation time can be defined as scale2. The resulting schedule is the product of both scales. If one scaling factor is needed only the second scaling factor should be set to 1.

Since gain types can now be defined related to the reference floor area, a multiplication factor “fraction of airnode reference floor area” is added. If this factor is set to 1, the gain is multiplied with whole reference floor area. If e.g. the gain should refer to 30 % of the floor reference area only the “fraction of airnode reference floor area” has to be set to 0.3.

For gains of artificial lighting (gain category = lights), a daylight depending control can be added. This prevents unnecessary internal gains due to artificial lighting when natural daylight is sufficient. If the daylight depending control is switched on, a previously defined daylight control type can be selected.

## 4.2. Integrated daylight simulation

TRNSYS 18 offers the option to perform an integrated daylight simulation based on DaySIM. DaySIM is a validated, radiance based daylighting analysis software that models the annual amount of daylight in and around buildings. ([daysim.ning.com](http://daysim.ning.com), [www.radiance-online.org](http://www.radiance-online.org)).

According to the DaySIM approach daylight coefficients for every sensor point are generated in a preprocessing step based on the geometry and material definitions in a radiance format. During the simulation the daylight coefficients are used to calculate the illuminance on the sensor points.

The daylight model is based on the same 3D geometric data as the thermal model. Therewith, a 3D thermal model is the starting point. The following shows the basic steps in TRNBuild for daylight simulation:

Definition of radiance materials

Definition of daylight mode of thermal zone

Definition of daylight sensor points

Generation of radiance files

Daylight related outputs

### 4.2.1. Definition of radiance materials

For a daylight simulation radiance material names have to be assigned to construction types. For opaque construction types it is assumed that the visible light absorptance is equal to the solar absorptance. Therefore no additional daylight properties data is required.

For windows, the window type dialog has been extended for defining optional daylight properties by radiance material names. A radiance material name is assigned for two states of the window: shaded and unshaded

For selecting names click on the button “open radiance material file”, search for an appropriate material and copy the name e.g. glass\_80 into the input text box. The material “glass\_80” represents a glazing with a visible light transmittance of 80 %. The user can add missing radiance materials to the library. (There are data bases for radiance materials available e.g. [www.lighting-materials.com/learn](http://www.lighting-materials.com/learn).)

**Note:** The syntax of the radiance material file described in the file header has to be met!

To help selecting the radiance material of the unshaded state, the visible transmission for daylight related to the glazing ID is displayed.

If a window type has no operable shading device at all, the radiance material file for unshaded should be used for shaded as well.

If no detailed information is available for the shaded state, the visible light transmittance multiplied by a shading factor might be used as a first guess.

**Note:** The visible transmission for daylight do not represent the entire visible range, owing to the spectral sensitivity of the human eye, which means that it differs from the characteristic used by the 2-band thermal model. In most cases, the visible light transmittance for daylight is given in publications and is stored in the glazing data base (see section 4.1.3).

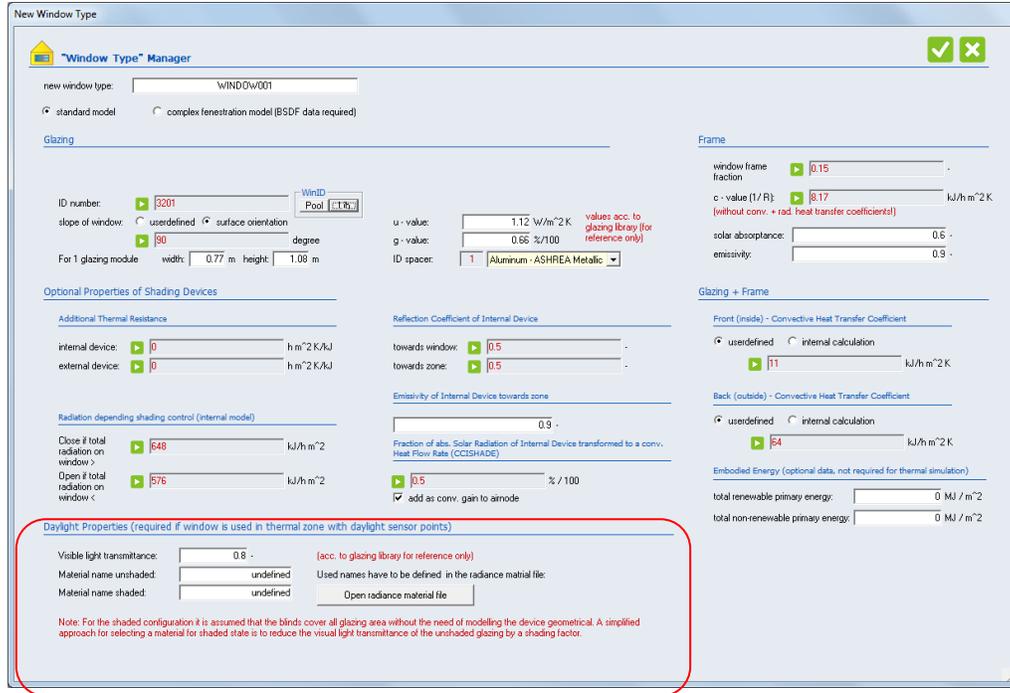


Figure 9: Window Type manager – optional daylight properties

```
#####
## radiance material file
#####
#
# syntax description:
# '#' - to start a comment lines
#
# each material description starts with a line: void material name
# with
# void - key word for defining a radiance material
# material
#
# - glass (transparent material)
# - plastic (opaque material with uncolored highlights)
# - metal (similar to plastic, but specular highlights are modified by ...)
# - mirror (used for reflecting planar surfaces)
# name - referenced for TRNSYS Type56 daylight material definition
#
# see material syntax in each section
# see also http://radsite.lbl.gov/radiance/refer/ray.html
#####

##### glazing #####
# glass_syntax description : #####
# void glass name
# 0 0 3 transmissivity_red transmissivity_green transmissivity_blue

.....

# glass_80
# visual transmittance: 80%
# visual transmissivity: 87.15%
void glass glass_80
0
0
3 .8715 .8715 .8715
```

Figure 10: Window Type manager – radiance material file

## 4.2.2. Definition of daylight mode of thermal zone

For calculating the illuminance on defined daylight sensor points within a zone (not airnode!) two configuration sets are generated by the integrated tool “Generate radiance files” (see section 4.2.4 ):

- Unshaded - The properties of the radiance material defined in the window type for “unshaded” are used.
- Shaded - The properties of the radiance material defined in the window type for “shaded” are used.

The user can now select between two different control modes for switching configurations during the simulation:

- Basic control  
The shaded configuration is used if all external windows of a zone with a defined external and/or internal shading device have a current shading factor > 0.01.  
(Note: For zones with adjacent windows only the basic control doesn’t work (zone is always unshaded). In this case user-defined control should be defined.
- User-defined control  
The user can use his own control strategy for switching between unshaded and shaded configurations during the simulation. The unshaded configuration is used when the control signal is set to 0. The shaded configuration is used when the control signal is set 1.

It is recommended to use the output DLSHADE (Daylight shading control signal) for checking the control signal. (NType 403)

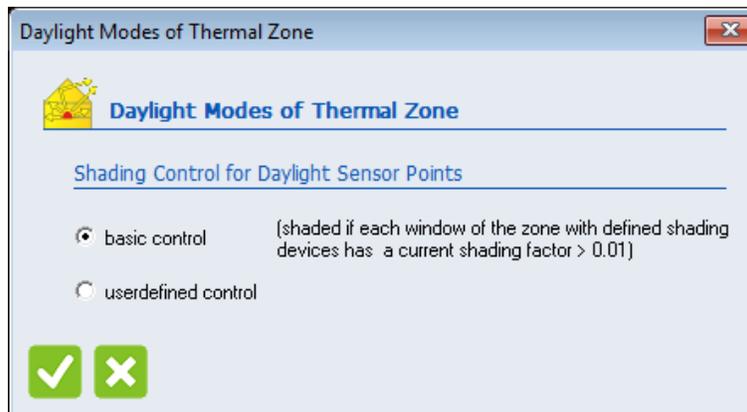


Figure 11: Daylight mode of thermal zone

### 4.2.3. Definition of daylight sensor points

The position of daylight sensor points is defined in the Geo-Info dialog in the GeoPosition section like GeoPositions for comfort calculation.

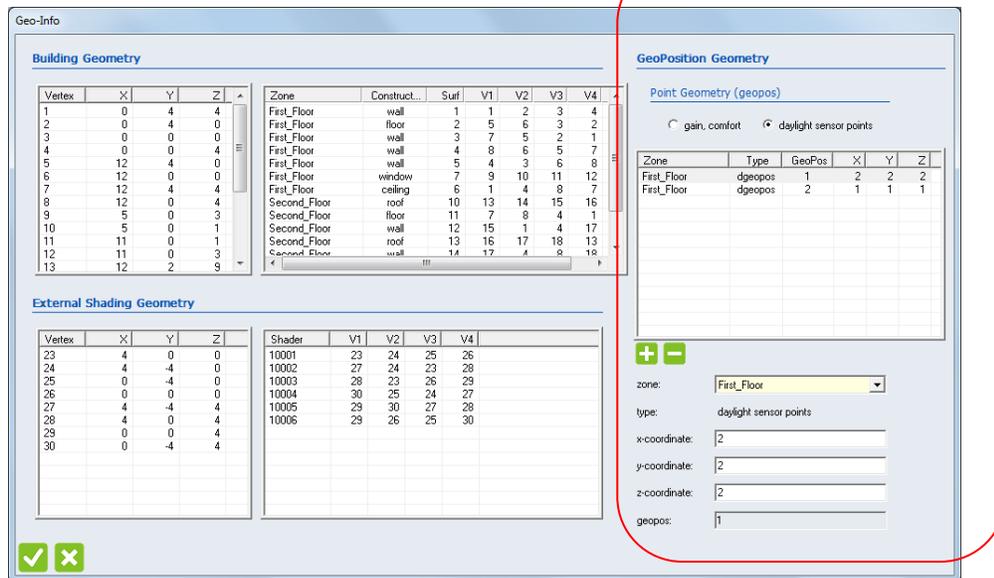


Figure 12: Daylight sensor points

### 4.2.4. Generation of radiance files

According to the DaySIM approach, daylight coefficients for every sensor point are generated in a preprocessing step based on the geometry and material definitions in a radiance format. Therefore select "Tools" from the menu of TRNBuild and then "generate radiance files".

For generating radiance files there are 3 options available.

1. Generate radiance input files (\*.rad) only:  
This option is used to produce radiance files only for using them in other applications. The radiance files consist of the zone geometry and all relevant shading geometry including self-shading by surfaces of other zones,
2. "classic" format of daylight coefficients for DAYSIM:  
Radiance files are generated (see option 1). DAYSIM Routine "gendc" is called to generate daylight coefficients according to the classic DAYSIM approach. The data is saved in two files per zone (unshaded and shaded).
3. "dds" format of daylight coefficients for DAYSIM:  
Radiance files are generated (see option 1). DAYSIM Routine "gendc" is called to generate daylight coefficients according to the dds approach. The data is saved in two files per zone.

**Generating Radiance Files**

**Pre-processing for daylight simulation**

For zones with daylight sensor points two configurations are generated: unshaded and shaded.

generate radiance input files (\*.rad) only  
 "classic" format of daylight coefficients for DAYSIM  
 "dds" format of daylight coefficients for DAYSIM

Scene rotation angle (north to east positive):  deg  
 Weather station latitude (north is positive):  deg  
 Weather station longitude (west is positive):  deg  
 Weather station meridian west of Greenwich (west is positive):  deg  
 Site elevation:  m

**Additional properties**

shader ID's representing the ground:   
 (e.g.:10003;10006)  
 ground reflectance:  -  
 shader reflectance:  -

**Radiance parameters**

number of ambient bounces (ab):  -  
 number of ambient divisions (ad):  -  
 number of ambient super-samples (as):  -  
 ambient resolution (ar):  -  
 ambient accuracy (aa):  -

A description of the radiance raytrace parameters can be found [here!](#)

**Generating Radiance Files**

Note: Depending on the parameters and project size this process may take some minutes up to hours.

Figure 13: Generate radiance files

The following information is required for successful radiance file generation:

- Location (Latitude, Longitude, standard meridian, site elevation) of the weather station
- Scene rotation angle, if the building should be modeled in orientation other than the original orientation as drawn with TRNSYS3d, enter the angle of rotation. Please make sure you use the same rotation as used in the manipulation of the azimuth angle (Input 7 of Type 56: AAZM)

### Additional properties

The ground may have a significant influence to the daylight results. The user may draw the ground in TRNSYS3d and assign the IDs here. The ground reflectance is applied to these shading surfaces. Note if no shading ID is defined the ground is modeled as a ground glow **generated with the ground reflectance.**

### Reflectivity of shading surfaces

Shading surfaces of the thermal model have no reflectivity. However, for the daylight model it is possible to take into account a reflectivity (default = 0). The entered value is used for all shading surfaces.

### Radiance parameters

Raytracing simulation and their results are highly dependent on the used parameters. The most important parameters appear in the TRNBuild interface:

- ambient bounces (ab): This is the maximum number of diffuse bounces computed by the indirect calculation. A value of zero implies no indirect calculation. An ab-value of 5 is already sufficient for a standard room without any complicated facade elements. This parameter significantly increases the required calculation time and should be set with care. It has to be even higher if interior rooms of facades including venetian blinds are considered, as rays may be reflected several times they find their way out of the building.
- ambient divisions (ad): Ambient divisions sets the number of initial sampling rays sent from each ambient point into the hemisphere to determine the indirect incident light. This parameter needs to be high if the luminance distribution in a scene with a high brightness variation. The error in the Monte Carlo calculation of indirect illuminance will be inversely proportional to the square root of

this number.

- ambient super-samples (as): The number of extra rays that will be used to sample areas in the divided hemisphere that appear to have high variance. Ambient super sampling should usually be set to about one half or one quarter of the Ambient divisions parameter. Super-samples are applied only to the ambient divisions which show a significant change.
- ambient resolution (ar): This number will determine the maximum density of ambient values used in interpolation. Error will start to increase on surfaces spaced closer than the scene size divided by the ambient resolution. The ambient resolution and ambient accuracy (see below) combined with scene size, gives the minimum geometry features that are resolved accurately:

$$\text{simulation resolution} = (\text{max scene size} \times \text{ambient accuracy}) / \text{ambient resolution}$$

- ambient accuracy (aa: This value will approximately equal the error from indirect illuminance interpolation. A value of zero implies no interpolation.

The default settings are related to the recommendation for DaySIM. Depending on the complexity and size of the model the file generation may take some minutes up to hours. For checking of the work flow it might be useful to reduce the generation time by using less accurate settings.

	ambient bounces	ambient divisions	ambient samples	ambient resolution	ambient accuracy
Fast (for checking only)	3	32	32	300	0.2
Default	5	1000	20	300	0.1

Figure 14: Radiance parameters

It is highly recommended to study the daylight fundamentals for selecting appropriate parameters matching the project. Additional radiance parameters are stored in the building description file. If needed they can be modified there.

**Resulting files**

The generated data files are all stored in the subdirectory \daylight relative to the building description file BUI. Figure 15 provides an overview of the file extensions.

File extension	Description
*.hea	DaySIM header file
*.pts	Sensor geometry files
*.rad	Geometry files
*.dc	Daylight coefficients used by Type56
*.cfg	Configuration file used by Type 56
*.log	Log file of the generation process

Figure 15: File extensions related daylight files

In general, two sets of daylight models are generated automatically for each zone. One representing the unshaded state (shd0) where all operable shading devices are up and the shaded state (shd1) where all operable shading devices are down. The following file naming convention is used:

*yyy\_shdx\_name.\**

yyy - zone number  
shdx - shd0...unshaded, shd1 shading state  
name - zone name

### 4.2.5. Daylight related outputs

Daylight related outputs are the calculated outside illuminance (NType 400 – 402) and a standard output file (NType 435). A standard daylight output file is written for selected zones in the subdirectory \Daylight\\*.ill. It contains the hourly integrated illuminance values for each sensor point. In addition, the following common daylight metrics are calculated for the whole simulation period:

- Daylight Autonomy (DA), default: < 300 lux
- Continuous Daylight Autonomy (cDA), default: < 300 lux
- Useful Daylight Illuminance (UDI), default: 100 – 2000 lux
- Daylight factor (DF) for CIE overcast sky

The thresholds of the daylight metrics are stored in the building description file and can be edited if needed. In general, these metrics are relevant during occupation only. Therefore, a schedule is assigned to the NType as additional data. The value of the schedule has to be 0 (off) or 1 (on).

## 4.3. Extended comfort calculation

For the evaluation of comfort concepts with tempered air and elevated air speed in warmer zones such as tropical climates adaptive comfort models are required. In TRNSYS 18 the procedure for evaluating the cooling effect of elevated air speed using the Standard Effective Temperature (SET) described by ASHRAE Standard 55-2013, Appendix G is implemented. This feature is especially useful to evaluate comfort concepts with tempered air and elevated air speed in warmer zones such as tropical climates.

SET is defined as the equivalent air temperature of an isothermal environment at 50 % relative humidity in which a subject, wearing clothing standardized for the activity concerned, has the same heat stress (skin temperature) and thermoregulatory strain (skin wettedness) as in the actual environment. The values for skin temperature and wettedness are derived from a two-node model of human physiology (Gagge et al. 1971, 1986).

The SET can be calculated for a wide range of six environmental and personal parameters: air temperature (Tair), mean radiant temperature (MRT), relative humidity (RH) average elevated air speed (v), clothing factor (clo) and metabolic rate (met). To evaluate the cooling effect of elevated air speed, first the SET is calculated for the parameters and the given air speed. In a second step the air speed is replaced by still air (0.15 m/s) and an adjusted averaged air and mean radiant temperature is calculated to achieve the same SET as in the previous step (ANSI/ASHRAE. 2015). With the adjusted averaged temperatures, the air speed of still air and the remaining parameters the Predicted Mean Vote for elevated air speeds (PMVeas) is calculated.

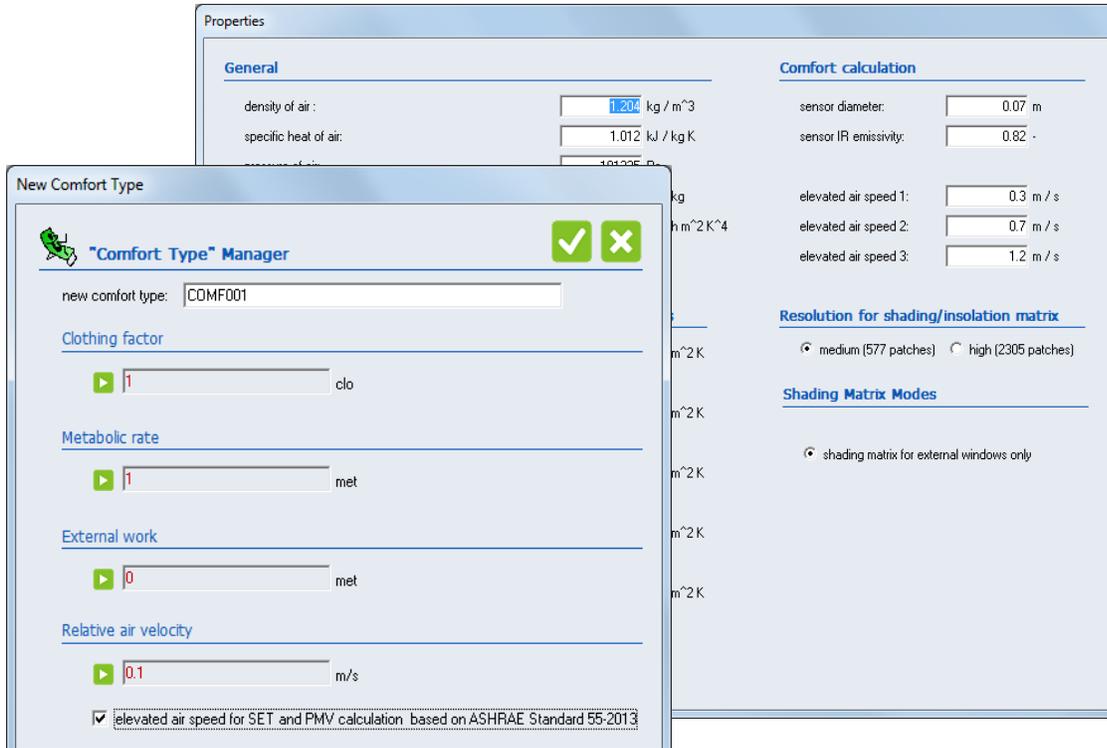


Figure 16: Comfort definition with elevated air speed

To be useful for the evaluation and design of climate concepts, the method is implemented to simulate an occupant-controlled fan. The user can specify up to 4 air speed levels and the code automatically selects the lowest airspeed level required to achieve a PMV<sub>as</sub> of ±0.5 which is equivalent to a satisfaction of 90 % of the occupants with the environmental conditions.

The comfort type data has been extended for switching the elevated air speed option on. The 1st air speed level is defined within the comfort type whereas the additional 3 are defined under properties. The SET temperature as well as the optimized elevated air speed level and the resulting air velocity are new outputs (NType 123, 131, 132).

## 4.4. Integrated Supply air conditioning

For TRNSYS 18 a simple model is provided in TYPE 56 to model preconditioning of supply air to the airnode. The calculated energy for heating, cooling, dehumidification and humidification refers to a conditioning from outdoor air and to supply air condition. The feature allows calculating conditioning including optional sensible heat recovery.

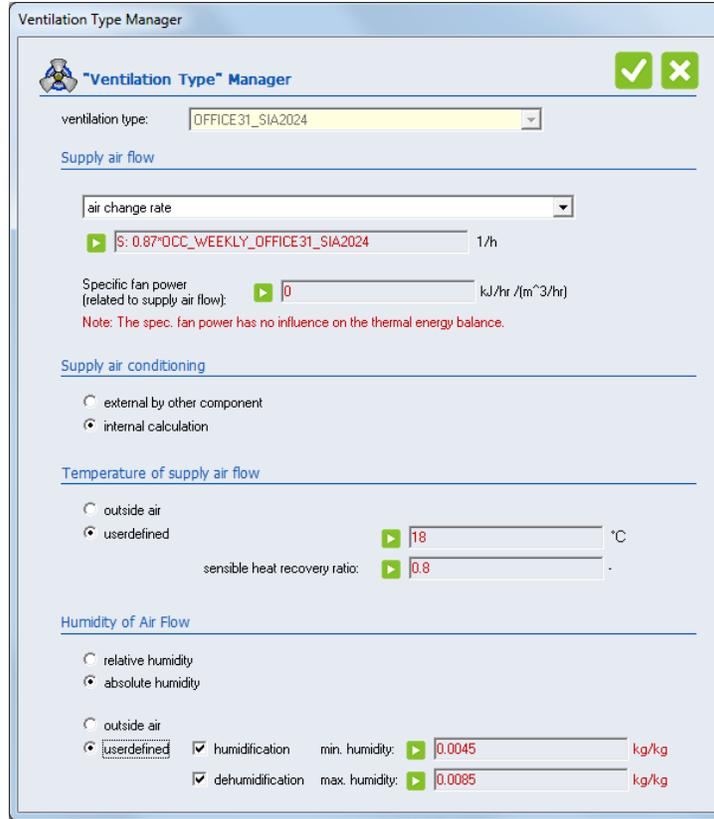


Figure 17: Ventilation with air supply conditioning

The temperature of the supply air  $T_{HR}$  after the heat exchanger is calculated with the sensible efficiency  $\eta_{sens}$ , and the return  $T_{RA}$  and outdoor air temperature  $T_{OA}$ ,

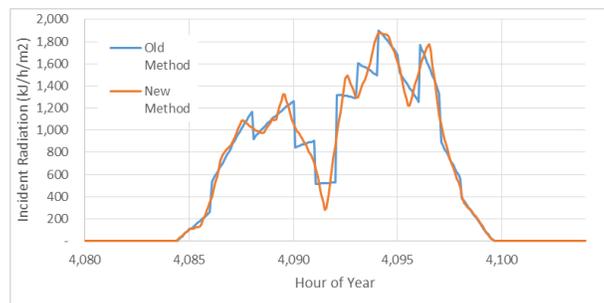
Depending on the technology, air handling units have frost protection systems to avoid icing of the heat exchanger. The implemented model assumes that the exhaust air won't be cooled down below  $T_{EA,min} = 4^{\circ}C$ . The sensible energy to heat up  $\dot{Q}_{ht,sens}$  or cool down  $\dot{Q}_{cl,sens}$  the air to set point temperature  $T_{Set}$  is calculated for the defined the mass flow  $\dot{m}$ .

The max. and min. humidity ( $w_{min}$  and  $w_{max}$ ) have to be set by the user. If the outdoor humidity is within the range, no humidification or dehumidification energy is calculated. Otherwise it is calculated with the evaporation enthalpy  $\Delta h_V$ . The dehumidification process is divided into three processes, a sensible part where the air is cooled down to dew point temperature and the latent part where water condenses, the energy for both processes are summarized in  $\dot{Q}_{cl,dehum}$ . The third process is reheating the air  $\dot{Q}_{ht,reheat}$ .

## 5. TRNSYS ENGINE

### 5.1. Improved solar radiation interpolation

Two changes have been made to the solar radiation routines in this release. The first is that now the diffuse horizontal and direct normal are used to calculate the remaining solar radiation values. This ensures that whenever there is positive diffuse horizontal in the data file there will be diffuse horizontal calculated by TRNSYS. The second is that a new method for determining the sub-hourly radiation has been added. This method eschews physical based shaping of the radiation for a mathematical model. In this method, the ending point for the hourly radiation is estimated from the starting point for that hour (the ending point for the previous hour or 0 at sun-up) and the radiation over the up-coming hour. The ending point is also forced to be zero at sundown. Knowing the starting and ending point for the hour and the total radiation over the timestep from the weather file, the value at the midpoint of the hour can be determined. The radiation is assumed to vary linearly from the start point to the midpoint and from the midpoint to the endpoint. This technique still preserves the hourly total from the weather files, avoids negative values and produces a smoother curve for the radiation values as shown below.

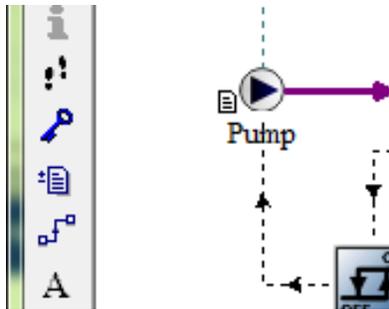


### 5.2. Updated psychrometric properties

Over the years, ASHRAE modifies the psychrometric routines in the Handbook of Fundamentals as more accurate measurements are available. A complete review of the psychrometric calculations was undertaken and algorithms were modified so that the TRNSYS psychrometric routines are up-to-date with the latest ASHRAE algorithms.

### 5.3. Automatic report generation

With TRNSYS 18, a simple, yet efficient method to produce useful default reports has been introduced: every component defines a standard set of data potentially interesting to the user. For instance, when a solar collector (Type 1) is used in a project, the user might be interested in a summary of the component configuration (Collector Array Area, Number of Collectors in Series, etc.) as well as average values, extremes and integrals over the simulated period (Total Energy Gain, Maximum Value of Outlet Temperature, etc.). The user can now include this data in a standard simulation report by simply selecting the corresponding model in the project and activating the 'report' icon for it as shown below.



## 6. NEW COMPONENTS

The standard library has been supplemented with a large number of basic component models that will allow for beginning users to easier learn how to use the software. These simpler component models will also facilitate the use of TRNSYS earlier in the design process when less detailed information is known about the process being modelled. These basic models can then be replaced with detailed models as more information is known. For example, early in the design process the overall cooling load made be known but the cooling coil may not yet be selected. The simple cooling coil model that only requires the capacity of the coil can be used in this early stage and once the cooling coil has been designed, the simple cooling coil model can be replaced with the detailed cooling coil model.

### 6.1. *New Controller Components*

- Simple Thermostat
- Simple Humidistat
- Dehumidistat
- Aquastat (heating and cooling)
- Tempering Valve (heating and cooling)
- Delayed Inputs
- Simple Differential Controller

### 6.2. *New Electrical Components*

- Four Parameter PV
- Five Parameter PV

### 6.3. *New HVAC Components*

- Electric Resistance Heater (air and liquid)
- Gas Heater (air and liquid)
- Air Cooled Chiller
- Air-to-Air Heat Pump
- Boiler
- Chilled Water Coil (dry or wet and partially wet)

Simple Cooling Tower  
Direct Expansion Coil  
Fan Coil  
Furnace  
Hot Water Coil (constant UA and varying UA)  
Water Cooled Chiller  
Water-to-Air Heat Pump  
Residential Split System AC  
PTAC  
VAV Air Handler  
VAV Air Handler with PFP Boxes  
Detailed Cooling Tower

## ***6.4. New Hydronics Components***

Duct  
Constant Speed Fan  
Variable Speed Fan  
Air Diverter  
Return Plenum

## ***6.5. New Loads and Structures Components***

NIST Simple Infiltration  
Simple Natural Ventilation

## ***6.6. New Thermal Storage Components***

Simple Gas Heated Liquid Storage  
Simple Electric Heated Liquid Storage  
Constant Volume Liquid Storage – with HX  
Constant Volume Liquid Storage – no HX

## ***6.7. New Utility Components***

Calling External Programs (MATHIS)  
Calling External Programs (Python)  
Calling External Programs (CoolProp) – not a Type but the routines can be called by other Types

---

# 7. ADD-ONS (NOT INCLUDED IN PACKAGE)

## 7.1. TRNSYS3d (free of charge)

This section provides an overview of improvements related to the Trnsys3d plugin for Sketchup. The new plugin can be installed as Add-On within the regular installation process or can be downloaded from [www.trnsys.de](http://www.trnsys.de).

### Templates for room types

Upon launching Google SketchUp after the TRNSYS3d plugin has been installed, you will be prompted to choose a template for your 3D model. These templates contain pre-defined information for your \*.b18 file for schedules, heating, cooling, ventilation, infiltration, internal gains and daylight. If you don't want to use a predefined template, choose *NewFileTemplate.idf*.

For the German library, these zone templates according to SIA 2024 are available:

1. apartment
  - Living/bedroom
  - kitchen
2. hotel
  - hotel room
  - reception
3. office
  - office 1
  - office 2
  - meeting
  - reception
4. school
  - classroom
  - staffroom
  - library
  - lecturehall
  - specialroom
5. supermarket
  - commercial
6. restaurant
  - restaurant
  - kitchen

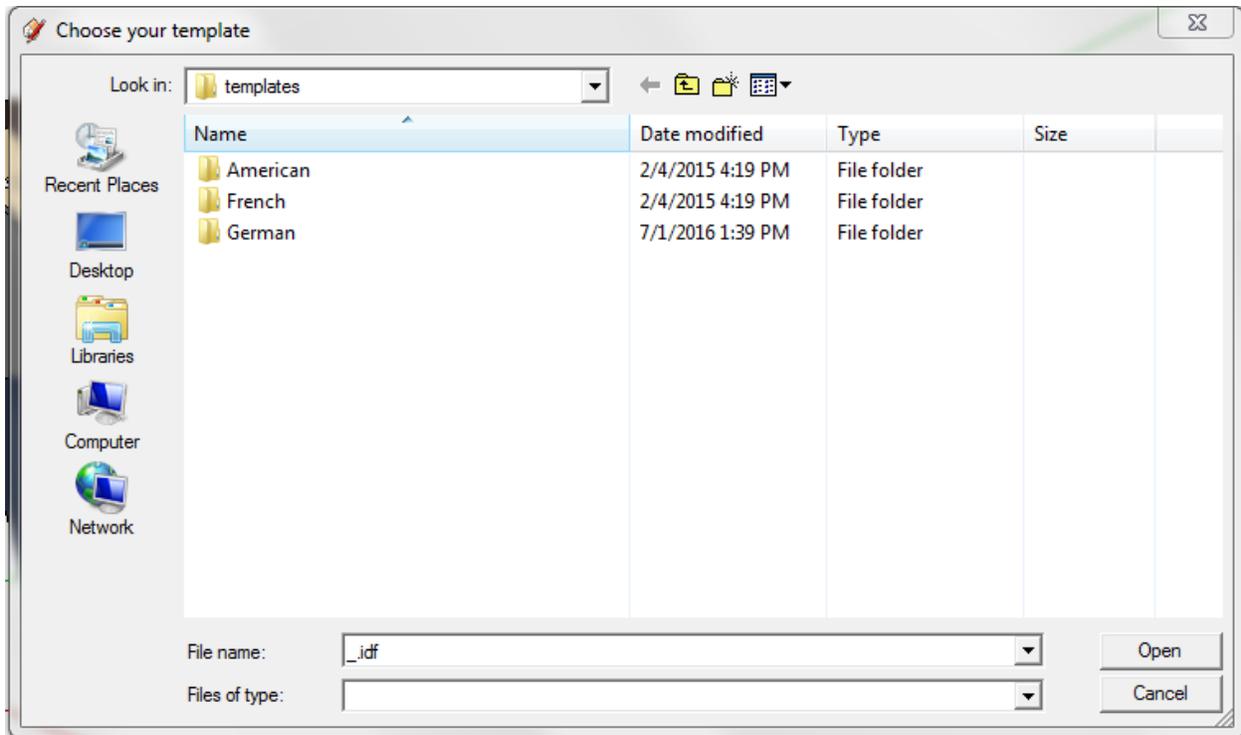


Figure 18: Pop up window to choose file template

To apply a room type to a zone, the Object Info Tool can be used by marking the zone and choosing from the “Type” drop down menu.

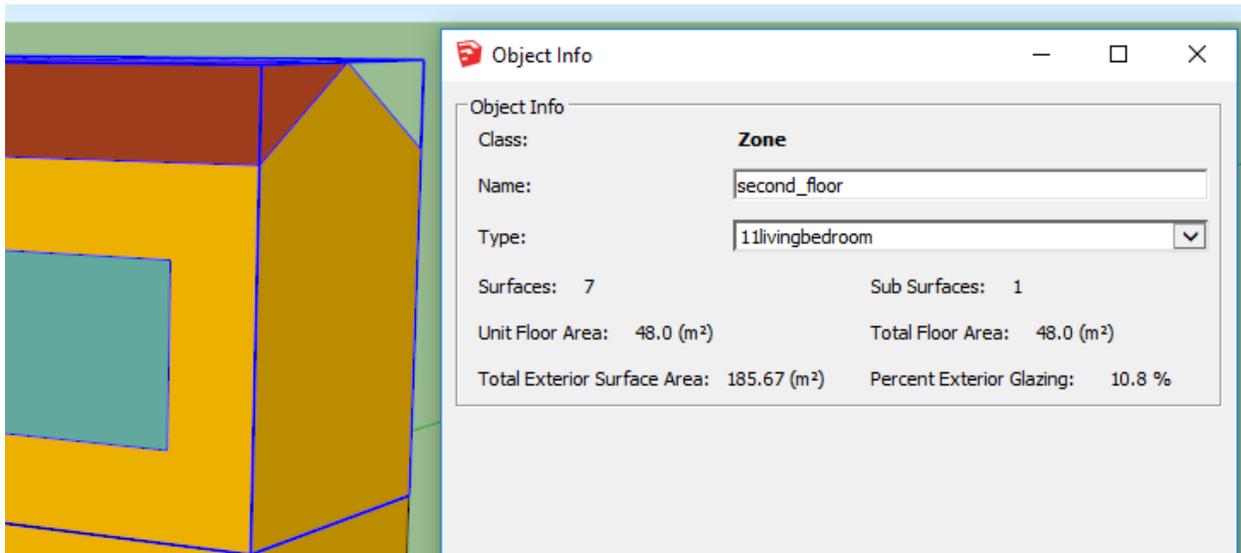


Figure 19: Apply SIA room types to zone

### Determine reference floor area

In the building description file (.bui or .b18), the keyword REFAREA is introduced to describe zones reference floor area. This value is determined automatically from the 3D geometry for each zone during the import of geometry files (.idf) into TRNBuild.

### Surface matching option: Replace Construction type

During the surface matching of zones that are adjacent to each other, it can be decided whether one wants to replace existing constructions with default constructions for adjacent walls (check box) or whether one wants to keep the existing definitions of surface constructions (uncheck box).

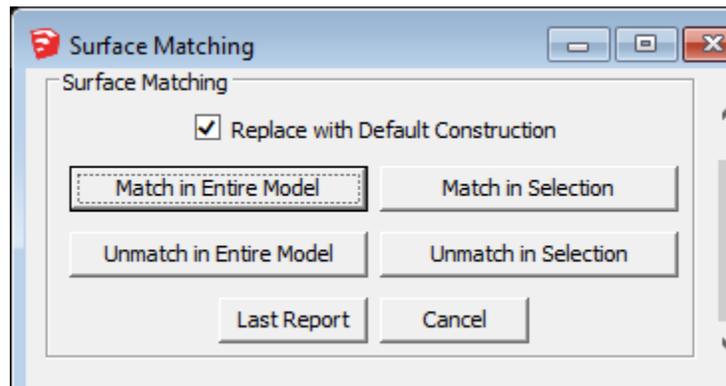


Figure 20: Matching Process - Replace construction type

## 7.2. TRNLizard (free of charge)

TRNLizard is a free plugin for the Grasshopper interface within the Rhinoceros 5 program developed by Transsolar Energietechnik GmbH, Stuttgart. It allows users to perform combined thermal and daylight simulations by using the simulation engine of TRNSYS 18. It considers 3D-geometries in combination with various artificial lighting, ventilation, heating and cooling concepts.

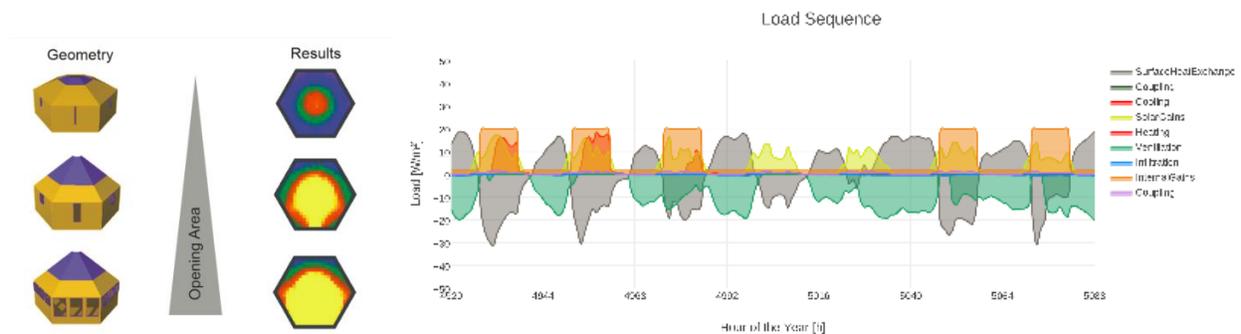


Figure 21: Combined thermal and daylight simulation - Results visualization

The strength of TRNLizard lies in its ability to create both complex and simple building models in a user-friendly “building-block” environment. The parametric architecture and the open source coding of TRNLizard allows the user to perform detailed studies that may require custom model definition. Additionally, pre-defined templates allow the user to quickly set up a working framework so that he can focus on analysis of the resulting standardized outputs, which are quickly generated. Users can drag-and-drop components as necessary to incorporate more custom and advanced inputs.

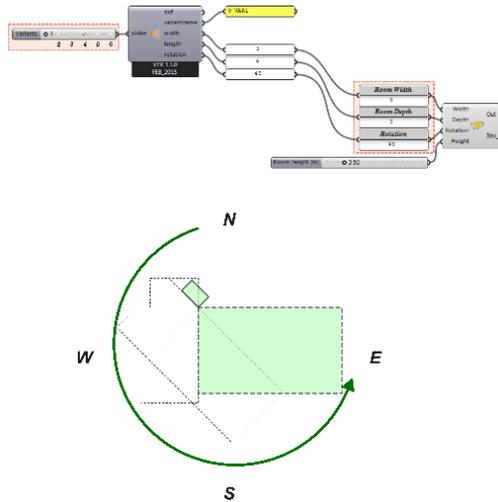


Figure 22: Parametric Model definition

The modular architecture allows for ample flexibility in its use and considers the latest developments of TRNSYS 18. Many new features of TRNSYS18 are already integrated in the TRNLizard plugin. Models are defined completely within the Grasshopper environment, requiring no additional software or post-processing. Parametric simulation models are managed directly in the Grasshopper environment and generated in separate simulation folders such that each model can be modified as needed without affecting the others.

TRNLizard closes the gap between parametric modeling and TRNSYS 18. The main features are:

- 3D-model definition in Grasshopper/Rhinoceros
- Multiple-Airnodes (Atria, Double facade)
- Complex shading geometries (attached and detached)
- Regime definition (properties for heating, cooling, etc.) can be assigned to multiple zones
- Definition of the daylight simulation grid
- Definition of the comfort simulation grid
- Visualization of the 3D-model with boundary conditions
- Visualization of selected simulation results in 3D
- Individual output of model information from the Online Plotter or printer file

### 7.3. Complex fenestration model (Type 56)

Innovative glazing layers are complemented with elements for effective use of daylight, reduction of unwanted solar gains as well as the avoidance of glare effects. These elements place higher demands on modeling.

Particularly the bidirectional scattering of radiation which e.g. occurs in slat systems or honeycomb structures and the interaction with the other layers should be depicted. Furthermore, the opening areas of individual layers influence convection and long wave radiation.

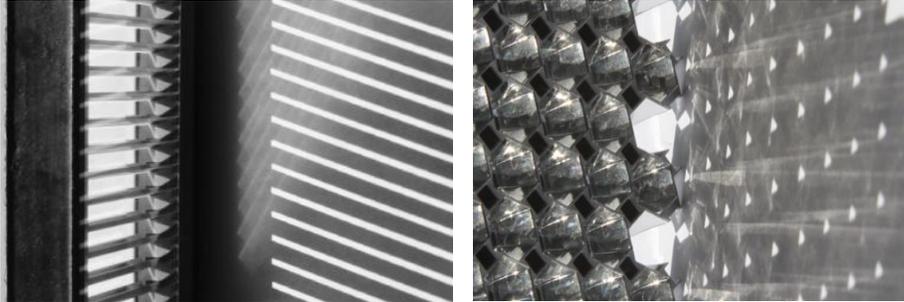


Figure 23: Complex glazing systems

A new glazing model was developed by Schöttl in 2013 to enable a reliable and detailed CFS simulation with relatively little input by the user. (Schöttl, 2013) This model has been restructured and integrated into the multi-zone building model (Type 56) for TRNSYS 18.

A key aspect when creating the model was flexibility to allow the user to portray any combination of shading/glazing in detail, while also to easily generate the inputs from the manufacturer information.

The aim of the new model is to represent the bidirectional scattering of radiation which occurs in slat systems or honeycomb structures and the interaction with the other layers. Furthermore, the opening areas of individual layers influencing convection and long-wave radiation exchange is taken into account. The main model features are:

- variable number of layers with different gas mixtures in between (max. 6 layers)
- optical model based on BSDF on so-called “Bidirectional Scattering Distribution Function” (BSDF). This function describes the ratio of incident light, reflectance and transmittance for exactly two 3D angle pairs that define the direction of the incident and reflected or transmitted radiation.
- calculation of heat fluxes and layer temperatures based on the comparatively complex model of the standard ISO 15099
- modeling of infrared transparent systems
- natural convection around shading layers
- mechanical ventilation of max. 2 gaps

## Implementation

The new model is implemented in addition to the standard window model of Type 56. As in the existing window model of Type 56, the calculation of optical properties of the CFS occurs in the external program Window 7 (Window 7 is developed by the Lawrence Berkeley National Laboratory (LBNL) and is available for no charge). This program not only includes a large product database, but also algorithms to calculate different shading systems like horizontal or vertical slat systems, perforated screens or woven layer, etc. Additionally, any shading system data can be imported as an xml-file.

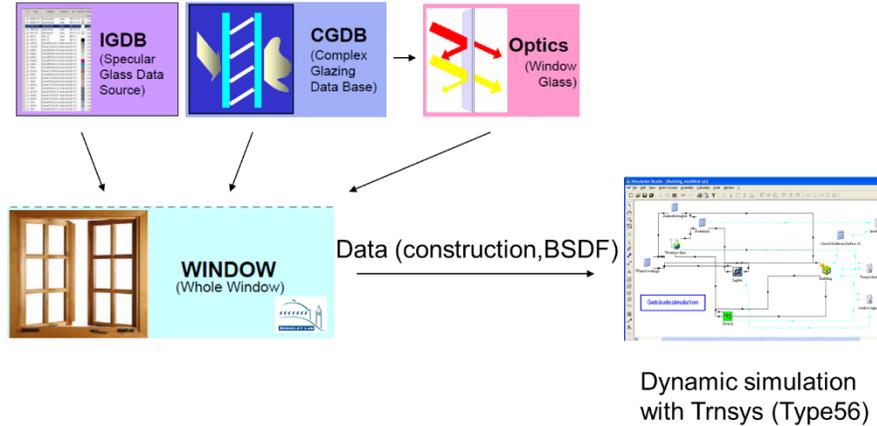


Figure 24: Preprocessing step for complex glazing system

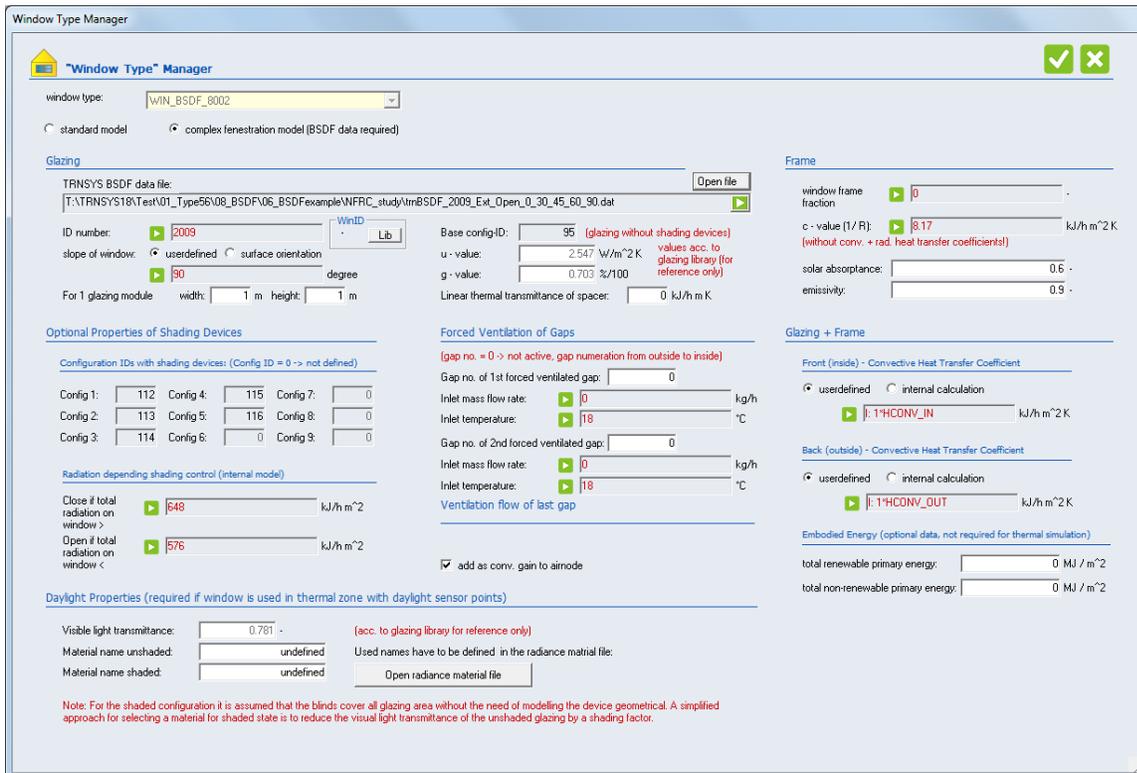


Figure 25: Window type manager for complex glazing system

For every glazing/shading configuration, the BSDF matrixes (transmission front/back, reflection front/back and absorption per layer) must be generated beforehand for the whole system in the solar and visual band. The BSDF matrixes as well as the glazing construction of the different shading configurations are combined into one external file that is imported by Type 56 during the initializing step.

During the simulation, the configuration can be changed in every time step, for example, depending on the irradiation. For the current position of the sun in a time step, the optical system properties are determined by a bilinear interpolation of the matrix values.

### **Availability**

The CFS model is available as a so-called No-Standard-Component for advanced users. A separate tutorial explains the usage of the model in more detail. Please contact Transsolar for further information ([hotline@transsolar.com](mailto:hotline@transsolar.com))