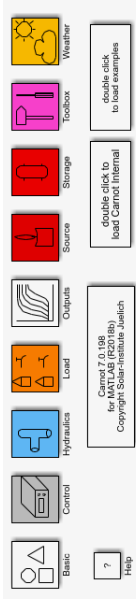


New developments in Carnot

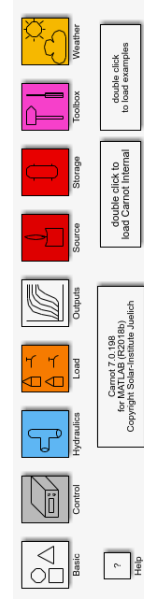
Carnot User Meeting Bologna 23/06/2023

Bernd Hafner



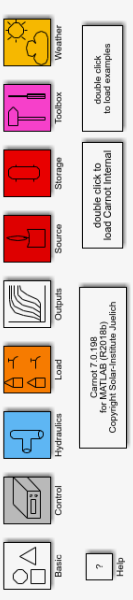
Carnot

- Major application
- Where to find it
- Development group
- Bug fixes and new features

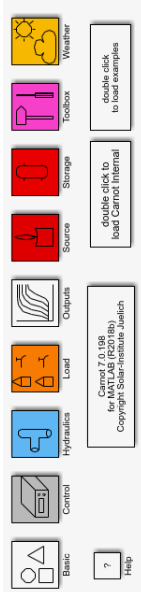
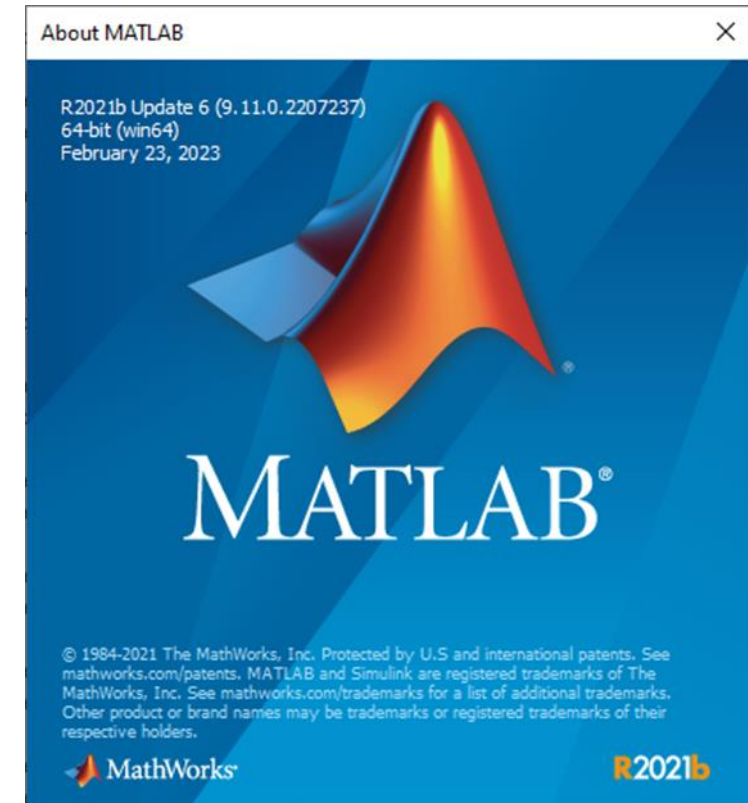
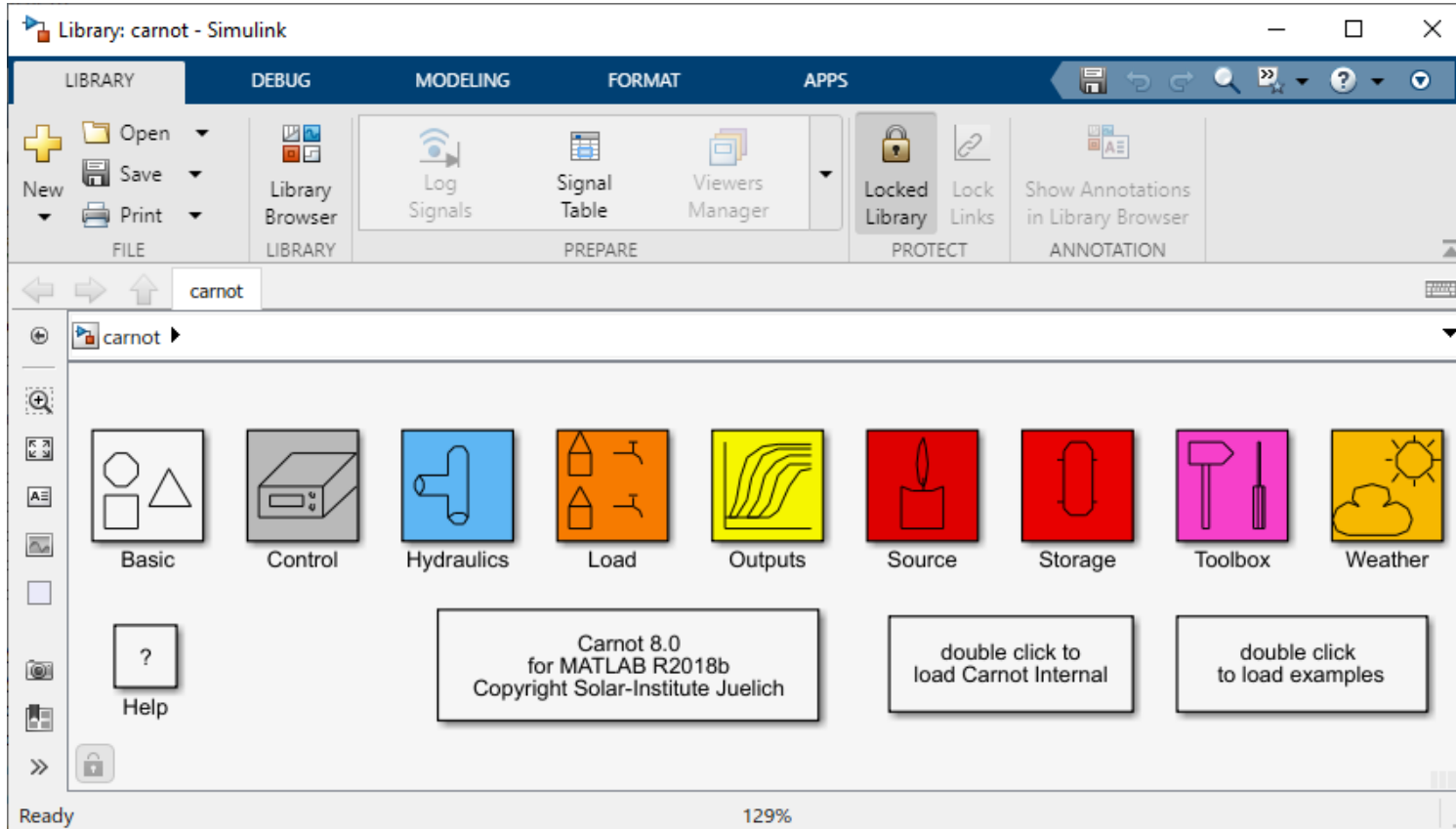


Carnot : Major Application

- Simulation of solar systems (thermal & electric)
- Simulation of HVAC systems
- Calculation of fluid properties, solar position, fluid flow and heat transfer characteristics (Reynolds, Grashof, Prandtl, ...)
- A quite powerful tool for Model Based Development using the Matlab features for requirement engineering, MIL / HIL / SIL, code generation and testing
- Published by FH Aachen as open source under BSD license

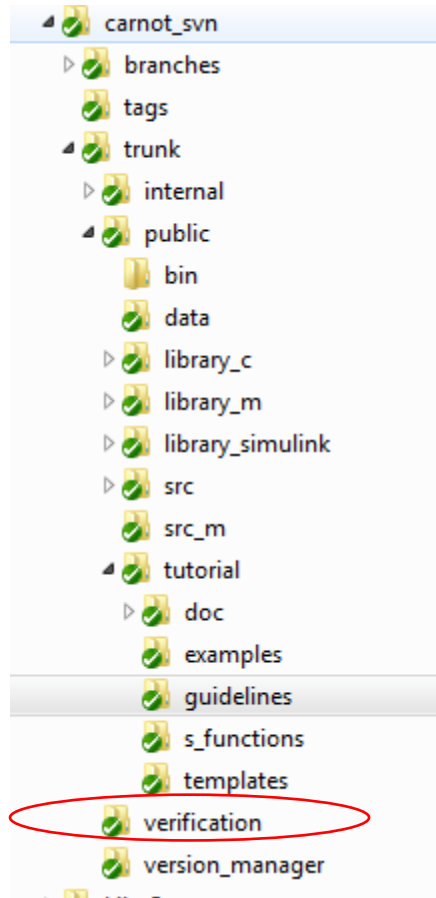


Carnot 8.0 for Matlab R2021b



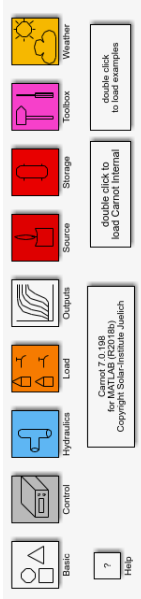
... available since 20/06/2023

Verification



The image shows two overlapping windows. The top window is a 'Command Window' with a blue header. It displays the execution of a MATLAB script: `>> run('C:\repos\Lib_Carnot\verification\verification_carnot.m')`. Below the command, it shows the output: `--- starting verification of CARNOT library and functions ---`, followed by three lines of verification results: `density of Water OK: error 0.000`, `heat_capacity of Water OK: error 0.003`, and `thermal_conductivity of Water OK: error 0.011`. The bottom window is a text editor titled 'verification_carnot_results.txt - Editor'. It shows a list of 333 items, each with a status and an error value. The items are: 327 of 333: FixedSurface OK: error 0; 328 of 333: RadiationOnInclinedSurface OK: error 3.59e-12°; 329 of 333: RadiationOnInclinedSurface OK: error 0.0296°; 330 of 333: TrackedSurface OK: error 0.000; 331 of 333: verify_WeatherDatafile_md1 OK: error 0; 332 of 333: WeatherSimpleModel OK: error 0; 333 of 333: validating WeatherFromWorkspace OK: error 0. The editor's status bar at the bottom shows 'Zeile 1, Spalte 1', '100%', 'Unix (LF)', and 'UTF-8'.

verification is correct for Matlab R2021b
... for R2022b and R2023a still to be done



Carnot – Where to find it?

<https://www.fh-aachen.de/forschung/solar-institut-juelich/carnot/>

Email: carnot@sjj.fh-aachen.de

<https://de.mathworks.com/matlabcentral/fileexchange/68890-carnot-toolbox>

User Group: <https://www.gomatlab.de/carnot-toolbox-f108.html>

SIJ | SOLAR-INSTITUT JÜLICH CARNOT Toolbox

CARNOT is a toolbox extension for MATLAB SIMULINK. It is a tool for the calculation and

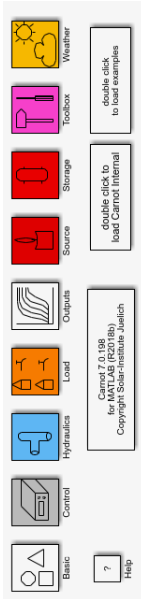
File Exchange

MATLAB Central ▾ | Files | Authors | My File Exchange | Contribute | About

View badges you can earn by participating in the File Exchange community.



CARNOT Toolbox



Carnot – Documentation <https://fh-aachen.sciebo.de/index.php/s/0hxeb0iIjruj3ED?path=%2F>

The screenshot displays the sciebo file manager interface. The top navigation bar is green and contains the sciebo logo, a search bar with the text "Hinzufügen fh-aachen.sciebo.de", and a "Herunterladen" button. Below the navigation bar, there are two panels. The left panel shows a list of files and folders with columns for Name, Größe, and Geändert. The right panel shows a detailed view of the "Nutzertreffen" folder, listing sub-folders for various years and locations.

Name	Größe	Geändert
CARNOT_documentation_7.1	60.4 MB	vor 2 Jahr
Nutzertreffen	244.3 MB	vor 2 Mon
Publikationen	24.7 MB	vor 12 Tag
Versionsarchiv	1.2 GB	vor 2 Mon
CARNOT_7.3.zip	222.8 MB	vor 2 Mon
CARNOT_Anfaenger_Anleitung_ZIES_F... .pdf	1.2 MB	vor 6 Jahr
ReleaseNotes_Carnot_7.3.txt	4 KB	vor 2 Mon

Name
2006_Duesseldorf
2009_Duesseldorf
2011_Ingolstadt
2012_Bayreuth
2013_Basel
2014_Juelich
2015_Innsbruck
2016_Rapperswil
2017_Duesseldorf
2018_Darmstadt
2019_Wels
2020_Biberach

A vertical sidebar of utility icons is located on the right side of the page. From top to bottom, the icons are: Weather, Firefox, Storage, Source, Originals, Load, Hydraulics, Control, and Basic. Below these icons are two buttons: "double click to load Carnot Internal" and "double click to load Carnot Internal".

CARNOT development group

Sorted members list:

Mara Magni, Elisa Venturi, Fabian Ochs,

Christoph Messmer, Stephan Volkmer,

Patrick Kefer, Thorsten Summ,

Marco Griesbach, Jens Schaumann,

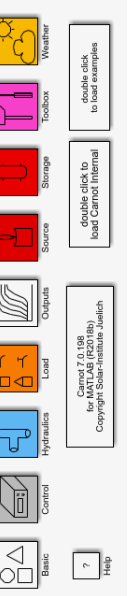
Bernd Hafner, Tobias Blanke,

Joachim Götsche, Ralf Dott,

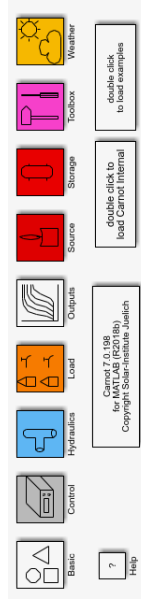
Arnold Wohlfeil, Dennis Götzelmann

- Web-conference every 4-8 weeks
- New features
- Bug reporting
- Organize the user meeting

Nr.	Datum	Titel	Beschreibung	Verantwortlich	Termin	Status	Aktueller St
341	337	24.08.2021	Matlab-Version f. zukünftige Releases	für 2021b erstellen, u.a. wg. besserem Zeitreihen-Handling			zur Info
342	338	19.10.2021	Webconf 15 Uhr	Arnold, Bernd, Dennis, Elisa, Fabian, Jens, Mara, Patrick, Sebastian, Joachim			
351	347	30.11.2021	Webconf 15 Uhr	Dennis, Patrick, Fabian, Christoph, Elisa, Jens, Ralf, Bernd			
354	350	30.11.2021	git statt SVN	Synchronisationstool gestoppt. Bitte nur noch git verwenden, bitte testen.	Joachim	●	2
355	351	30.11.2021	verification	Schwellwerte? Wo sinnvoll, Abweichungen in % angeben. Im Einzelfall anschauen, Zahlen-Darstellung ändern (%g)	Joachim	Jun 22 ●	2
356	352	21.12.2021	Webconf Nutzertreffen '22				
357	353	22.02.2022	Webconf 16 Uhr				
358	354		Neue Solver in Simulink	neue Solver ode78 und ode89 prüfen			
360	356	29.03.2022	Webconf 16 Uhr	Patrick, Fabian, Dennis, Thorsten, Elisa, Christoph, Mara, Jens, Ralf			
362	358		html-Dok zu CARNOT auf FH-Seite erneuern		Joachim	31.03.2022 ●	2
363	359	03.05.2022	Webconf 16 Uhr	Mara, Elisa, Fabian, Dennis, Jens, Patrick, Bernd, Joachim			
364	360	14.06.2022	Webconf 15 Uhr	Elisa, Fabian, Thorsten, Bernd, Patrick, Jens, Joachim			
365	361		Skript zum Anpassen an aktuelle Matlab Version	Patrick erstellt Skript zum Anpassen der Toolbox an jeweils aktuelle Matlab/Simulink-Version	Patrick	01.10.2022 ●	2
366	362		Prozedere zum Erstellen neuer Versionen dokumentieren	z. B. auf gitlab-Wiki	Patrick	01.10.2022 ●	2
367	363	20.07.2022	Webconf 14 Uhr				
368	364						

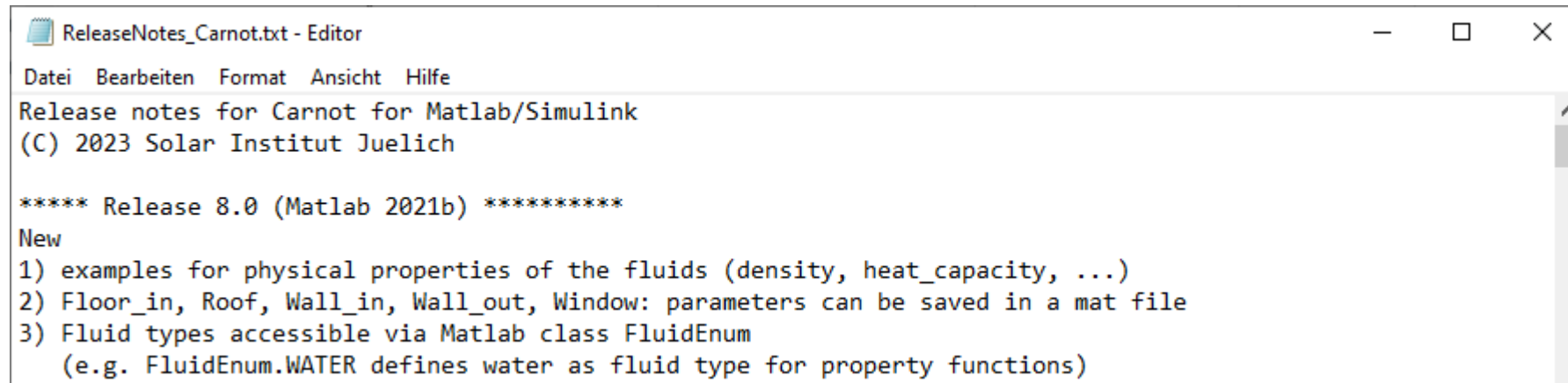


Carnot 8.0 : Improvements & New Features



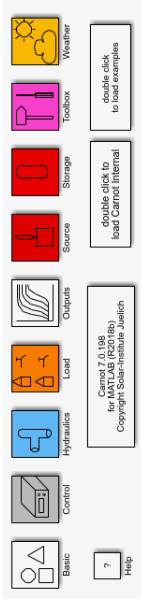
Carnot 8.0: Bug fixes

... refer to the release notes



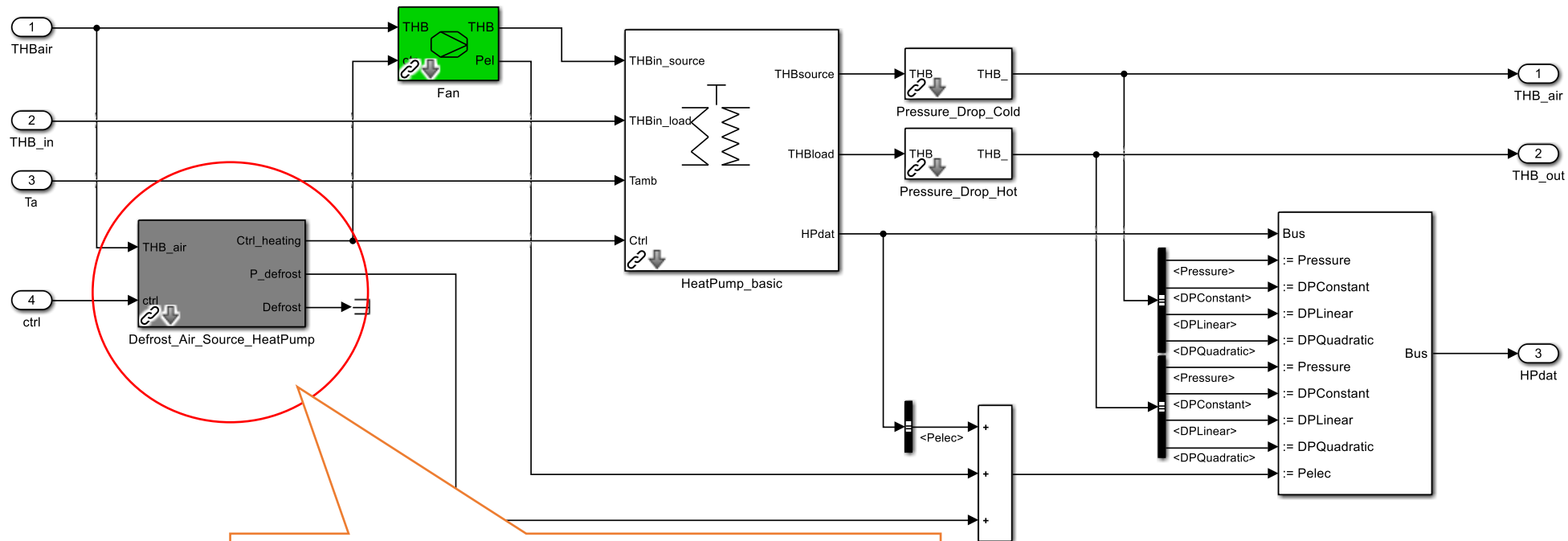
```
ReleaseNotes_Carnot.txt - Editor
Datei Bearbeiten Format Ansicht Hilfe
Release notes for Carnot for Matlab/Simulink
(C) 2023 Solar Institut Juelich

***** Release 8.0 (Matlab 2021b) *****
New
1) examples for physical properties of the fluids (density, heat_capacity, ...)
2) Floor_in, Roof, Wall_in, Wall_out, Window: parameters can be saved in a mat file
3) Fluid types accessible via Matlab class FluidEnum
   (e.g. FluidEnum.WATER defines water as fluid type for property functions)
```



Carnot 8.0 : new Features

HeatPump_Air_Source



Defrost model: operation and defrost time from look-up table fitted to measurement

- Weather
- Tools
- Storage
- Source
- Outputs
- Load
- Hydraulics
- Control
- Basic
- Help

double click to load examples

double click to load Carnot Internal

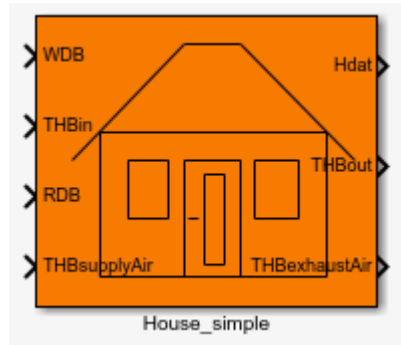
Click F1 (MS for MATLAB (2020)) Copyright Solar-Institute Juelich

Carnot 8.0 : Improvements

House_simple

TBH input for ventilation

HeatTransfer2Ground_ISO13370 with the options: slab on ground, heated basement, unheated basement



Block Parameters: HeatTransfer2Ground_ISO13370

Heat Transfer to Ground ISO 13370 (mask) (link)

Ground heat transfer for a floor "SLAB ON GROUND", "HEATED BASEMENT" and "UNHEATED BASEMENT" according to ISO 13370:2018. Use function fitSineToTamb to find the weather parameters.

Parameters

General Dimensions Heat Transfer

ground coupling mode **slab on ground**

Time shift where outside temperature is used for fitSineToTamb [h] 319*3600

Mean annual inside temperature [°C] 23.8

Annual amplitude of inside temperature [°C] 3.8

Mean annual outside temperature [°C] 11

Annual amplitude of outside temperature [°C] 9.3

OK Cancel Help Apply

Weather

Troubleshoot

Storage

Source

Outputs

Load

Hydraulics

Control

Basic

Help

double click to load examples

double click to load Carnot Internal

Copyright © 2020 (R) Steffen-Juergel

Carnot 8.0 : new Features

Room_radiator, Room_floor_heating

Block Parameters: Room_Floor_Heating

Room (mask) (link)

Model of two neighbour rooms with a floor heating.

Parameters

General Room 1 Room 2 Calculation

Parameters of Room 1 and 2

Orientation of facade B (0° = south, +90° = west) 0

Width of rooms in m (= length of wall B and D) 5

Height of rooms in m 2.5

Wall between Room 1 and 2

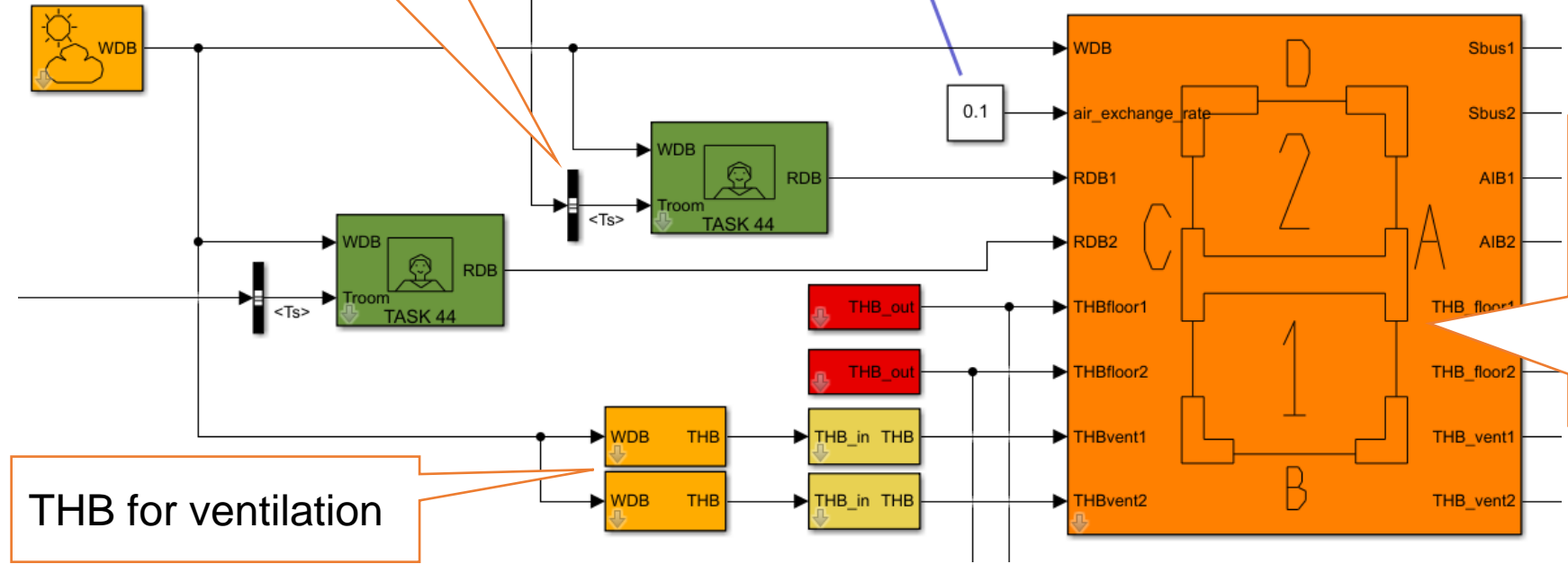
Path fullfile(path_carnot('libs'), 'Basic', 'Thermal_Models', 'Wall_in', 'parameter_set')

Parameter set 'WallIn_set1.mat'

Carnot public data Carnot internal data Selected path

Parameters from mat-files

Resident Data as input



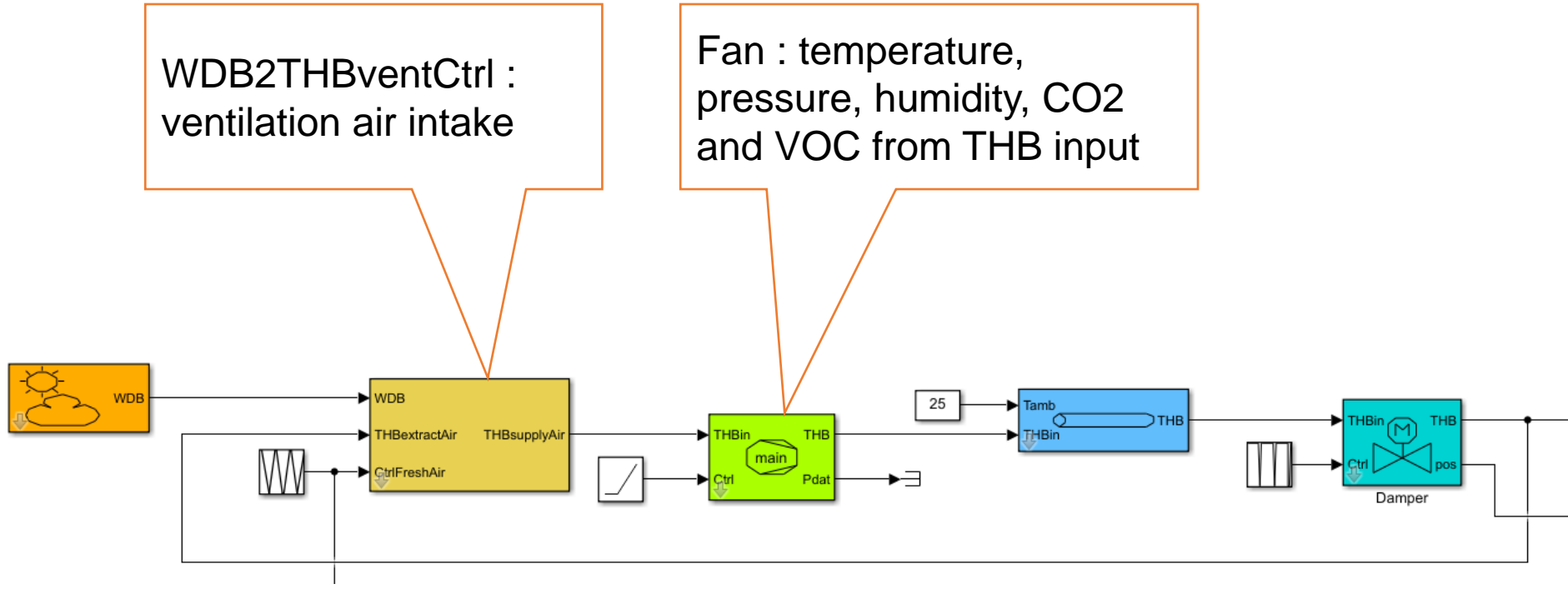
THB for ventilation

Concentration (CO2, VOC)

Window_ventilation

Carnot 8.0 : new Features

Fan models

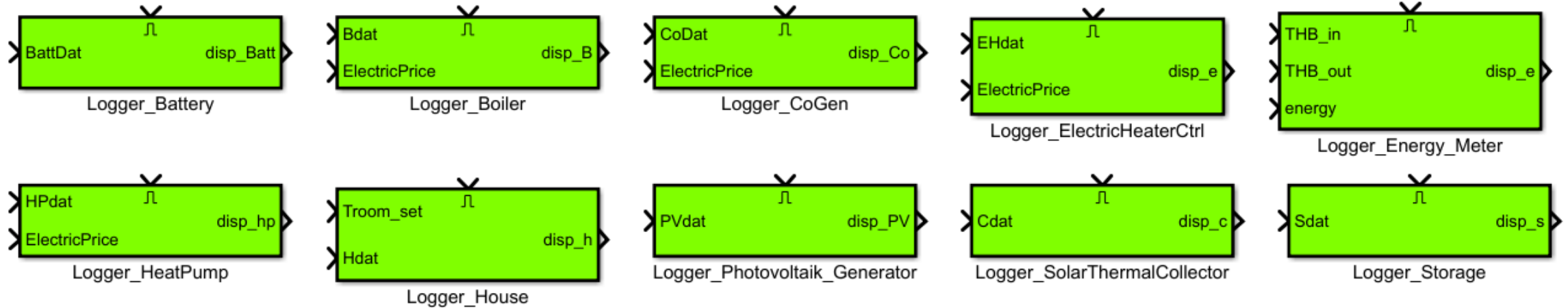


Weather
Toolbox
Storage
Source
Outputs
Load
Hydraulics
Control
Basic
Help

double click to load examples
double click to load Carnot Internal
Click F1 (MS for MATLAB (2021R))
Copyright Saba-Institute Juelich

Carnot 8.0 : new Features

Data_Logger blocks



m-functions for evaluation of the data

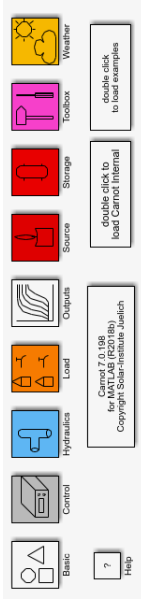
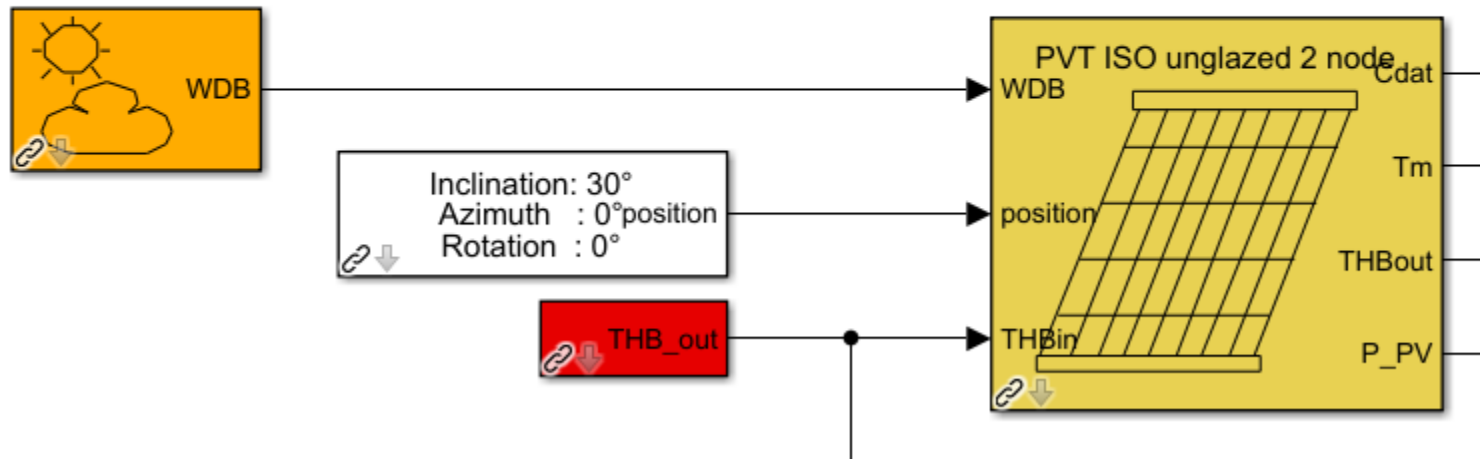
e.g. the calculation of the seasonal performance factor of a heat pump

or the specific heating demand of a house in kWh/m²

Carnot 8.0 : new Features

PVT_Collector_Unglazed_ISO_2node

photovoltaic thermal collector based on the PV model and the ISO model of an unglazed collector

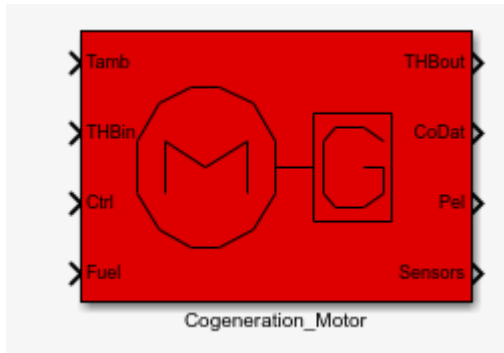


Carnot 8.0 : new Features

Cogeneration_Motor

model of a cogeneration unit with a gas motor

Based on Look-up Tables with some basic control functions (temperature limits)



Block Parameters: Cogeneration_Motor

Parameter set
'Default_Cogen.mat'

Edit path and name of parameter set

User defined parameters

Characteristics Controller

Control signal breakpoints
[0 0.5 0.75 1]

Electric power [W] at control breakpoint
[0 3000 4500 6000]

Fuel power [W] at control breakpoints
[0 14800 18900 22200]

Temperature breakpoints
[30 65]

Thermal power [W] at control and temperature breakpoints
[0 9700 12400 14900; 0 7663 9796 11787]

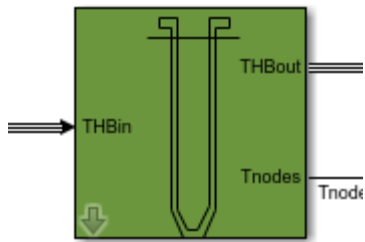
Losses to ambient in W/K
35.33333333333333

Electric standby power
65

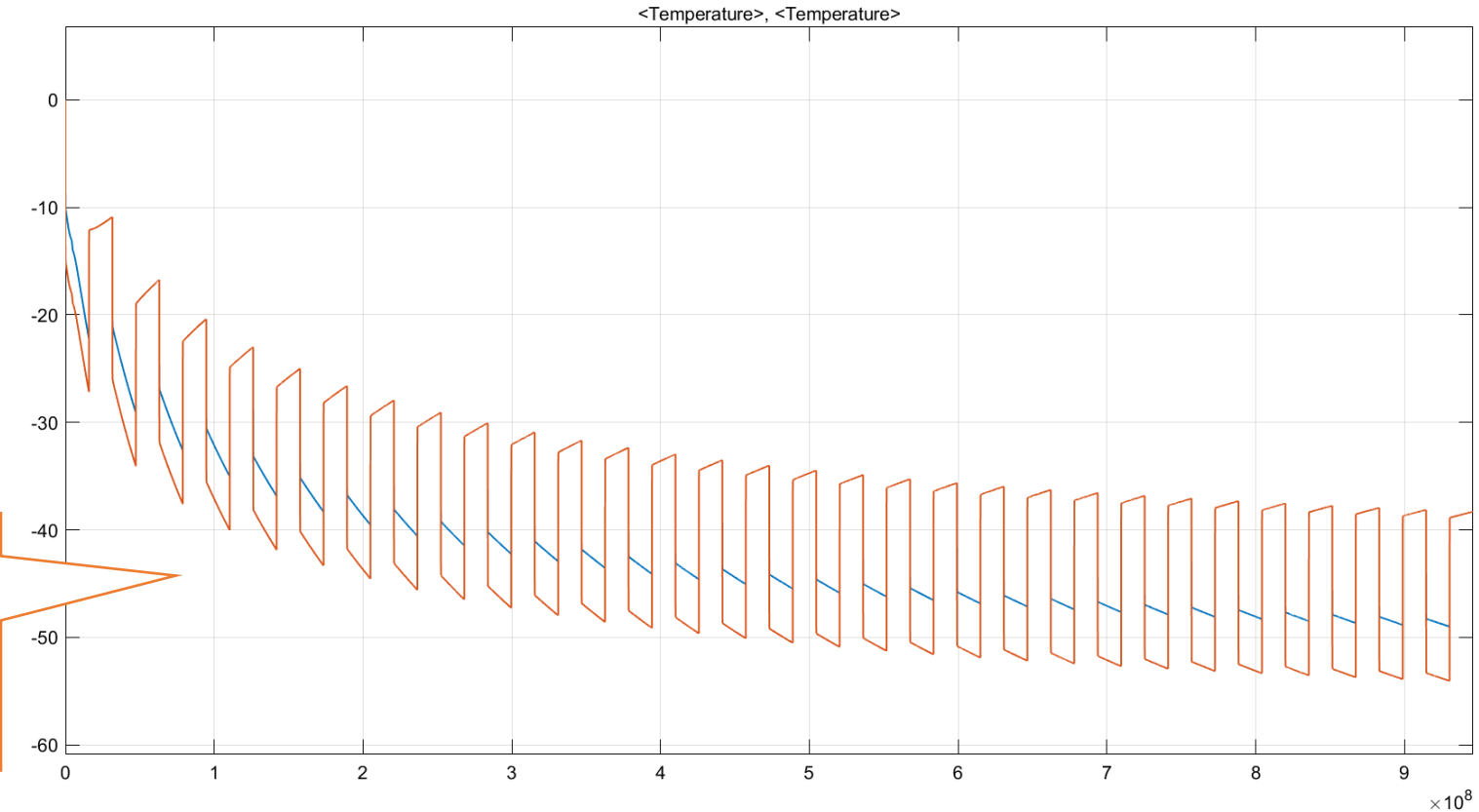
Thermal capacity on fluid side in J/K
41820

Carnot 8.0 : new Features

Ground_source_heat_exchanger – complete verification with literature and test data



Testcase [Huber]
30 years operation time
Simulation time 2 s 😊



Model and validation data: Huber A, Schuler O.: Berechnungsmodul für Erdwärmesonden (EWS). ENET Bericht Nr. 9658807-1, 1997

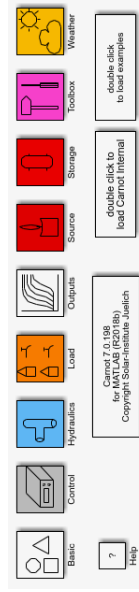
- Weather
- Toolbox
- Storage
- Source
- Outputs
- Load
- Hydraulics
- Control
- Basic
- Help

double click to load examples

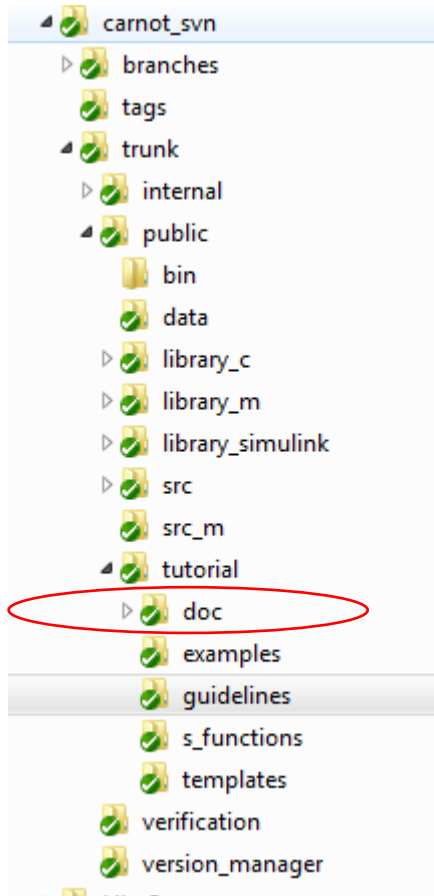
double click to load Carnot Internal

Click F1 (MS for MATLAB (2018)) Copyright Stein-Institute Juelich

Thank you for your attention



Carnot folders: Tutorial



Carnot m-Functions for Blocks Overview

Contents

- [Basic / Electric](#)
- [Basic / Heat_Transfer](#)
- [Basic / Hydraulics](#)
- [Basic / Material_Properties](#)
- [Basic / Thermal_Models](#)
- [Hydraulics](#)
- [Load / General](#)
- [Load / Hot_Water_Tapping](#)

Basic / Thermal_Models

[hp_param](#)

[CarnotCallbacks_WindowWithShading](#)

Hydraulics

[CarnotCallbacks_PumpAdditional](#)

Load / General

[CarnotCallbacks_Data_from_File](#)

[createDatafile](#)

Carnot m-Functions Overview

Contents

- [carnot_library_tools](#)
- [comfort](#)
- [data_input](#)
- [economy](#)
- [hydraulics](#)
- [material_properties](#)
- [physical_units](#)
- [time_functions](#)
- [weather_and_sun](#)

comfort

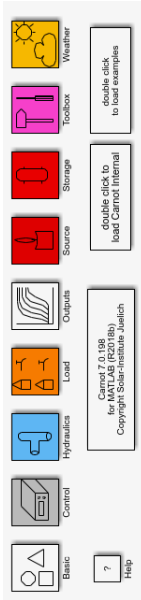
[calculate_pmv](#)

[clothing_area_factor](#)

[clothing_surface_temperature](#)

[heat_transfer_clothing](#)

[calculate_ppd](#)



Carnot 8.0 : new Features

ISO 7730 comfort rating

- WarmAndCoolFloor - comfort rating of temperature differences at the floor
- RadiantAsymmetryWall - comfort rating of different wall temperatures

Additional functions (data cannot be created with standard Carnot building models)

- VerticalAirTemperatureDifference - comfort rating of vertical temperature differences in the room
- DraughtRating - evaluation of air temperature and velocities

