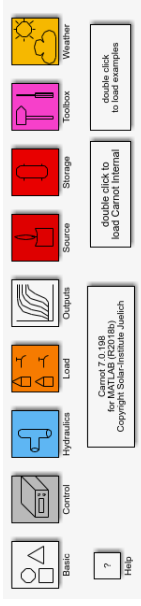


# Conventional And Renewable eNergy Optimization Toolbox

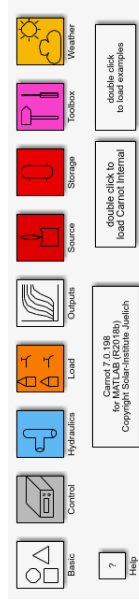
What is it made for?

Bernd Hafner



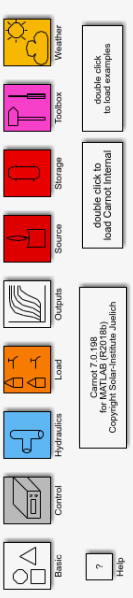
# CARNOT

- What is it
- Library structure
- Examples
- Helpfiles
- Internal structure
- Development group
- Where to find it



# CARNOT Toolbox – What is it ?

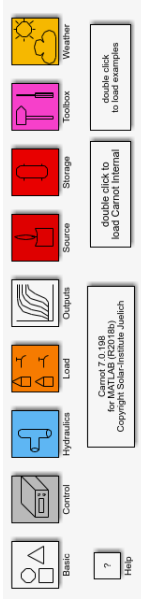
- Matlab-Simulink Blockset for simulation of
  - HVAC systems
  - Solar systems (thermal & electric)
  - Buildings
- Functions for solar position, fluid properties, fluid flow and heat transfer characteristics (Reynolds, Grashof, Prandtl, ...)
- Published as open source under BSD license
- **Compatible with other Matlab Toolboxes**



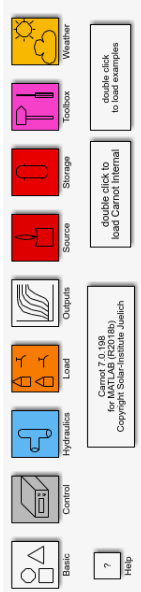
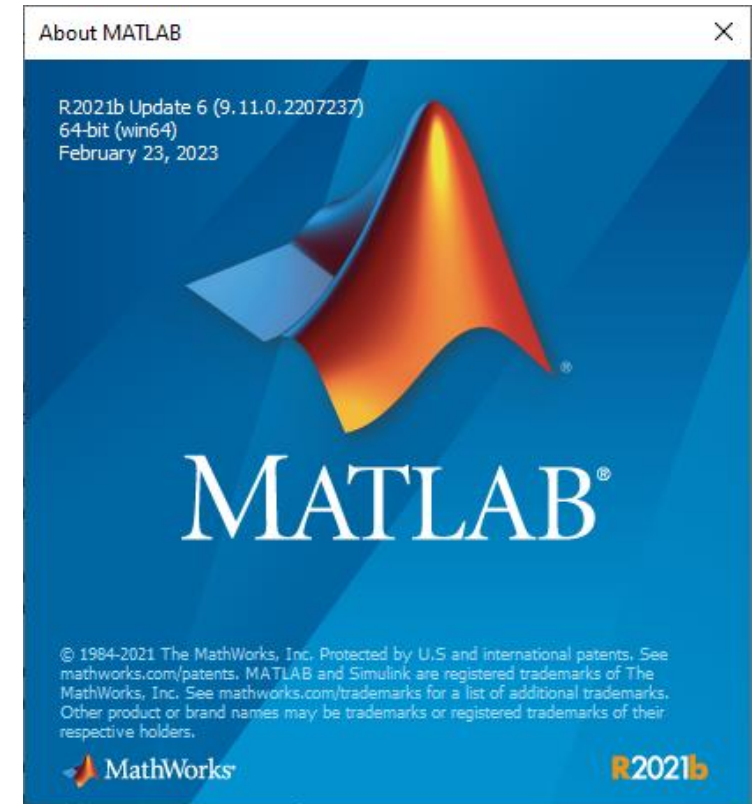
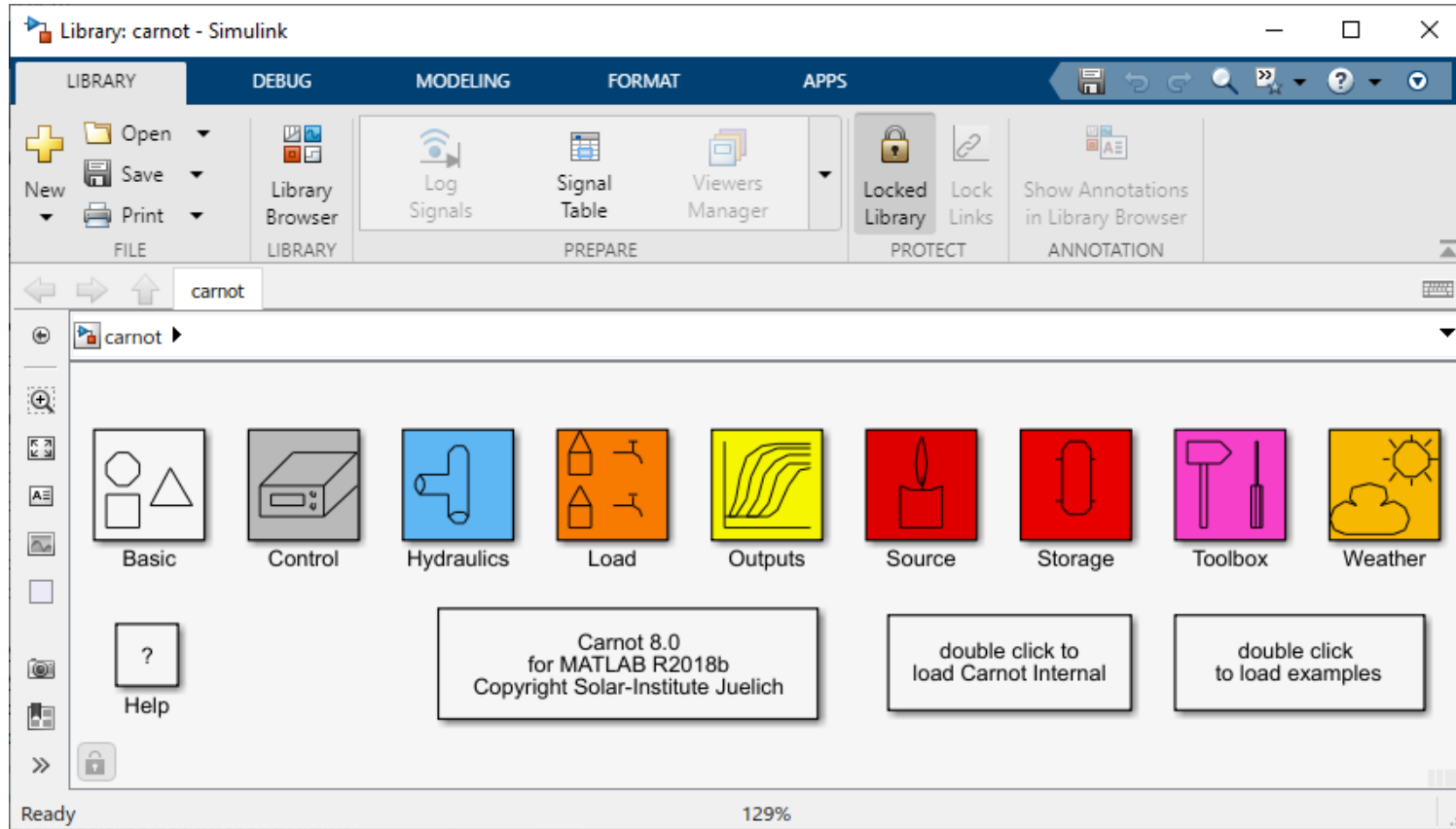
# CARNOT – What is it ?

## Strength

- Model Based Development using the Matlab features for requirement engineering, MIL / HIL / SIL, code generation and testing

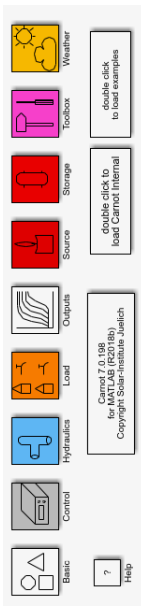
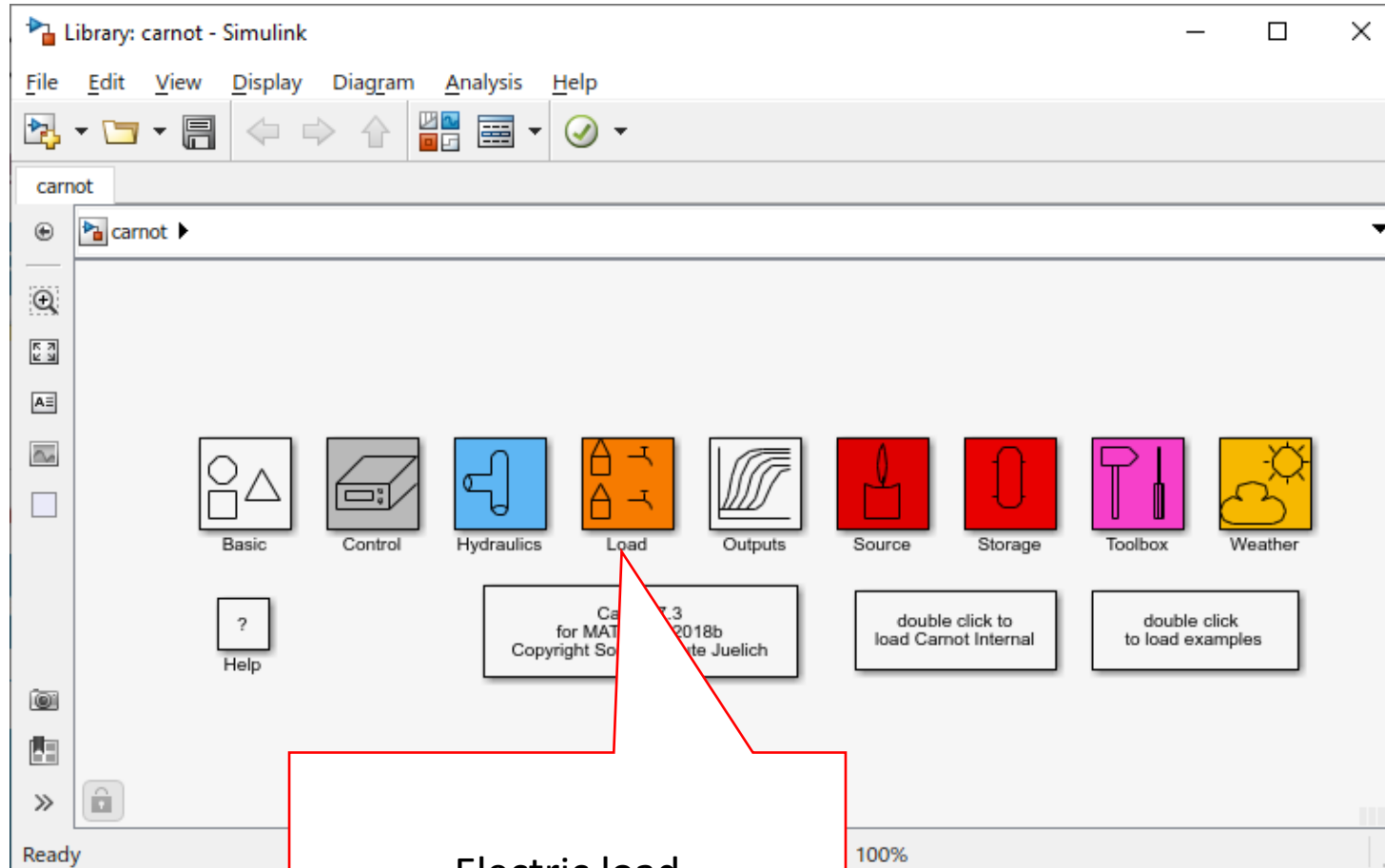


# CARNOT – What is it ?

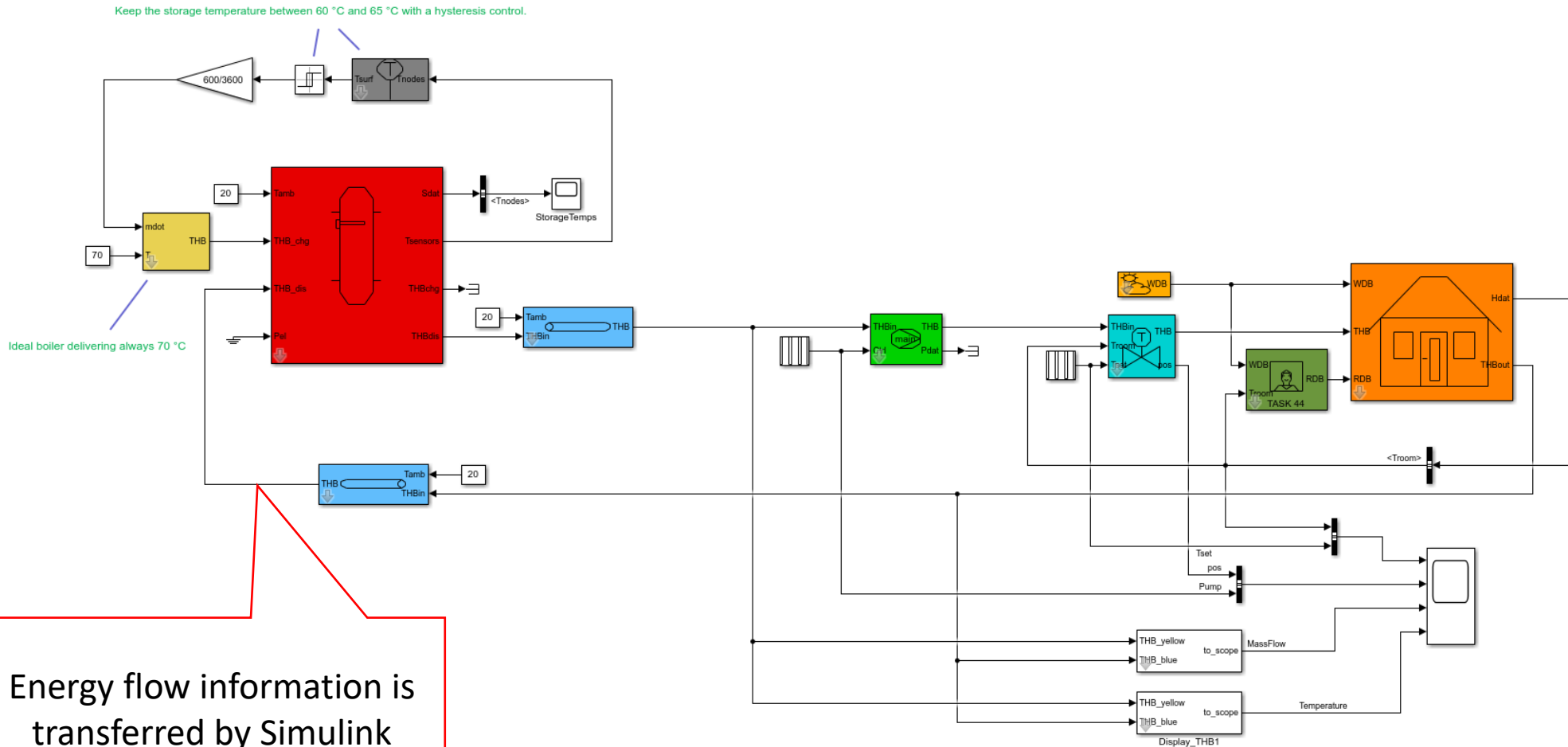


Carnot 8.0 for Matlab R2021b

# CARNOT – Library Structure



# CARNOT – Example of a (very simple) heating systems



Weather

Toolbox

Storage

Source

Outputs

Load

Hydraulics

Control

Basic

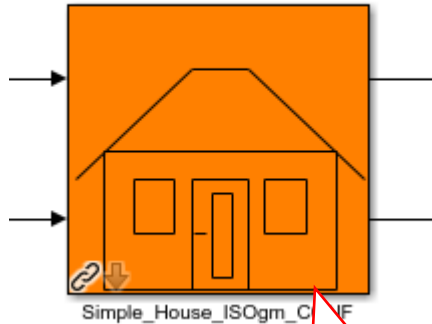
Help

double click to load examples

double click to load Carnot Internal

Click 7 of 168 for MATLAB (R2018b) Copyright Stefan-Hubert Juelich

# CARNOT – Examples

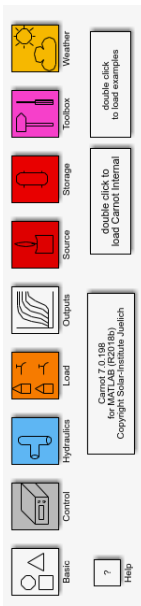


Many blocks allow to change parameters and save them as a parameter file

The screenshot shows the 'Block Parameters: Simple\_House\_ISOgm\_CONF' dialog box. It has a 'House' tab selected. The parameters are as follows:

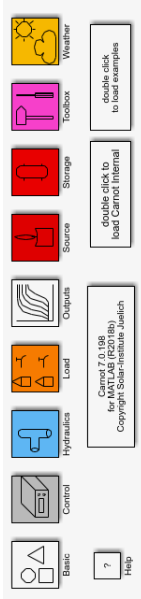
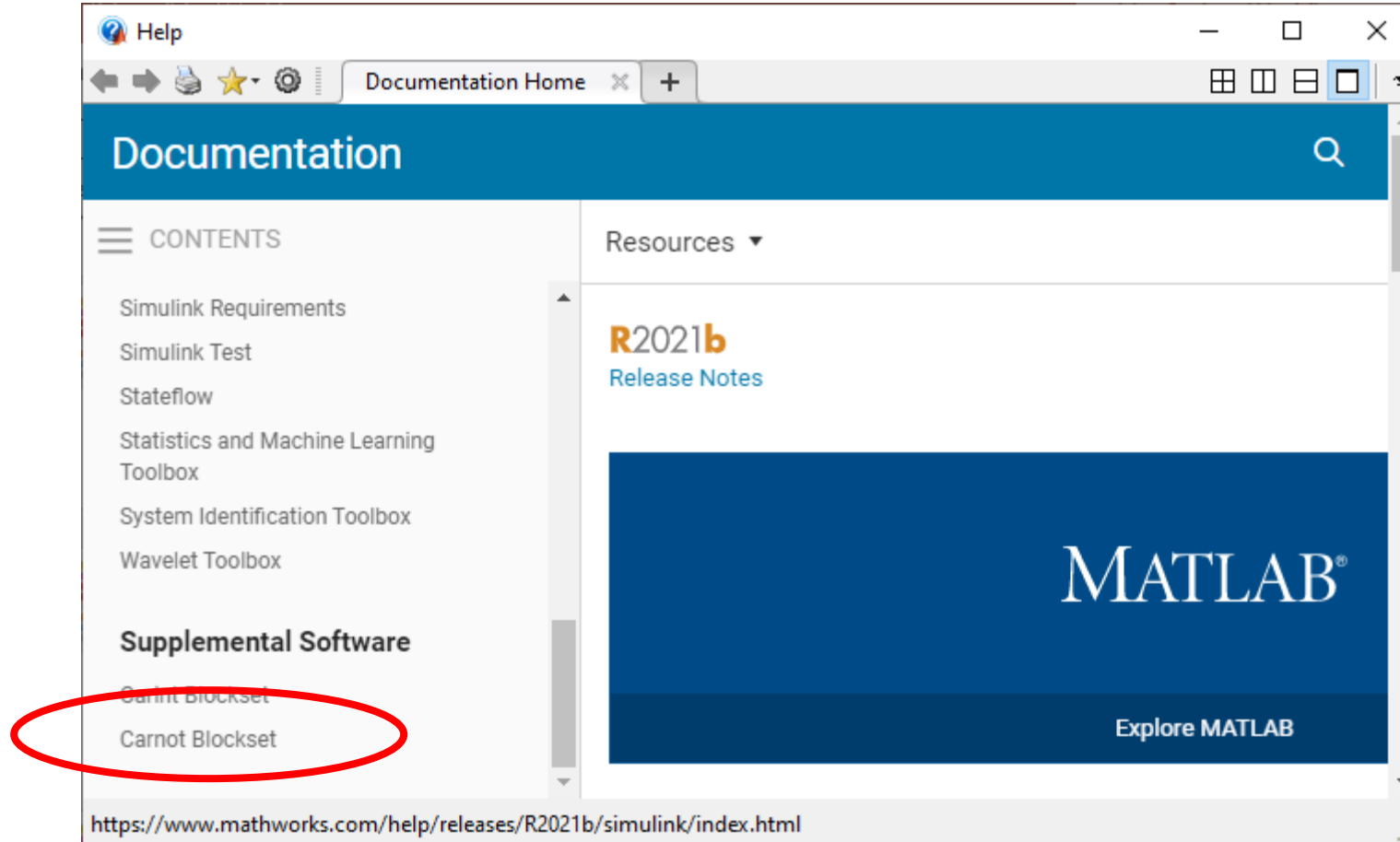
- Living surface in m<sup>2</sup>: 140
- height of rooms in m: 2.5
- Dimensions of slab in m [length width]: [7 10]
- Total heat transfer to ambient (walls/roof) in W/K: 100
- Total heat transfer to neighbour in W/K: 0
- Heat transfer coefficient of slab to ground in W/m<sup>2</sup>/K: 0.7
- Total thermal capacity in J/K: 70000000

At the bottom, there are two buttons: 'Save in Carnot internal data' and 'Save in selected path'. The dialog also has 'OK', 'Cancel', 'Help', and 'Apply' buttons at the very bottom.





# CARNOT - Helpfiles



# CARNOT - Helpfiles

Help

Custom Documentation

Documentation

Search Help

CONTENTS Close

« Documentation Home

▼ Carnot (Supplemental Software)

- Tutorial and Getting Started
- Basic Concepts
- Advanced Topics
- Blocks and Functions
- Verification
- Literature
- Carnot Web Site

## CARNOT

### Conventional And Renewable eNergy systems Optimization Toolbox

for MATLAB Simulink R2021b ©

Basic Control Hydraulics Load Outputs Source Storage Toolbox Weather

? Help

Carnot 7.1.0 for MATLAB (R2018b) Copyright Solar-Institute Juelich

double click to load Carnot Internal

double click to load examples

Weather

Toolbox

Storage

Source

Outputs

Load

Hydraulics

Control

Basic

Help

double click to load Carnot Internal

double click to load examples

Copyright Solar-Institute Juelich

# CARNOT - Helpfiles

The screenshot shows a web browser window titled 'Help' with a single tab 'Custom Documentation'. The page is titled 'Documentation' and features a search bar labeled 'Search Help'. On the left, a 'CONTENTS' sidebar is visible with a 'Close' button. The sidebar lists the following items: 'Documentation Home', 'Carnot (Supplemental Software)' (expanded), 'Tutorial and Getting Started', 'Basic Concepts', 'Advanced Topics', 'Blocks and Functions' (highlighted), 'Blocks', 'Block m-Functions', 'General m-Functions', 'C-Functions', 'Verification', 'Literature', and 'Carnot Web Site'. The main content area displays the following text:

## 4 Block and Function Reference

### 4.1 The Models

See [Carnot Block Overview](#) for the models and blocks.

Some models have dedicated m-Functions for parameter fitting or Callbacks. See [Carnot m-Functions for Models](#).

### 4.2 Utility Functions (m-Files and C-Libraries)

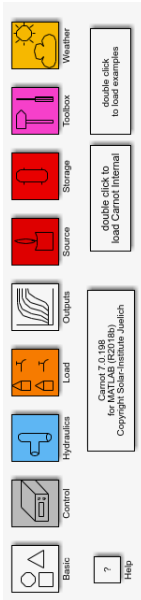
In this chapter, the utility functions already mentioned in [Basic Concepts \(chapter 2.3\)](#) are referenced. This utility functions are m-files or m-functions, that can be called from the workspace. Some utility function provide input values to specify the components in your model (like "taualfa"), other facilitate operations like compiling the underlying C-Mex m-Functions.

See [Carnot m-Functions Overview](#) for the m-files and functions

### 4.3 Utility Functions (C-Libraries)

Oher functions e.g. the Carlib library have supporting m-functions for Carnot s-functions (e.g. enum and class definitions). These libraries have to be compiled together with the s-function (see [3. Advanced Topics](#) for details).

See [Carnot C-Library Overview](#) for the C-libraries.

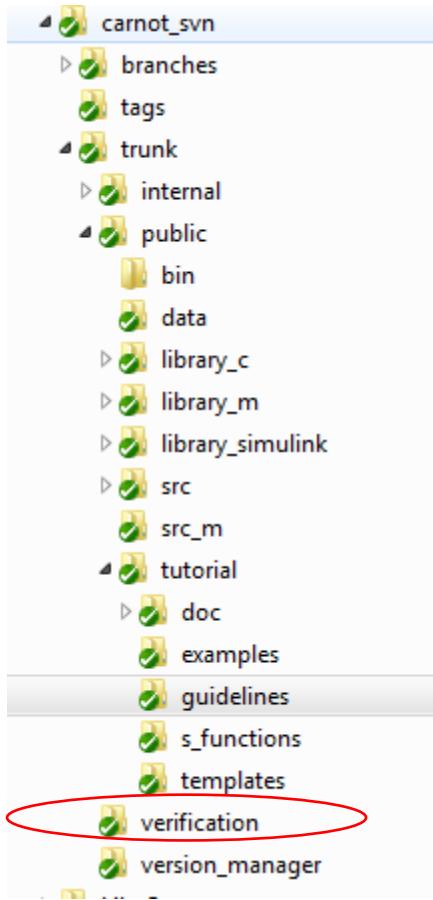


# CARNOT - Helpfiles

The image displays three overlapping screenshots of the Carnot software help documentation interface. Each window shows a 'Documentation' header and a 'CONTENTS' sidebar. The leftmost window is titled 'Carnot Blocks' and lists various categories under 'Carnot (Supplemental Software)'. The middle window is titled 'Carnot m-Functions for Block m-Functions' and lists categories like 'Basic / Electric' and 'Basic / Heat\_Transfer'. The rightmost window is titled 'Carnot m-Functions Overview' and lists categories like 'carnot\_library\_tools' and 'comfort'. A Windows taskbar is visible on the right side of the screenshots, showing icons for Weather, Toolbox, Storage, Source, Outputs, Load, Hydraulics, Control, Basic, and Help.

Helpfiles and summary are created („publish“) automatically using the Carnot folder structure

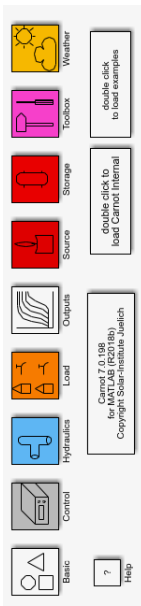
# CARNOT – Internal Structure : Verification



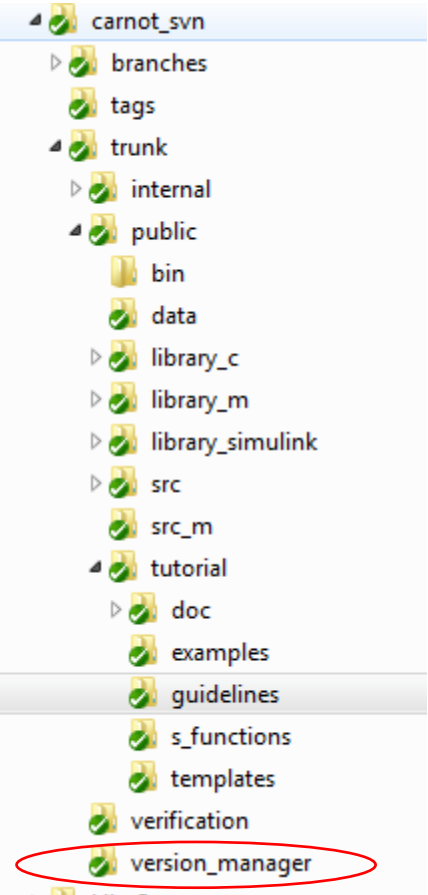
```
Command Window
>> run('C:\repos\Lib_Carnot\verification\verification_carnot.m')
--- starting verification of CARNOT library and functions ---
    density of Water OK: error 0.000
    heat_capacity of Water OK: error 0.003
    thermal_conductivity of Water OK: error 0.011
Warning in viscosity: temperature out of range!
Valid temperature range from 0°C to 160°C
Warning in viscosity: temperature out of range!
Valid temperature range from 0°C to 160°C
Warning in viscosity: temperature out of range!
Valid temperature range from 0°C to 160°C
Warning in viscosity: temperature out of range!
Valid temperature range from 0°C to 160°C
    kinematic_viscosity of Water OK: error 0.007

285 of 290: verify_Select_Weather_md1 OK: error 0.000
286 of 290: TrackedSurface OK: error 0.000
287 of 290: WDB2THB OK: error 0.000
288 of 290: verify_WeatherDatafile_md1 OK: error 0.000
289 of 290: WeatherSimpleModel OK: error 0.000
290 of 290: validating WeatherFromWorkspace OK: error 0.000
```

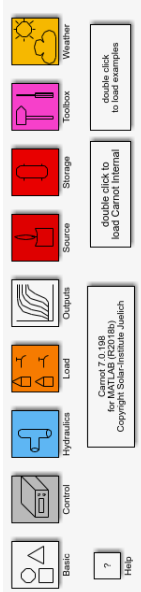
verification is correct for Matlab R2018b, R2020b, R2021b



# CARNOT – Internal Structure : Version Manager



- AddToCarnotMDL.m
- ChangeCopyrightNotice.m
- CheckForBadBlocks.m
- CheckUpgradeAdvisor.m
- CleanUp.m
- CopyRemainingFiles.m
- CreateCarintMDL.m
- CreateCarnotMDL.m
- CreateMFileHelp.m
- MakeMEX.m
- MakeMEX\_CleanUp.m
- SearchDirectory.m
- SearchFiles.m



# Carnot – Where to find it?

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

## File Exchange

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

The Exchange badges are here:

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



### CARNOT Toolbox

version 7.0 by Arnold Wohlfeil

The CARNOT toolbox contains models for thermodynamics/energy engineering with focus on HVAC systems.

<https://fh-aachen.sciebo.de/index.php/s/0hxub0ilJrui3ED>

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

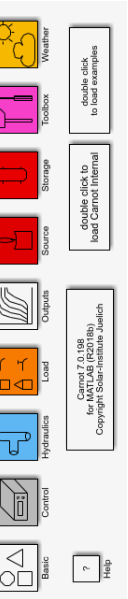
<https://www.fh-aachen.de/forschung/solar-institut-juelich/carnot/>

## SIJ | SOLAR-INSTITUT JÜLICH

# CARNOT Toolbox

CARNOT is a toolbox extension for MATLAB SIMULINK. It is a tool for the calculation and simulation of the thermal components of HVAC systems with regards to conventional and regenerative elements. The CARNOT Toolbox is a library of typical components of these systems. It is organized in Blocksets like the SIMULINK Library itself. The handling of the blocks is exactly the same as in SIMULINK, so that users familiar with SIMULINK can directly use the new Blocksets in the same way.

Email: [carnot@sj.fh-aachen.de](mailto:carnot@sj.fh-aachen.de)



# Carnot – Where to find it?

<https://fh-aachen.sciebo.de/index.php/s/0hxeb0iIJrui3ED?path=%2F>

The screenshot shows 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 is a breadcrumb trail "Alle Dateien >". The main content area displays a list of files and folders in a table format. The columns are "Name", "Größe", and "Geändert".

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

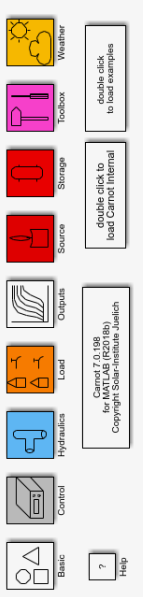
This screenshot shows a different view of the sciebo file manager, displaying a list of folders. The top navigation bar is green and contains the text "Hinzufügen fh-aachen.sciebo.de" and a "Herunterladen" button. Below the navigation bar, there is a breadcrumb trail "Alle Dateien > Nutzertreffen >". The main content area displays a list of folders in a table format. The columns are "Name" and "Größe".

Name	Größe
2006_Duesseldorf	
2009_Duesseldorf	
2011_Ingolstadt	
2012_Bayreuth	
2013_Basel	
2014_Juelich	
2015_Innsbruck	
2016_Rapperswil	
2017_Duesseldorf	
2018_Darmstadt	
2019_Wels	
2020_Biberach	
2021_Ingolstadt	
2021_Online_Workshop	

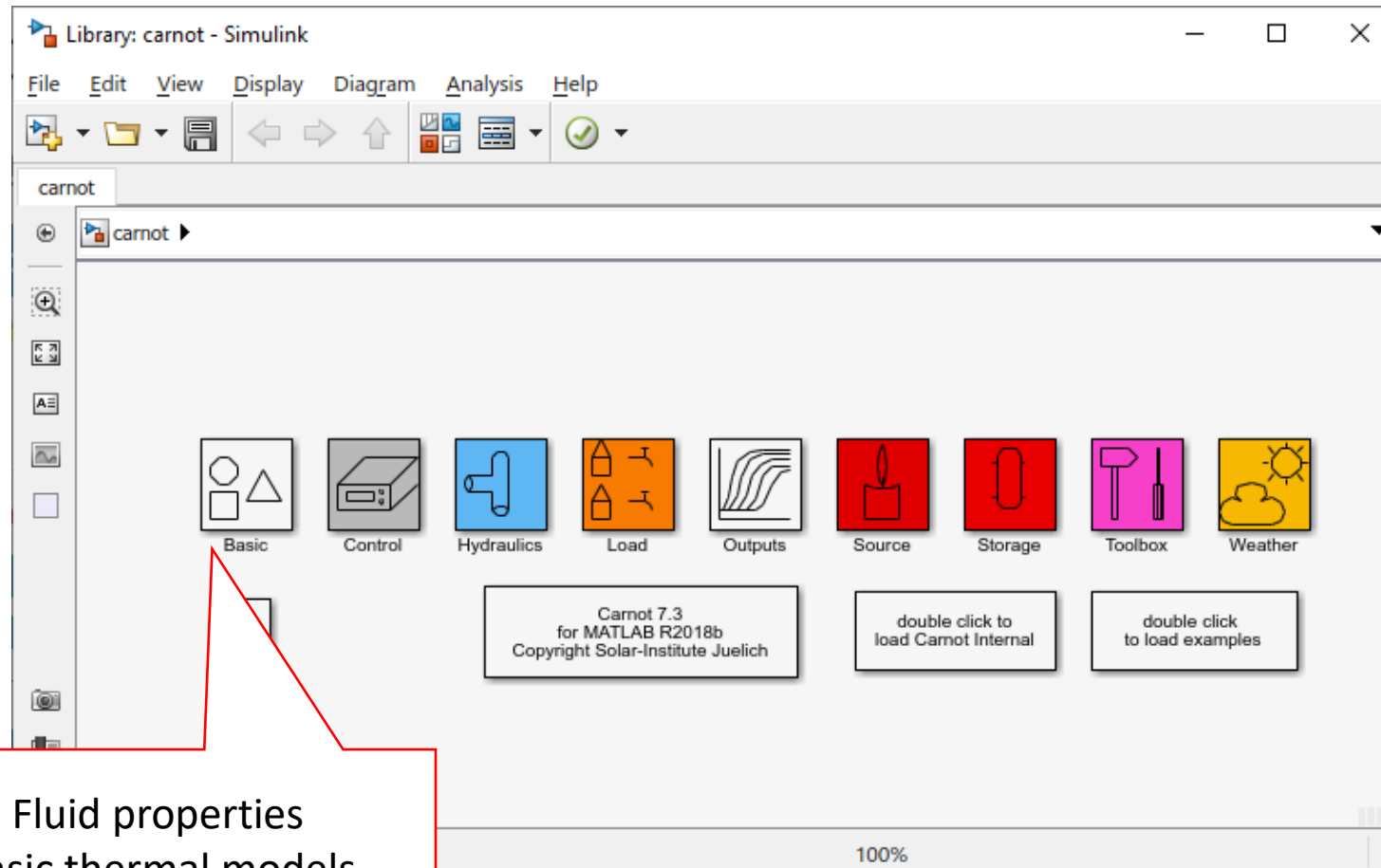
A vertical toolbar on the right side of the interface. It contains several icons for file management and navigation, including Weather, Trashbox, Storage, Source, Originals, Load, Hydraulics, Control, Basic, and Help. There are also two buttons with text: "double click to load examples" and "double click to load Carnot Internal".



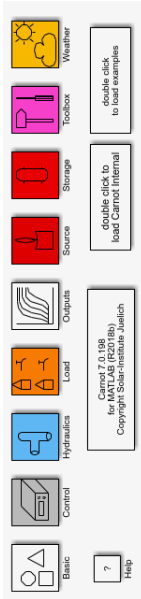
Thank you for your attention



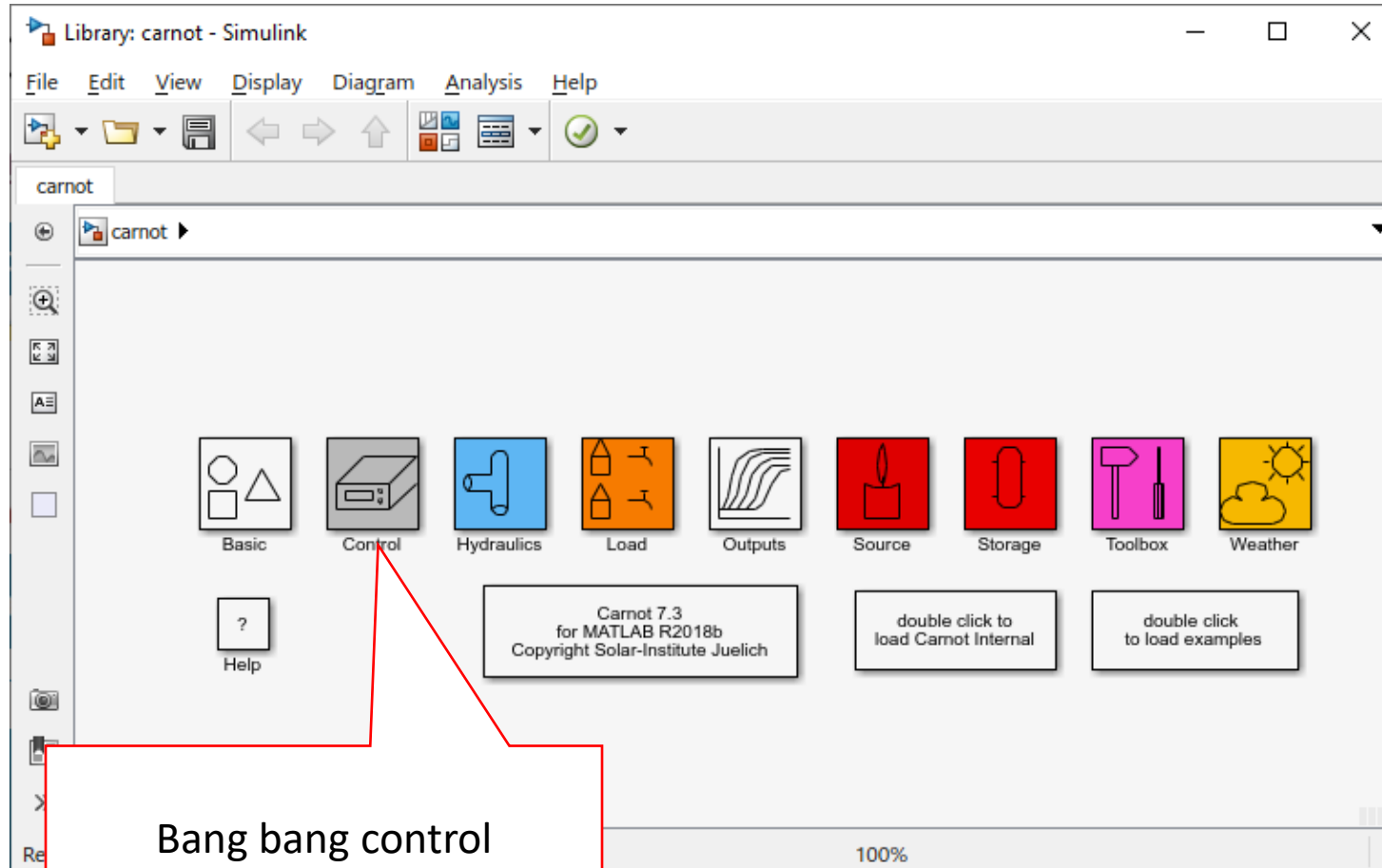
# CARNOT – Library Structure



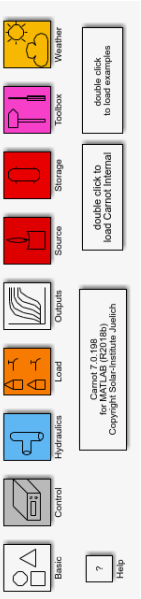
Fluid properties  
Basic thermal models  
Solar position & radiation  
Heat transfer functions  
Pressure drop functions



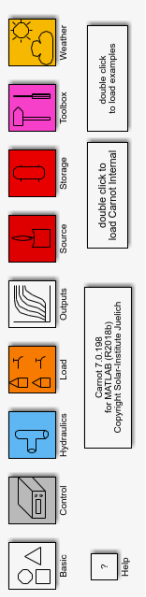
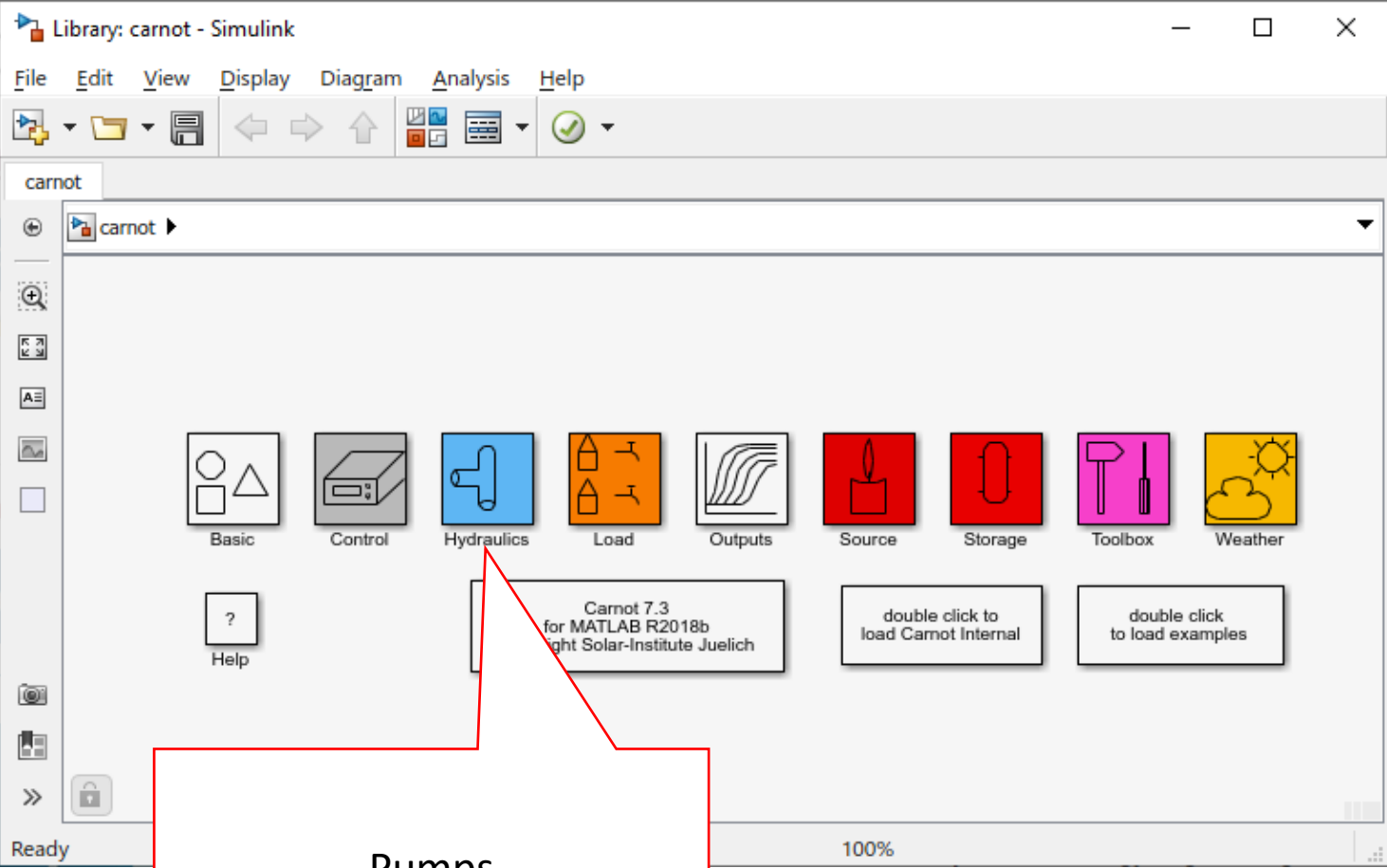
# CARNOT – Library Structure



Bang bang control  
Timers  
Sensors  
Radiator thermostat

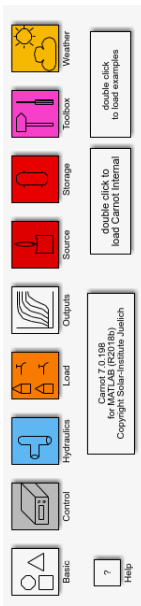
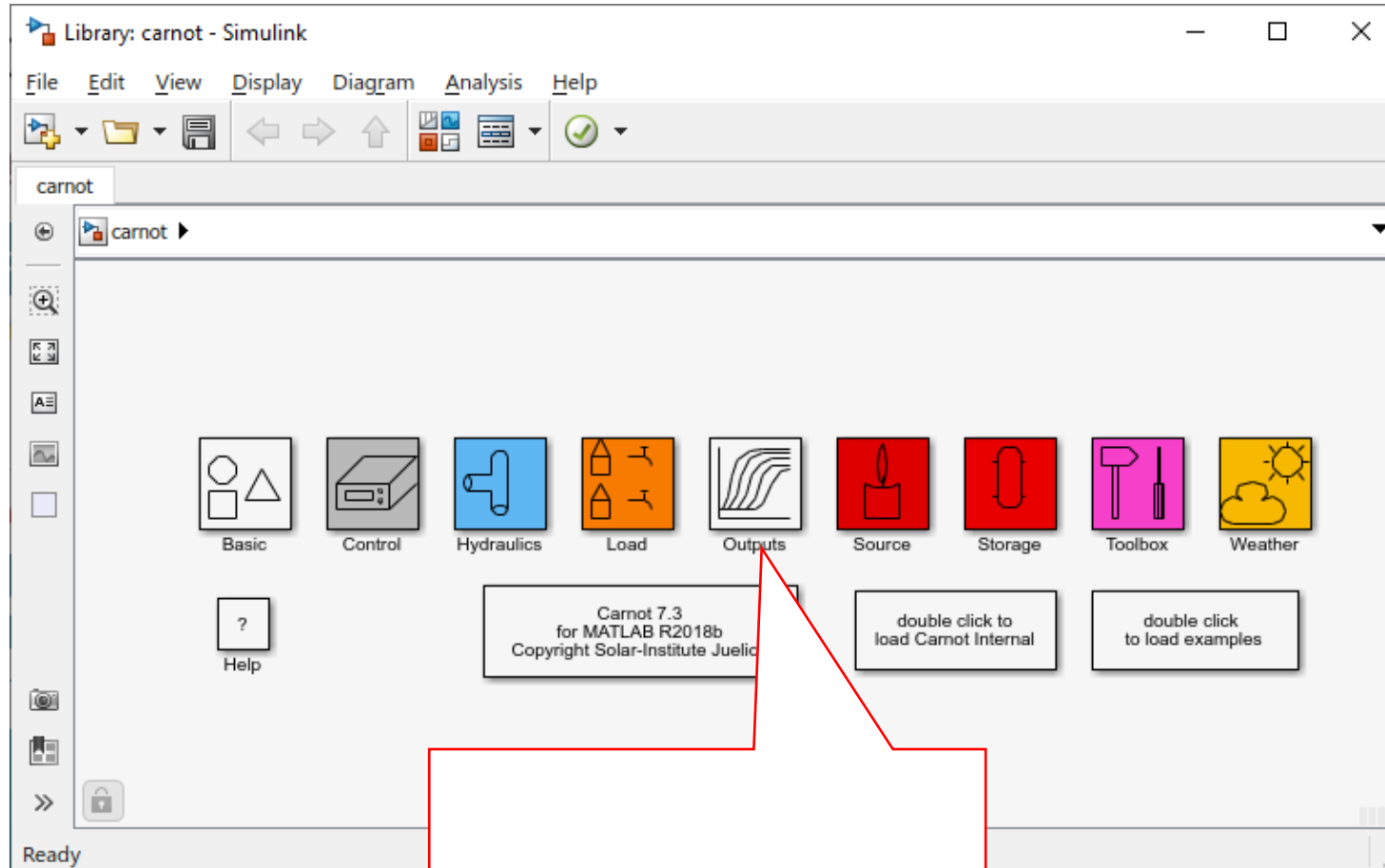


# CARNOT – Library Structure



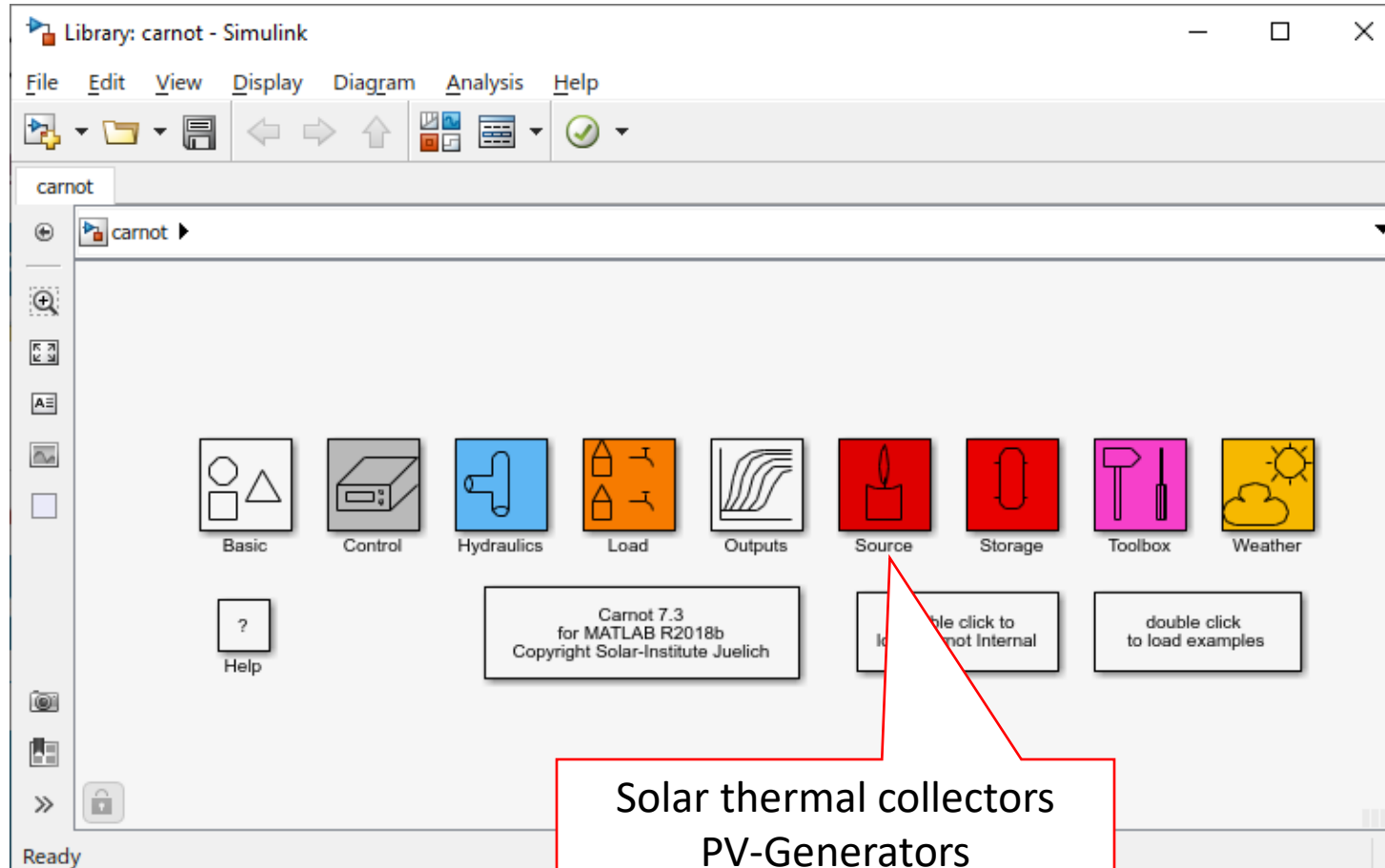
Pumps  
Valves  
Pipes

# CARNOT – Library Structure

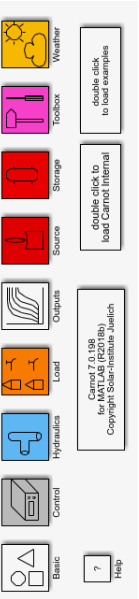


Displays Loggers

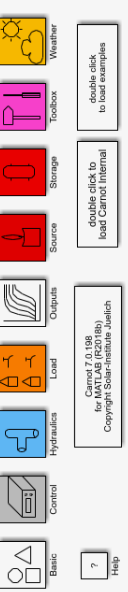
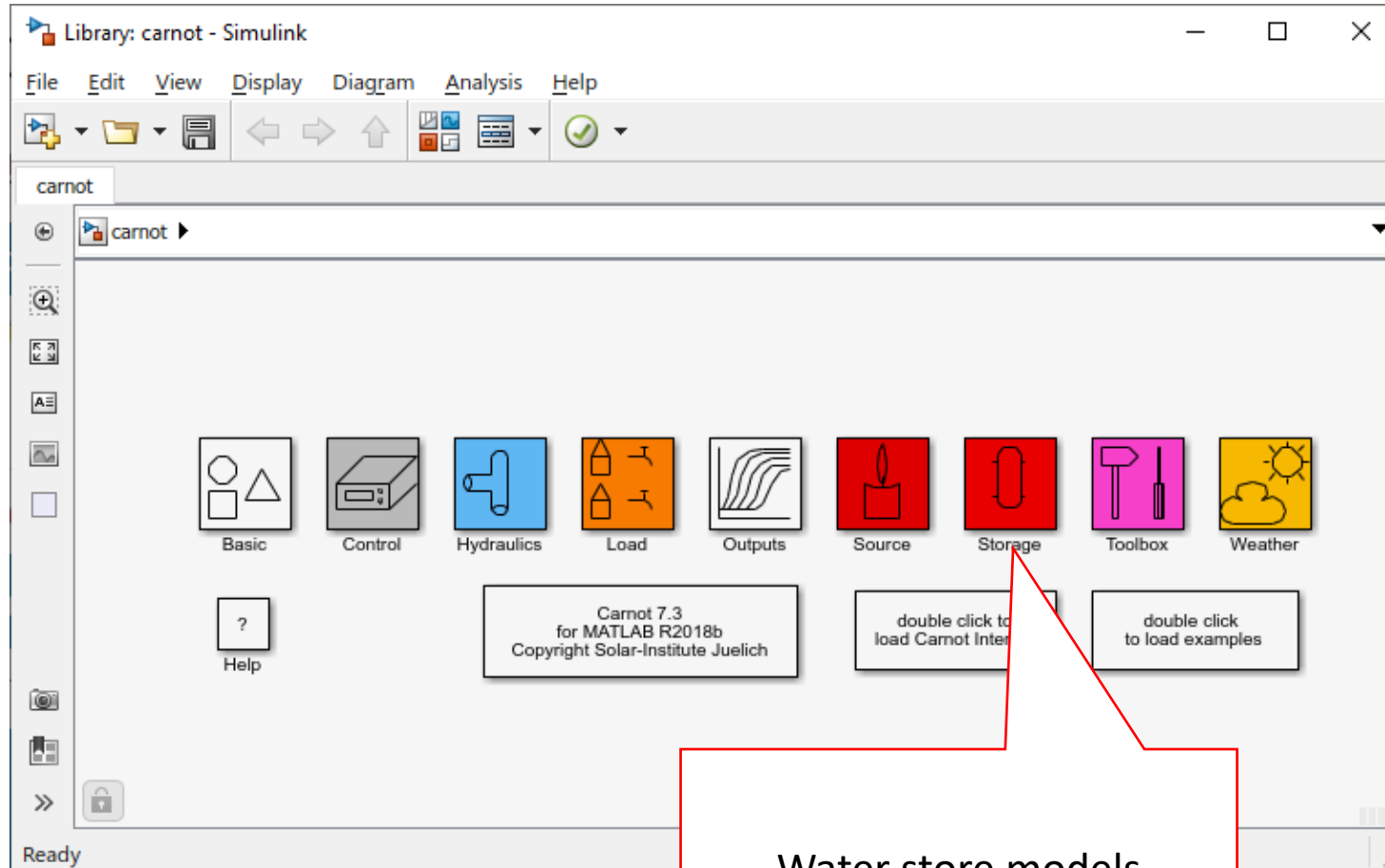
# CARNOT – Library Structure



Solar thermal collectors  
PV-Generators  
Cogeneration  
Heat Exchangers  
Heat Pumps  
Building ventilation

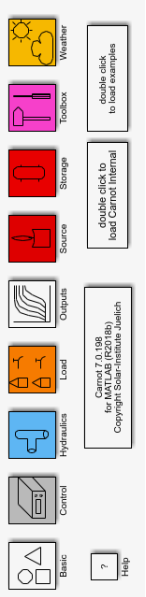
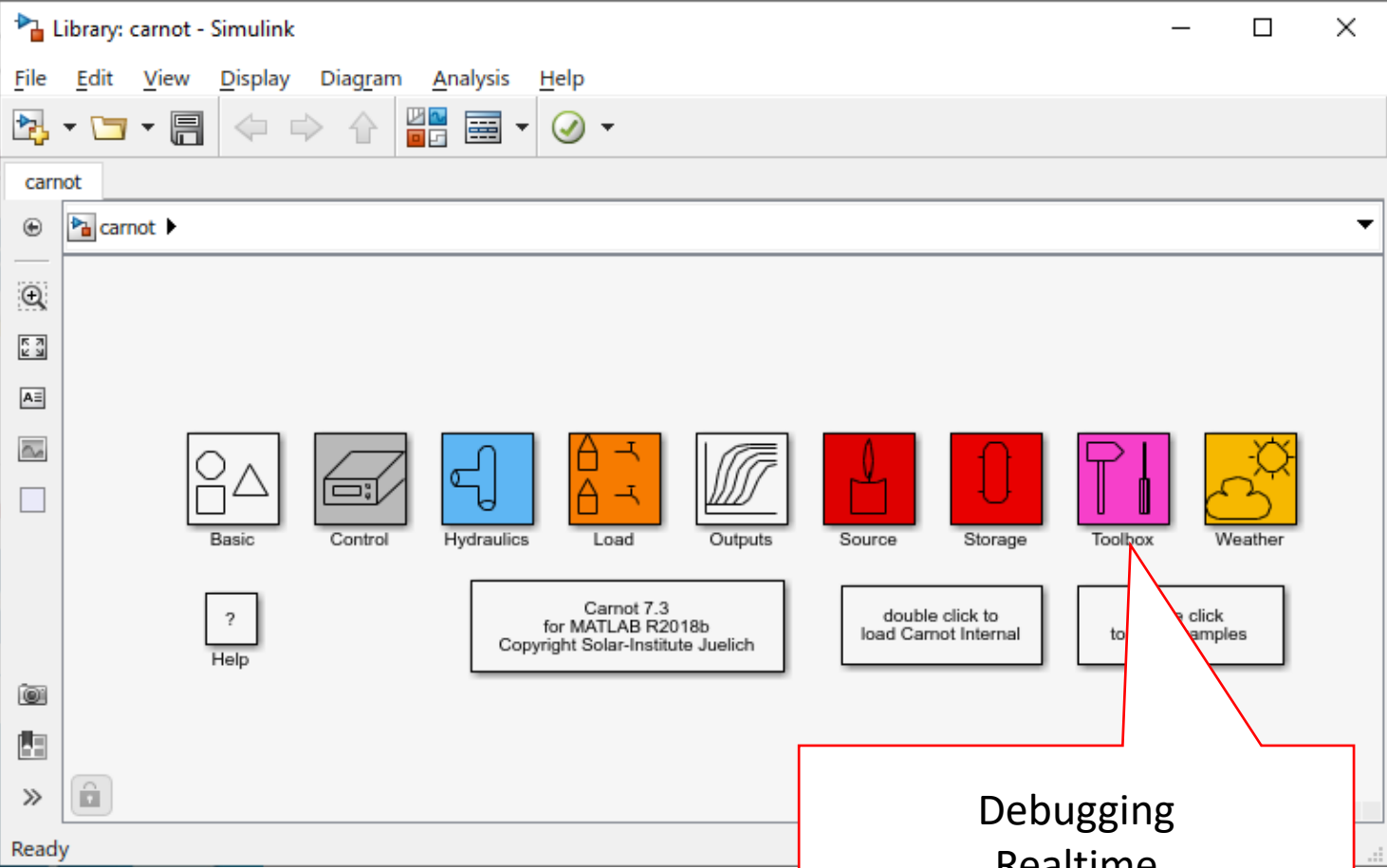


# CARNOT – Library Structure



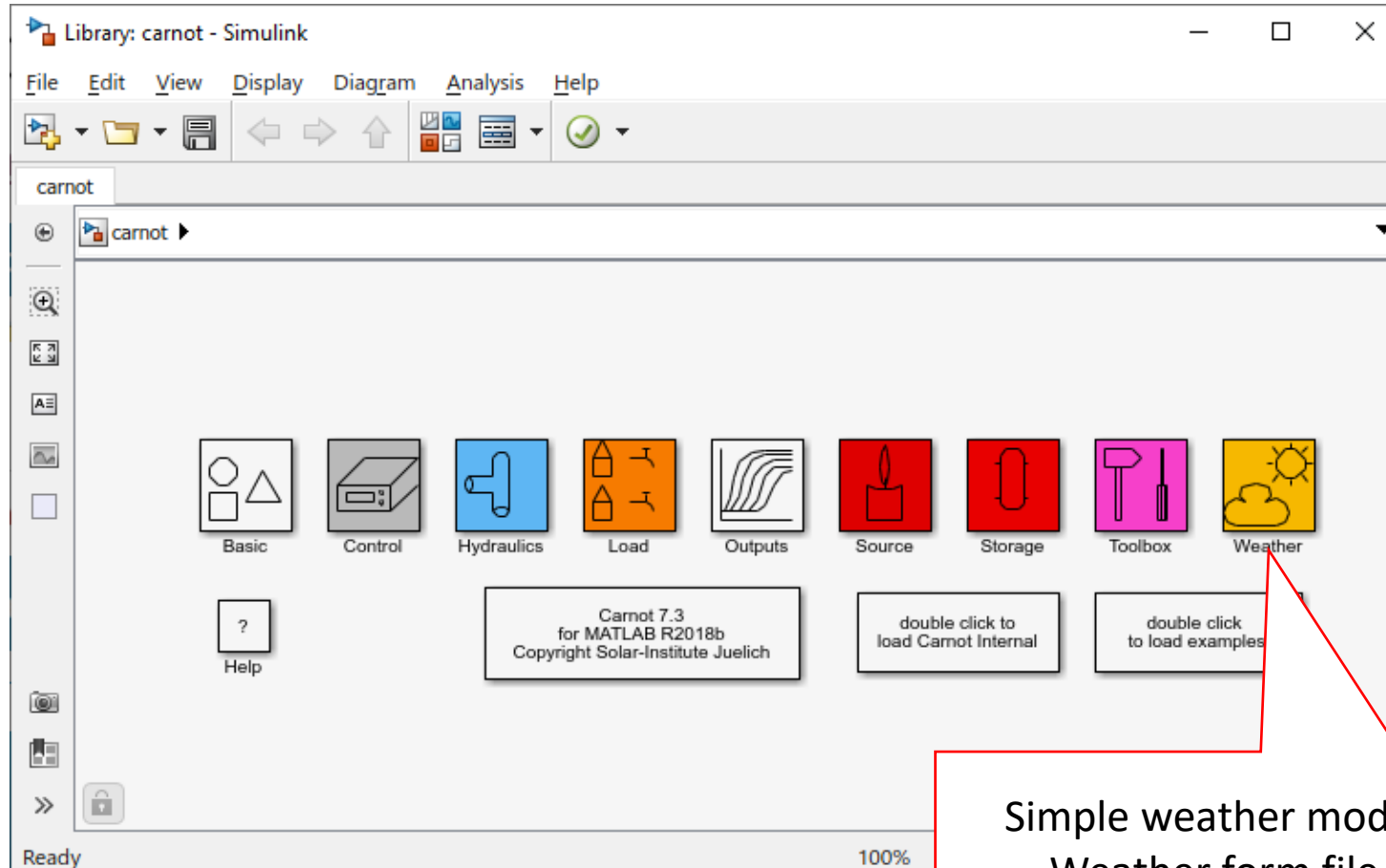
Water store models  
Ice store  
Battery

# CARNOT – Library Structure

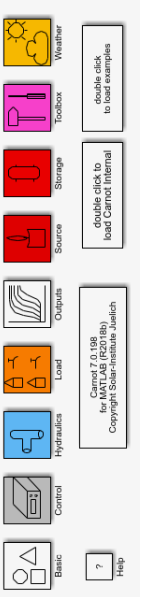




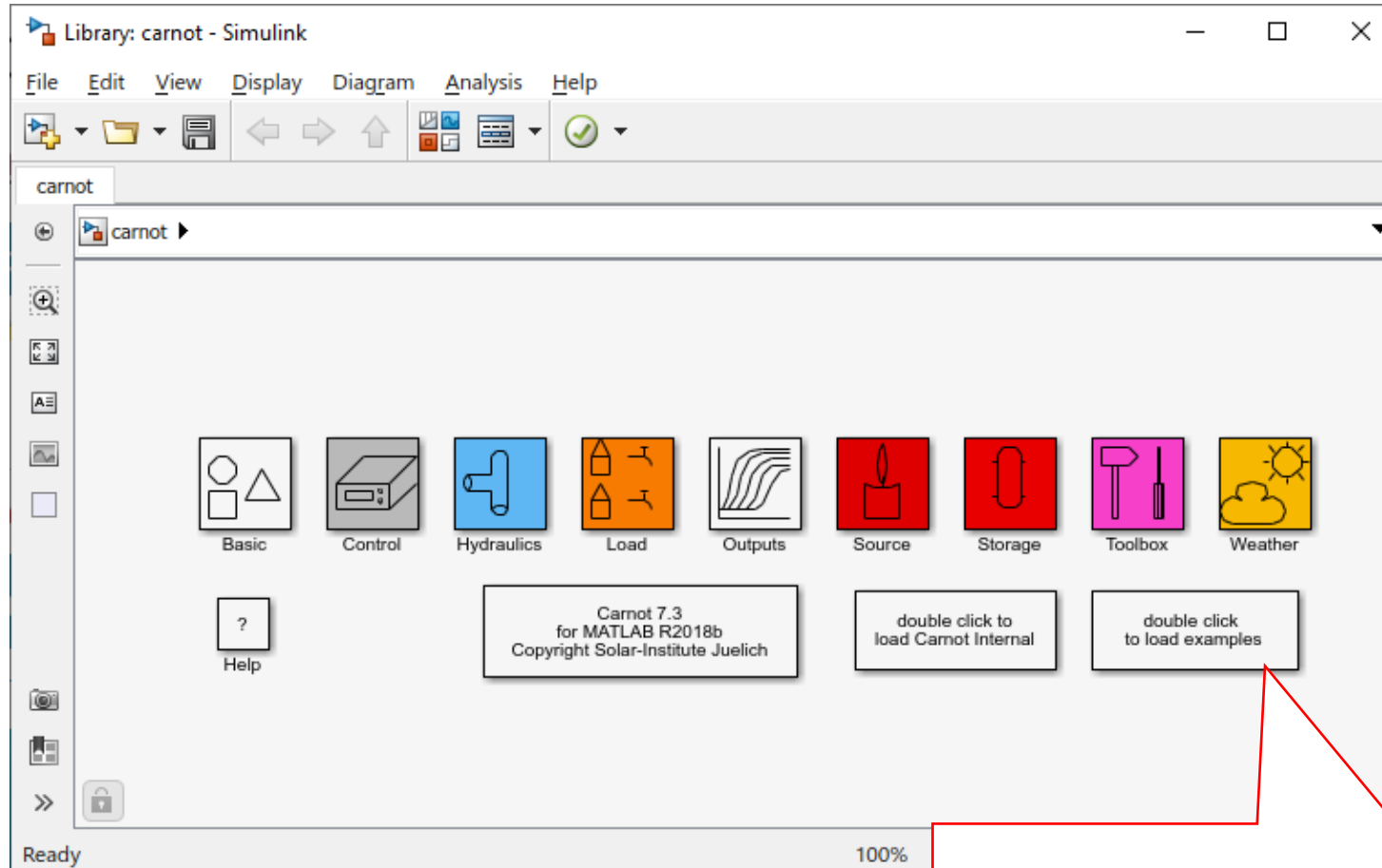
# CARNOT – Library Structure



Simple weather model  
Weather form file  
Solar position  
Solar radiation calculation  
(fixed or tracked surface)



# CARNOT – Examples



Examples of  
(almost) every block

