



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Dynamic simulations with **ALMABEST: ALMABuild e ALMAHVAC – CARNOT**

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Department of Industrial Engineering
Alma Mater Studiorum – University of Bologna

Contents



- ALMABEST: dynamic modeling of buildings → ALMABuild
- ALMABEST: dynamic modeling of HVAC systems → ALMAHVAC
- ALMABEST: an application case study

ALMABEST (Building Energy Simulation Toolbox)

Tool operating in the Simulink environment for the simulation of coupled **building-HVAC systems** under dynamic operating conditions

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ALMABUILD REQUEST FORM (IN PDF)

 [Request form](#) [.pdf 196Kb]

Bu

tion



ALMABuild is an open blockset of SIMULINK elements created by the Applied Thermal Engineering team of the University of Bologna.

ALMABuild is dedicated to students, researchers, architects, engineers and building management professionals.

ALMABuild is freely available for users upon filling in the request form available from this page. At least MATLAB R2021a and a Simulink licence are required to run the tool!

The signed request form has to be sent by e-mail to:

Dr. Claudia Naldi (e-mail: claudia.naldi2@unibo.it)

<https://site.unibo.it/almabuild/it>



ALMA MATER STUDIORUM
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ALMABEST (Building Energy Simulation Toolbox)



Automated building **implementation** in Simulink through Graphical User Interfaces (**GUIs**)

- **Fast** process
- **Limitation** of users' **errors**
- **No experience** required in Simulink or building modelling
- **No** necessity of **co-simulation**
- Building model **validated**
- **Variable time-step** suitable for HVAC system (seconds)
- **Compatibility** with **CARNOT**
- **Selection** of **the level of detail** in simulation and resolution of optimization problems

ALMABuild: NEW PROJECT

Project Name :

Buttons: Wheater Data, Add Structure, Add Floor, Add Window, Shutter and Curtains, Orientation, Shadings, Thermal Zone, Thermal Zone Properties

SAVE ALL DATA

CREATE THE MODEL

ALMABuild : STRUCTURES

Structure name: Typology:

Look old structures

	Thickness [cm]	Thermal conductivity [W/mK]	Density [kg/m^3]	Specific heat capacity [J/kgK]
Internal				
Layer 1	1.5	0.9	1800	900
Layer 2	25	0.3	1800	1000
Layer 3	5	0.04	40	1500
Layer 4	1.5	0.9	1800	900
Layer 5	0	0	0	0
Layer 6	0	0	0	0
Layer 7	0	0	0	0
Layer 8	0	0	0	0
Layer 9	0	0	0	0
Layer 10	0	0	0	0

☐ Outdoor convective heat transfer depending on wind velocity

	Solar absorbance	Infrared Emissivity
Internal	0.3	0.8
External	0.3	0.8

☐ Active layer

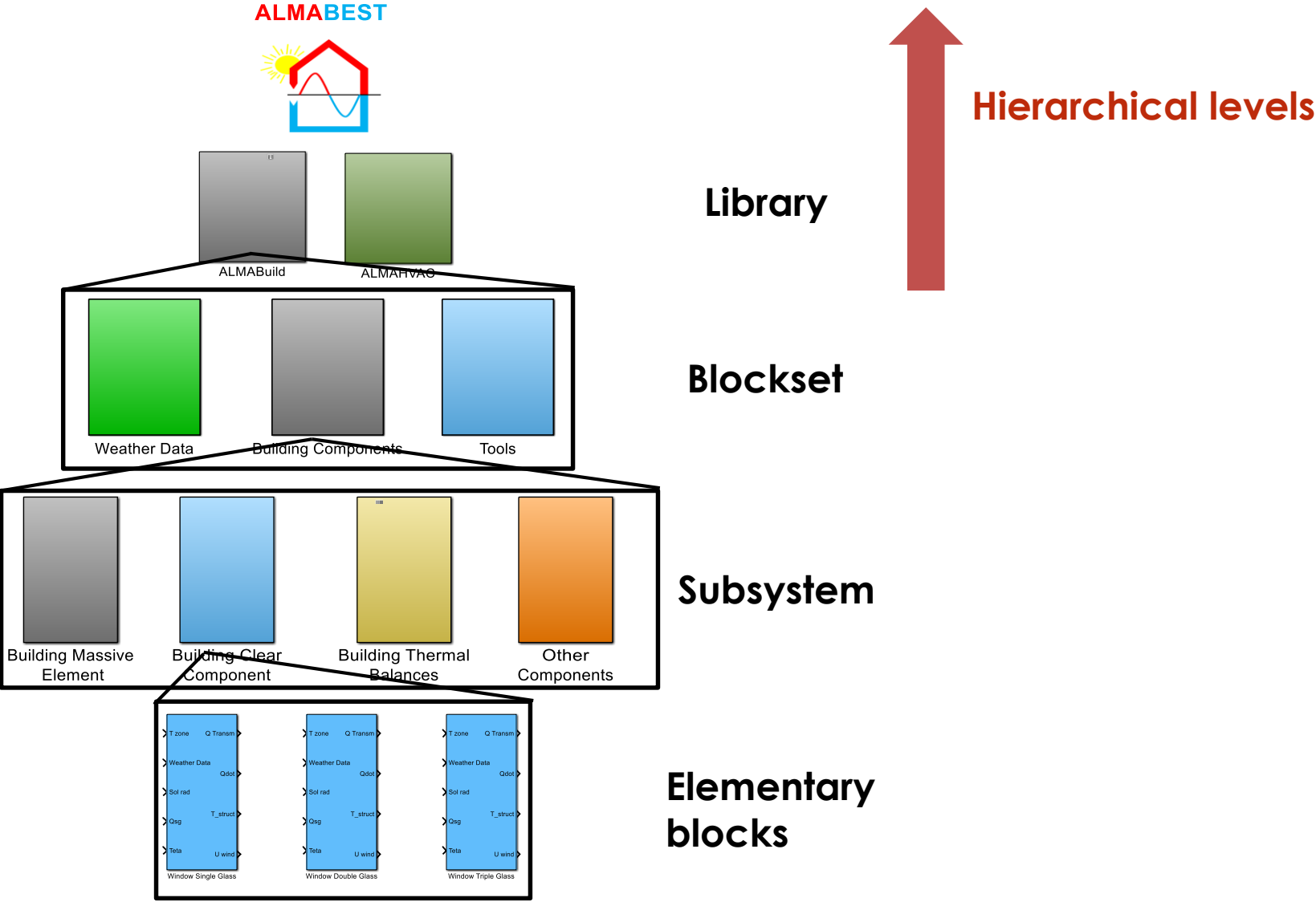
Active layer position:

Calculate structure's properties

U: 0.437 W/mqK M.S.: 506 kg/mq Thickness: 33 cm

Save Reset Close

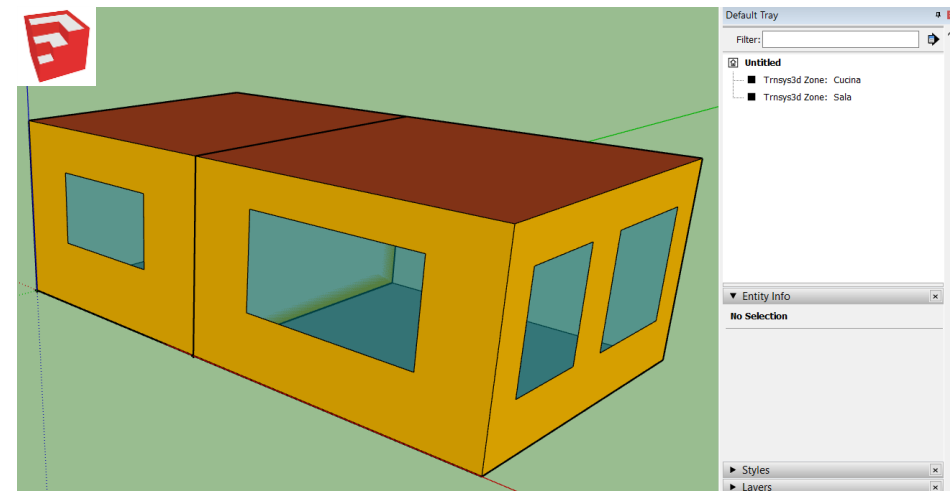
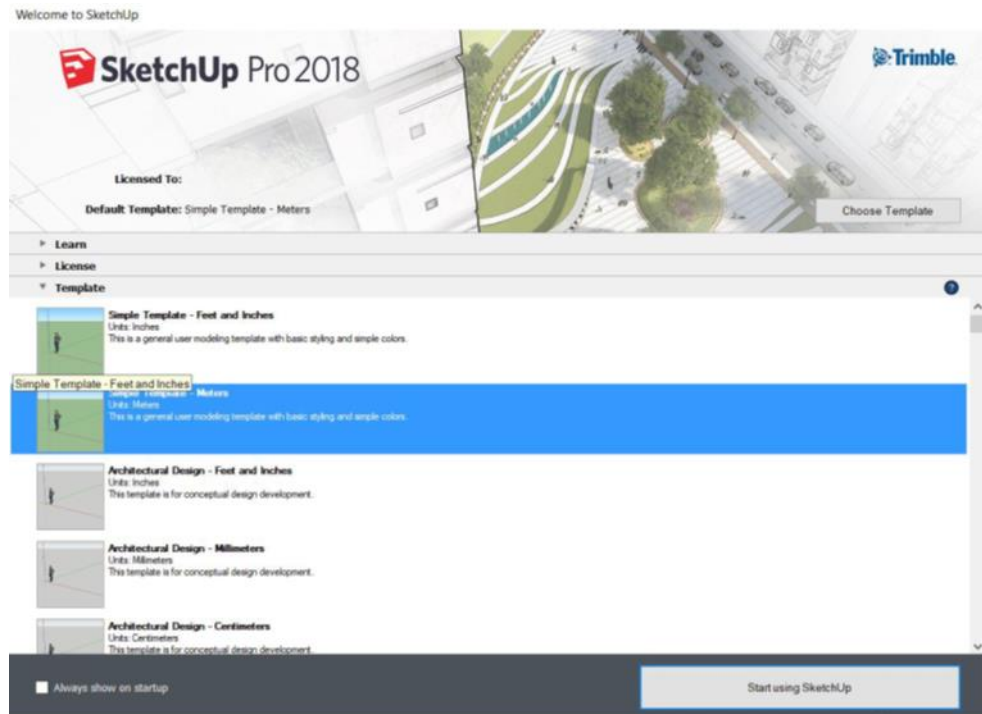
ALMABuild



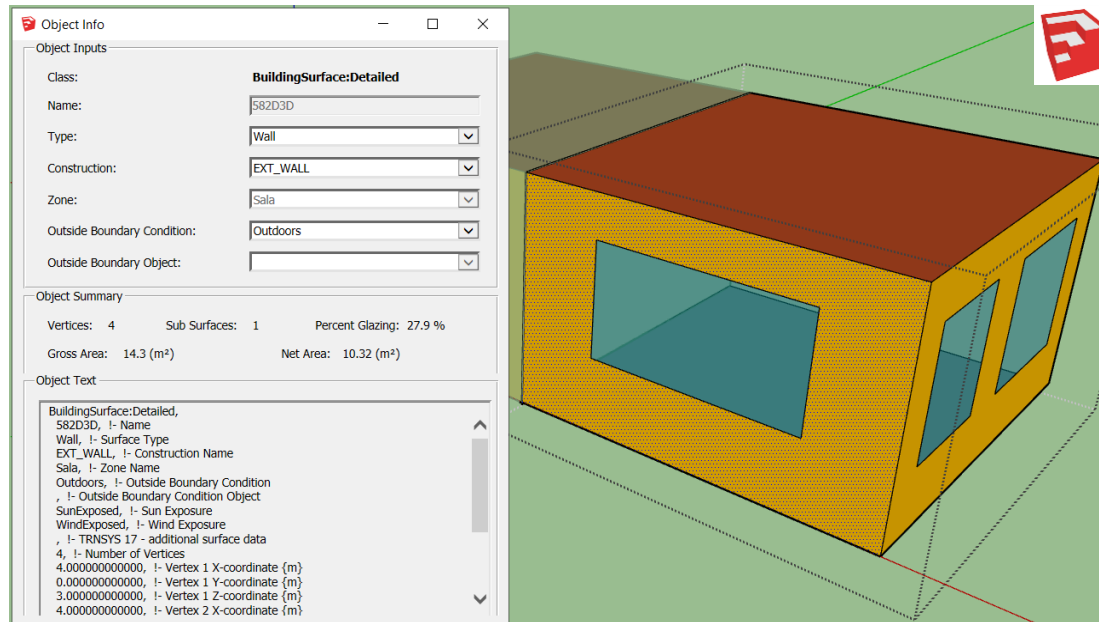
ALMABuild: 3D modeling of buildings

3D modeling of the building through **Google SketchUp** and plugin **TRNSYS 3D** (free)

Modeling of Multizone building and **automated geometry export** from Google SketchUp to ALMABuild



ALMABuild: 3D modeling of buildings



User draws 3D geometry of buildings, selecting the typology of each envelope element:
Floor/Wall/Ceiling/Roof

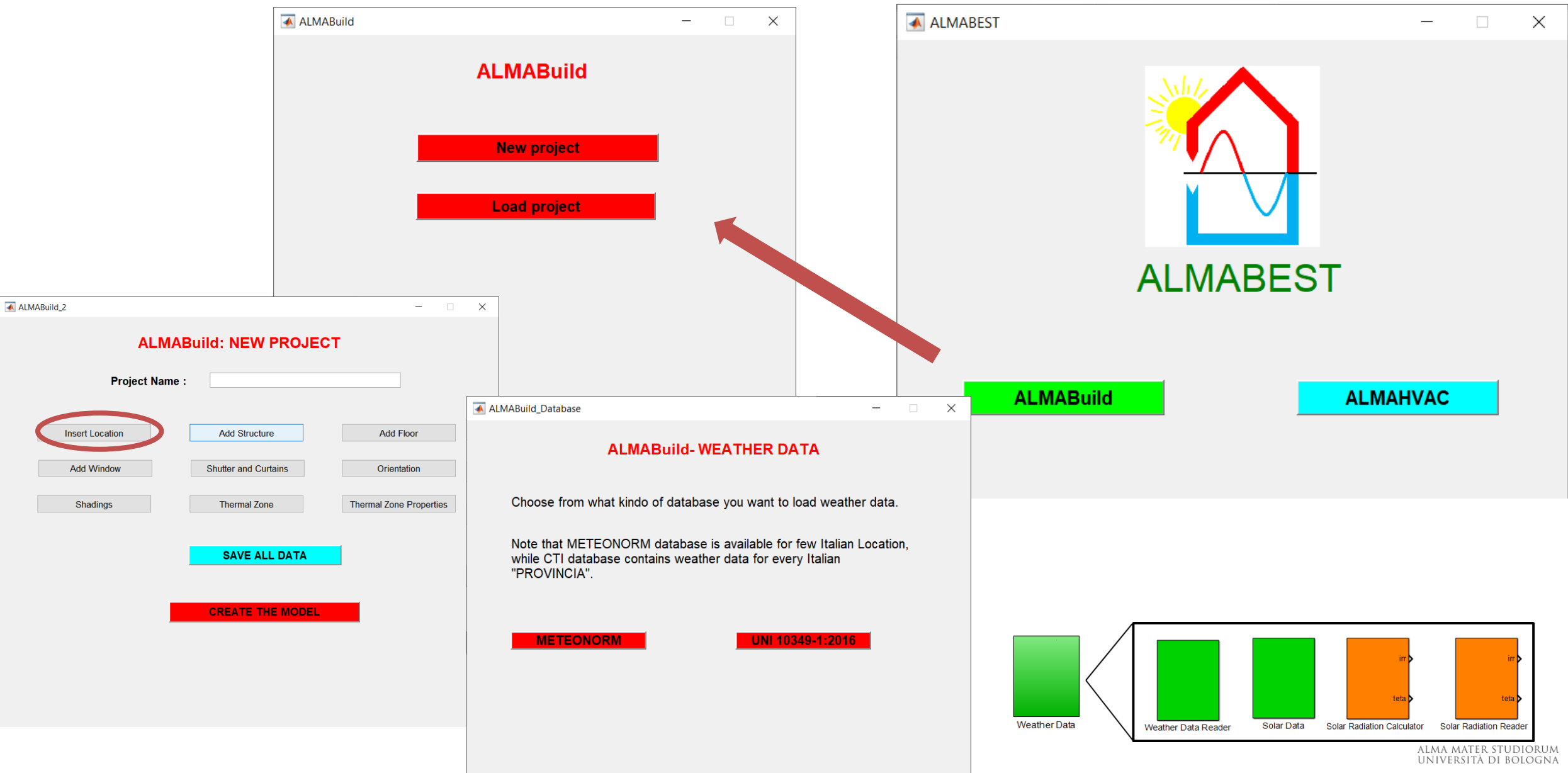
```
esempio.idf
403 Zone,
404     Cucina,  !- Name
405     0.0,  !- Direction of Relative North {deg}
406     0.0,  !- X Origin {m}
407     0.0,  !- Y Origin {m}
408     0.0,  !- Z Origin {m}
409     ,  !- ZONE_TYPE
410     1;  !- Multiplier
411
412 BuildingSurface:Detailed,
413     CEA875,  !- Name
414     Floor,  !- Surface Type
415     GROUND_FLOOR,  !- Construction Name
416     Cucina,  !- Zone Name
417     Ground,  !- Outside Boundary Condition
418     BOUNDARY=INPUT 1*TGROUND,  !- Outside Boundary Condition Object
419     NoSun,  !- Sun Exposure
420     NoWind,  !- Wind Exposure
421     ,  !- TRNSYS 17 - additional surface data
422     4,  !- Number of Vertices
423     5.000000000000,  !- Vertex 1 X-coordinate {m}
424     4.000000000000,  !- Vertex 1 Y-coordinate {m}
425     0.000000000000,  !- Vertex 1 Z-coordinate {m}
426     5.000000000000,  !- Vertex 2 X-coordinate {m}
427     0.000000000000,  !- Vertex 2 Y-coordinate {m}
428     0.000000000000,  !- Vertex 2 Z-coordinate {m}
429     0.000000000000,  !- Vertex 3 X-coordinate {m}
430     0.000000000000,  !- Vertex 3 Y-coordinate {m}
431     0.000000000000,  !- Vertex 3 Z-coordinate {m}
432     0.000000000000,  !- Vertex 4 X-coordinate {m}
433     4.000000000000,  !- Vertex 4 Y-coordinate {m}
434     0.000000000000;  !- Vertex 4 Z-coordinate {m}
```

A **.idf** file (**Input Data File**) with **name**, **typology** and **geometrical data** of each envelope component is built through TRNSYS3D



Input data for ALMABuild

ALMABuild: Graphical User Interfaces (GUIs)



ALMABuild: Graphical User Interfaces (GUIs)

ALMABuild_2

ALMABuild: NEW PROJECT

Project Name :

ALMABuild_Structure

ALMABuild : STRUCTURES

Structure name Typology

	Thickness [cm]	Thermal conductivity [W/mK]	Density [kg/m^3]	Specific heat capacity [J/kgK]
Internal	-	-	-	-
Layer 1	1.5	0.9	1800	900
Layer 2	25	0.3	1800	1000
Layer 3	5	0.04	40	1500
Layer 4	1.5	0.9	1800	900
Layer 5	0	0	0	0
Layer 6	0	0	0	0
Layer 7	0	0	0	0
Layer 8	0	0	0	0
Layer 9	0	0	0	0
Layer 10	0	0	0	0

☐ Outdoor convective heat transfer depending on wind velocity

	Solar absorptance	Infrared Emissivity
Internal	0.3	0.8
External	0.3	0.8

☐ Active layer

Active layer position:

U W/mqK M.S. kg/mq Thickness cm



RC model for envelope components

RC models

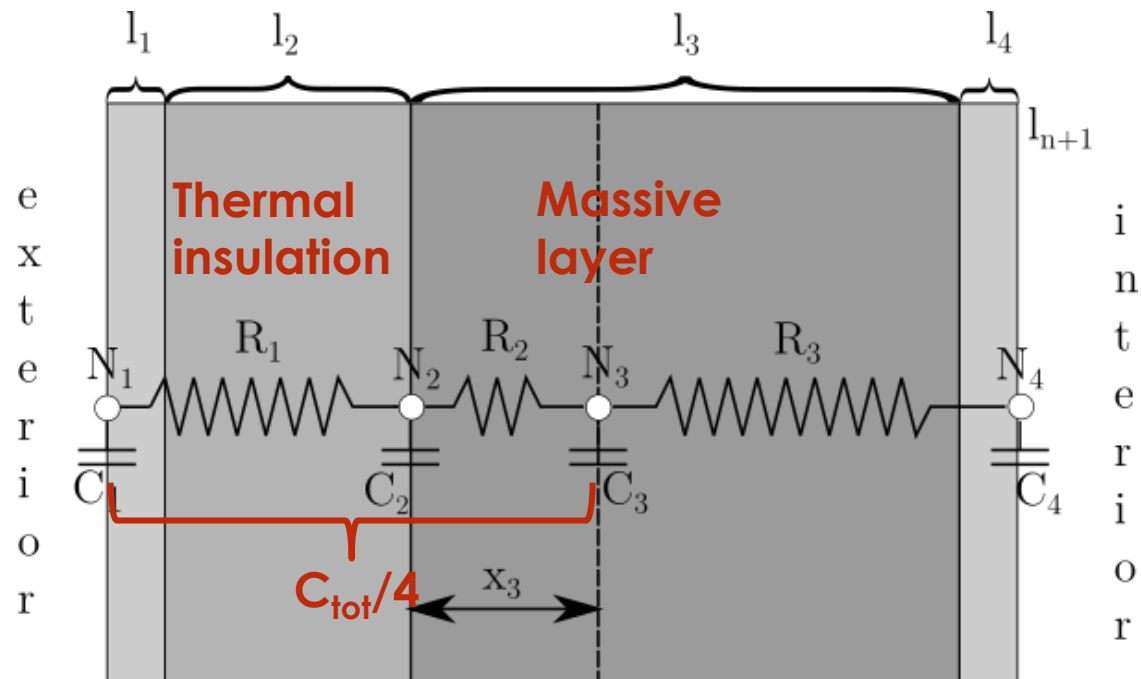
(thermal resistance + thermal capacity)

Lumped Parameters Whole Room (LPWR)

Lumped Parameters Construction Element (LPCE)

1 RC model for each envelope component

Opaque elements:
model 3R4C



RC model for envelope components

ALMABuild_2

ALMABuild: NEW PROJECT

Project Name :

Add Structure

Add Floor

Add Window

Shutter and Curtains

Orientation

Shadings

Thermal Zone

Thermal Zone Properties

SAVE ALL DATA

CREATE THE MODEL

ALMABuild_Finestre

ALMABuild : WINDOW

Name

Look structure

☐ Outdoor convective heat transfer depending on wind velocity

U value W/(m^2 K) Number of panes

OPTICAL PROPERTIES

	0	10	20	30	40	50	60	70	80	90	Hemis
Tsol	0.462	0.465	0.458	0.448	0.436	0.412	0.36	0.263	0.121	0	0.384
Abs1	0.114	0.114	0.116	0.120	0.125	0.132	0.130	0.146	0.147	0	0.128
Abs2	0.186	0.188	0.195	0.199	0.198	0.197	0.199	0.186	0.118	0	0.198
Rfsol	0.237	0.232	0.231	0.233	0.241	0.260	0.303	0.406	0.614	1	0.289
Rbsol	0.179	0.172	0.170	0.173	0.183	0.202	0.239	0.328	0.542	0.999	0.227

GAS PROPERTIES

	Thick [mm]	Cond [W/m K]	dCond *10^-5	Visc [kg/m s] *10^-5	dVisc *10^-8	Dens [kg/mc]	dDens	Pr	dPr [1/K]
Gap1	16	0.0162	5	2.11	6.3	1.78	-0.006	0.68	0.00066

GLASS PROPERTIES

	Glass1	Glass2
Emissivity Front	0.84	0.1
Emissivity Back	0.84	0.84
Thickness [mm]	4	4
Conduc. [W/m^2 K]	225	225

FRAME PROPERTIES

	Frame
F factor[%]	20
Uframe	2.27
Abs	0.6
Emis	0.9

SAVE

RESET

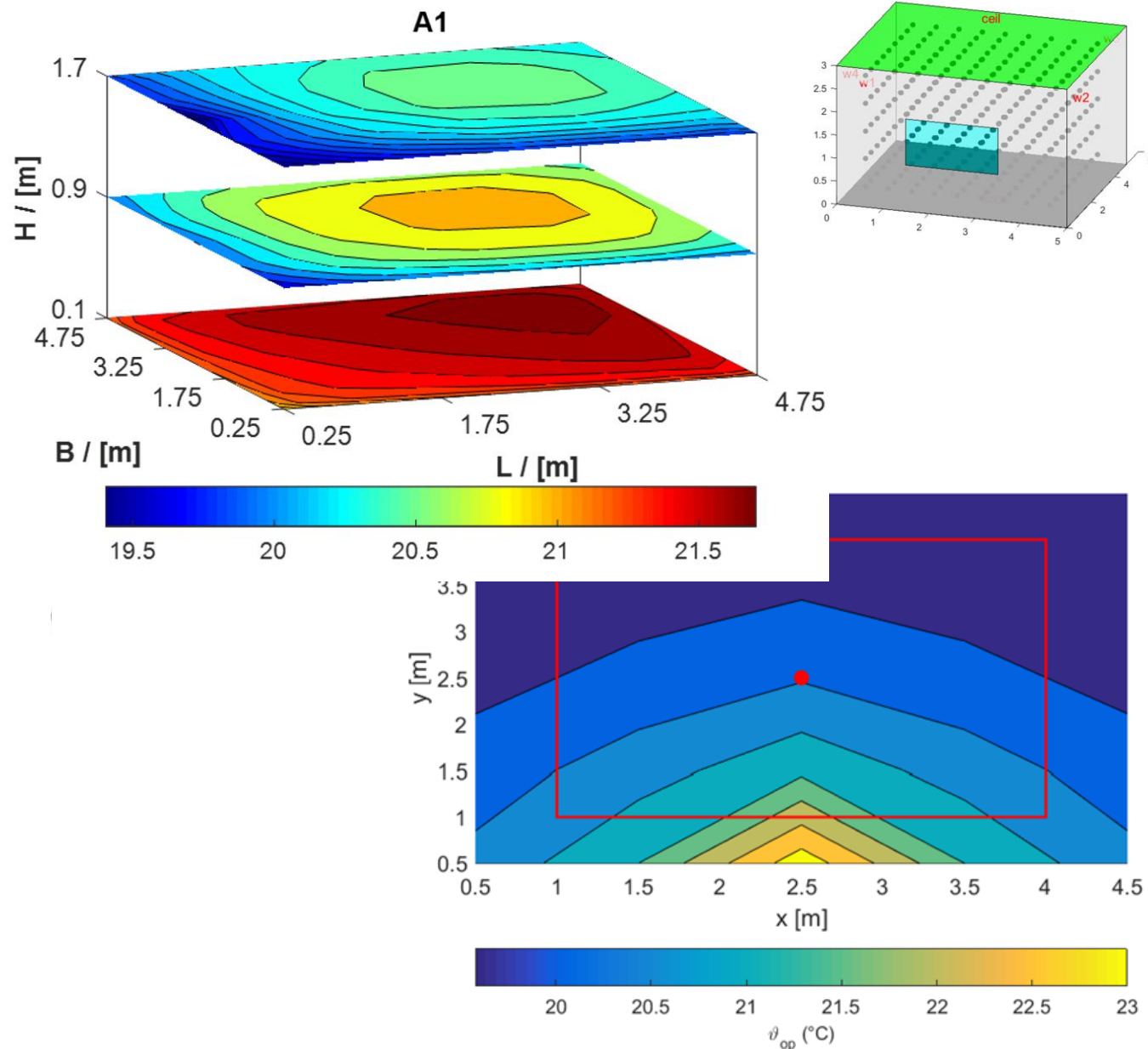
CLOSE

Frame: 1R2C

Glass (single/double) + gas: 1R2C



ALMABuild: Graphical User Interfaces (GUIs)



ALMABuild_Prop_Zone_Termiche

ALMABuild- THERMAL ZONE PROPERTIES

Floor Thermal zone name

Internal Volume m³

Initial Air Temperature °C

NOT DEFINED

NOT DEFINED

NOT DEFINED

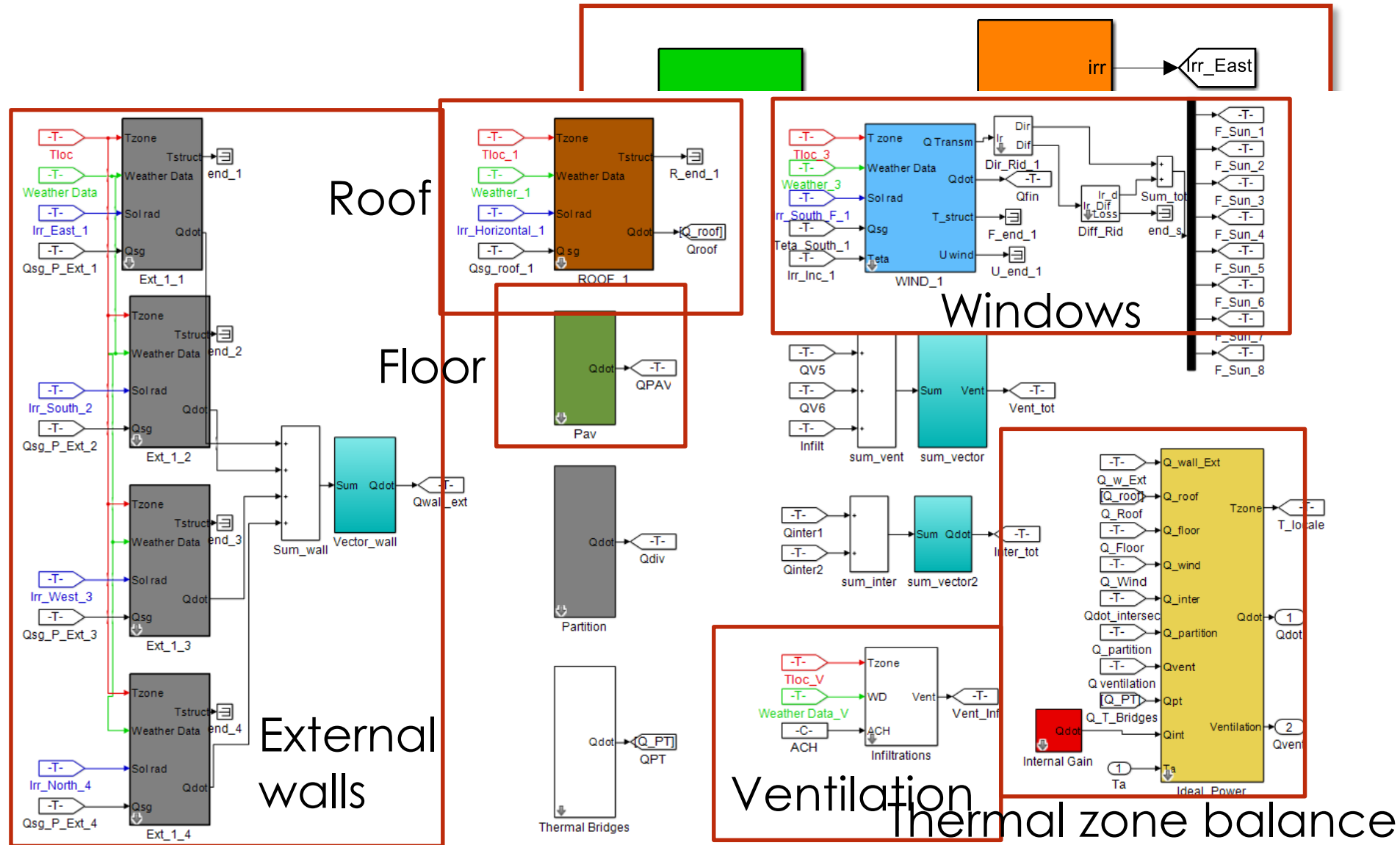
Choose model

Geometry **NOT DEFINED**

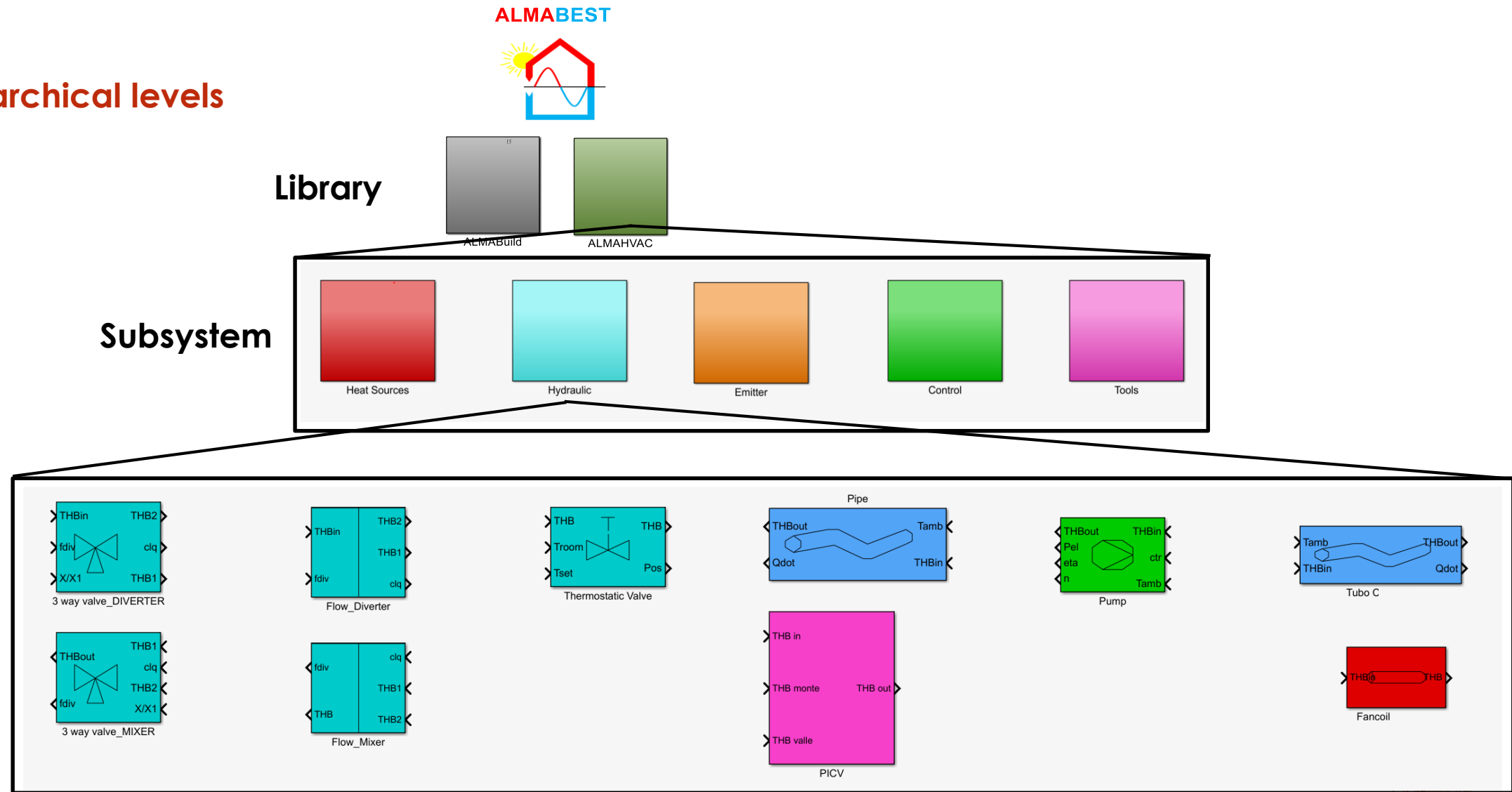
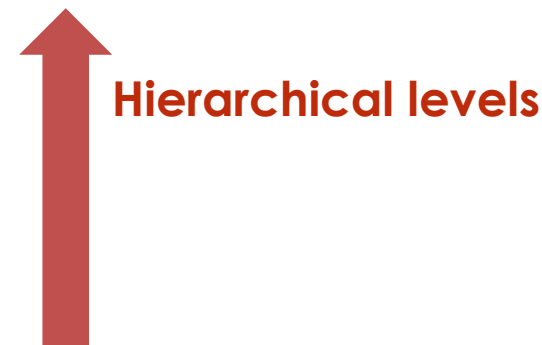
Evaluation of:

1 T_{air} + 3D T_{rad} **3D T_{air} + 1 T_{rad}** **3D T_{air} + 3D T_{rad}**

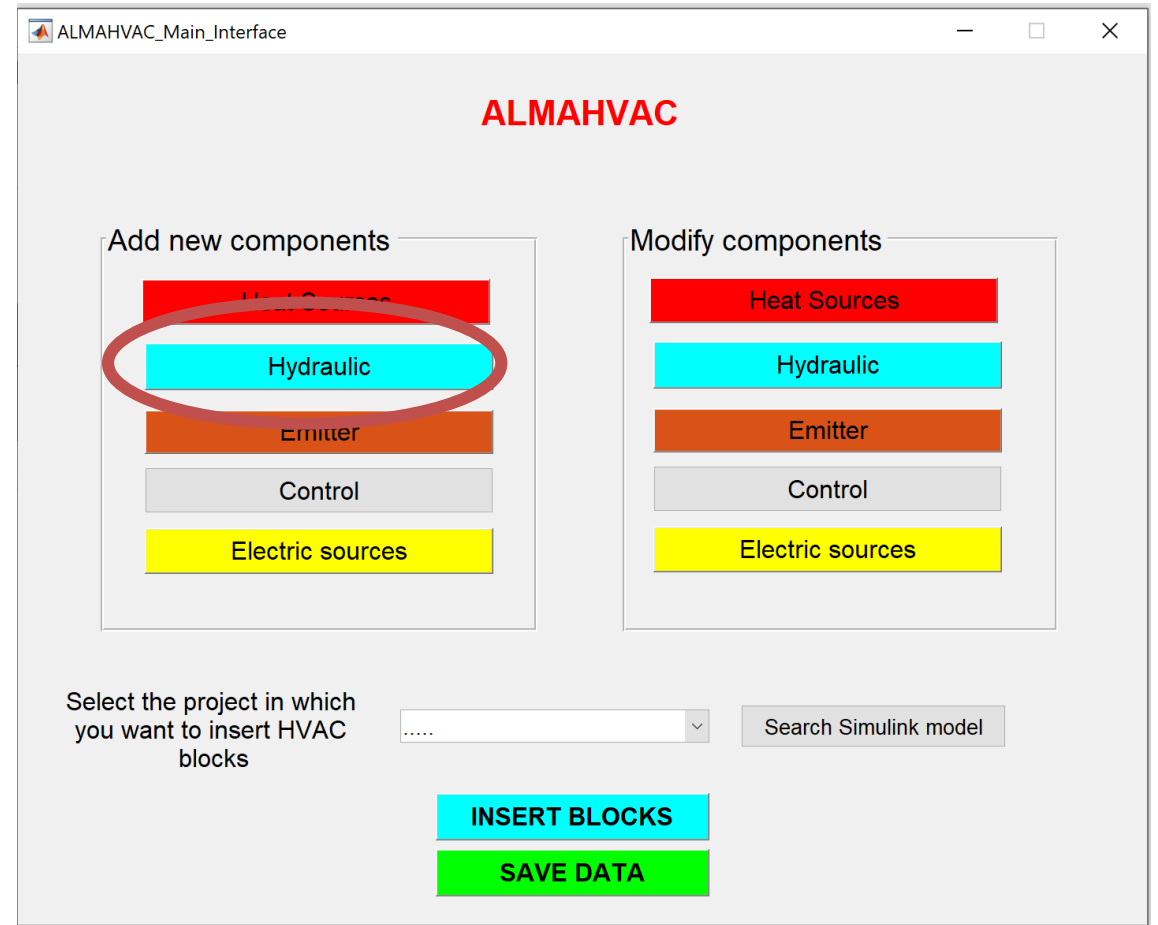
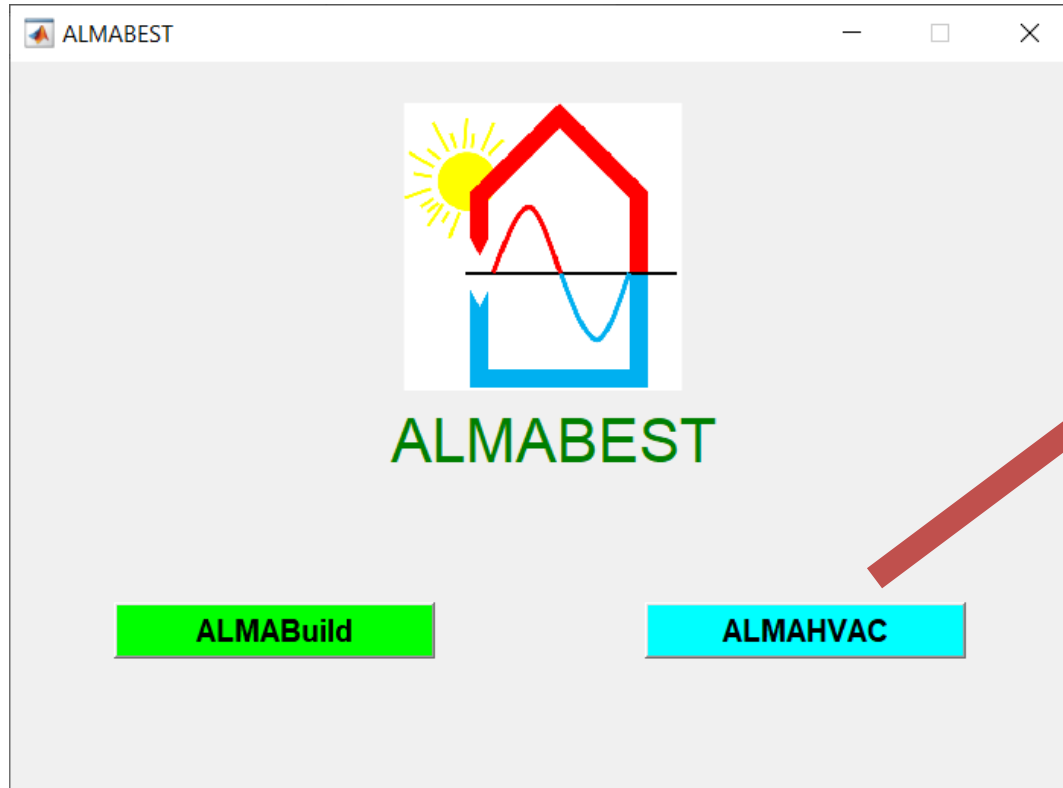
Simulink model: automatic implementation



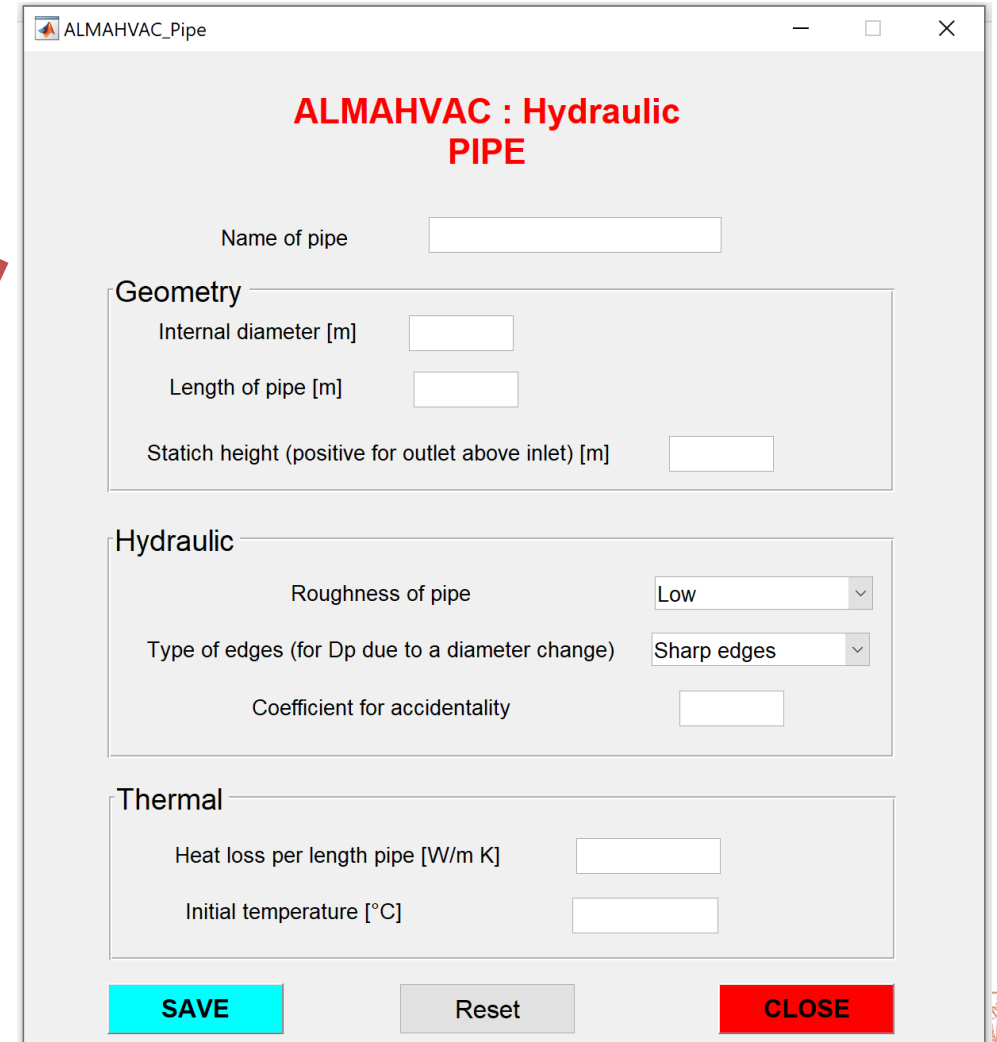
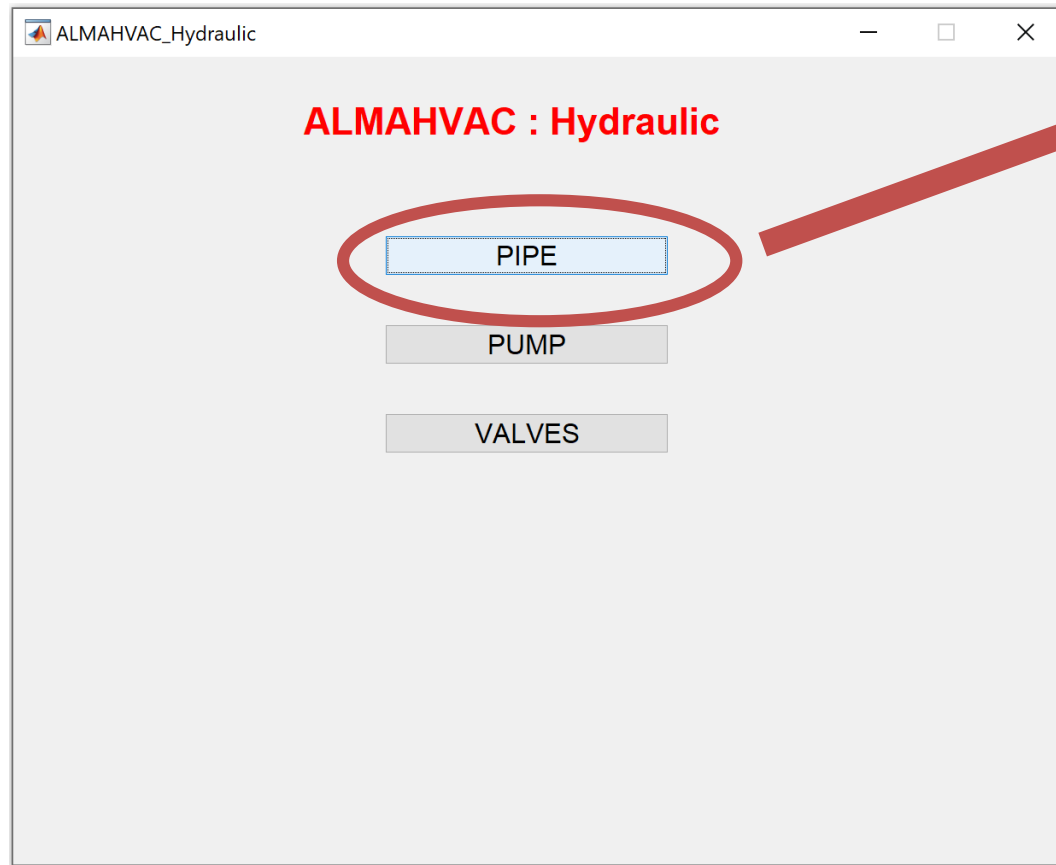
ALMAHVAC



ALMAHVAC: Graphical User Interfaces (GUIs)



ALMAHVAC: Graphical User Interfaces (GUIs)



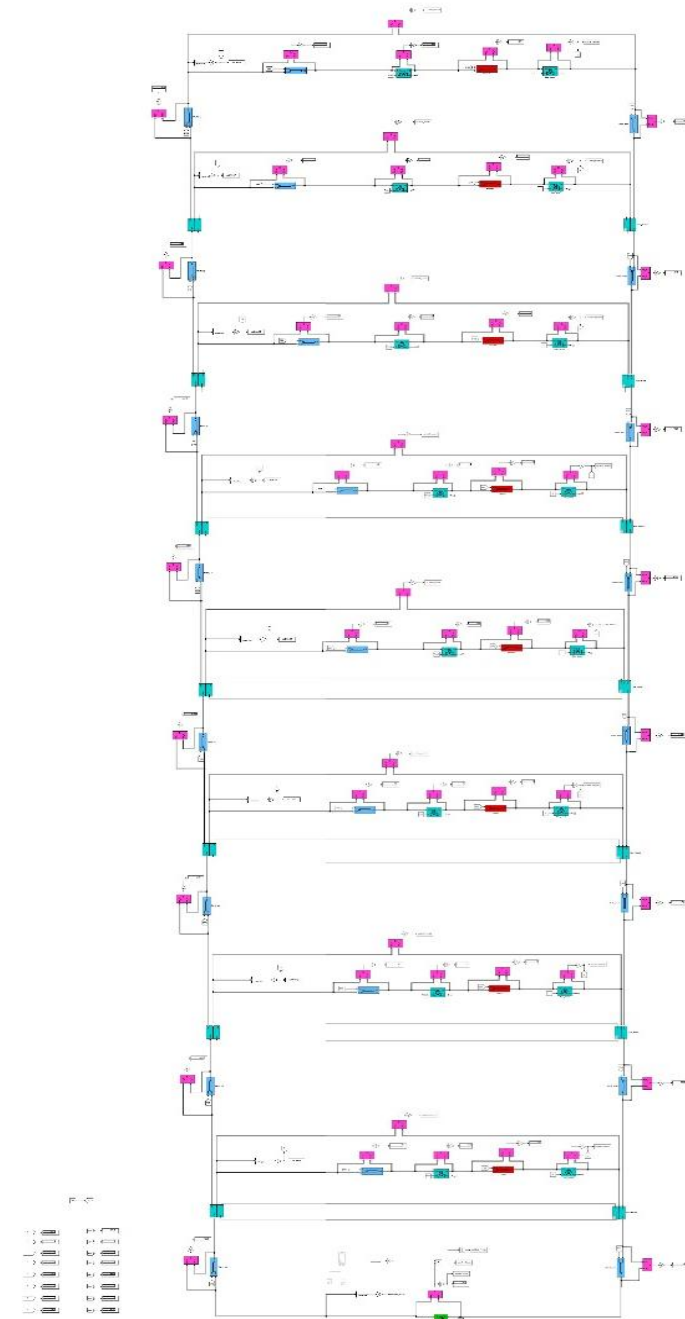
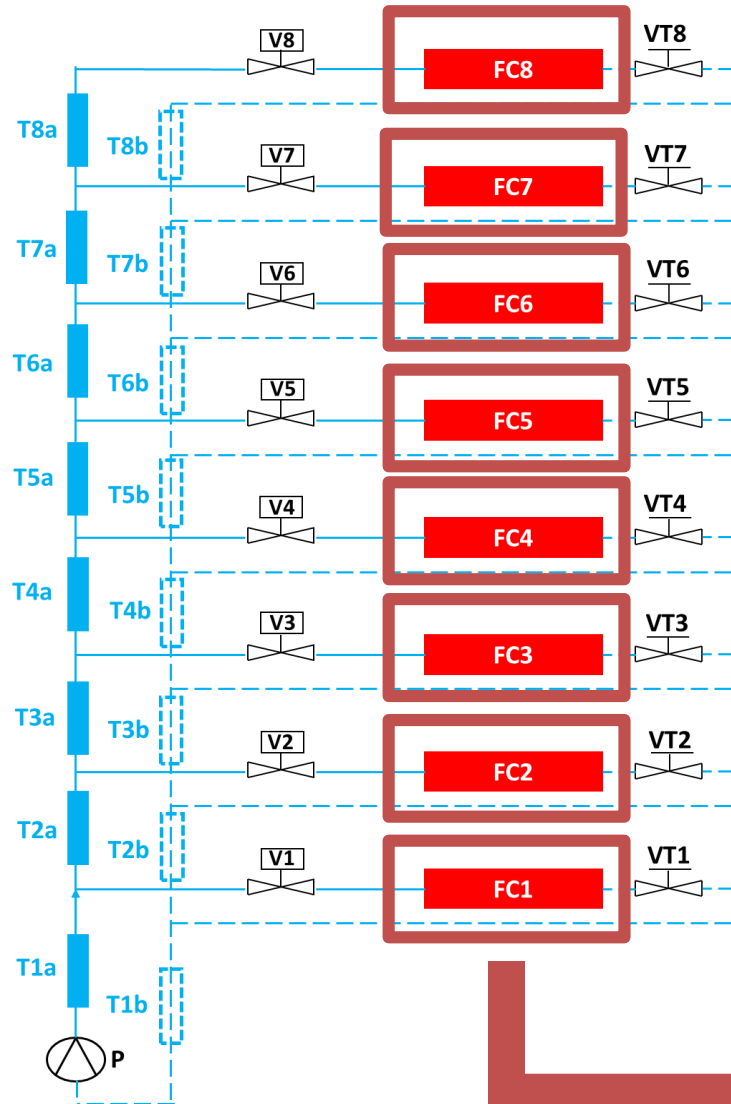
The image shows the "ALMAHVAC_Pipe" GUI form. The window title is "ALMAHVAC_Pipe". The main content area has a light gray background with the text "ALMAHVAC : Hydraulic PIPE" in red. The form is divided into several sections:

- Name of pipe:** A text input field.
- Geometry:** A section containing three input fields:
 - Internal diameter [m]
 - Length of pipe [m]
 - Static height (positive for outlet above inlet) [m]
- Hydraulic:** A section containing three input fields:
 - Roughness of pipe (dropdown menu, currently set to "Low")
 - Type of edges (for D_p due to a diameter change) (dropdown menu, currently set to "Sharp edges")
 - Coefficient for accidentality (text input field)
- Thermal:** A section containing two input fields:
 - Heat loss per length pipe [W/m K]
 - Initial temperature [°C]

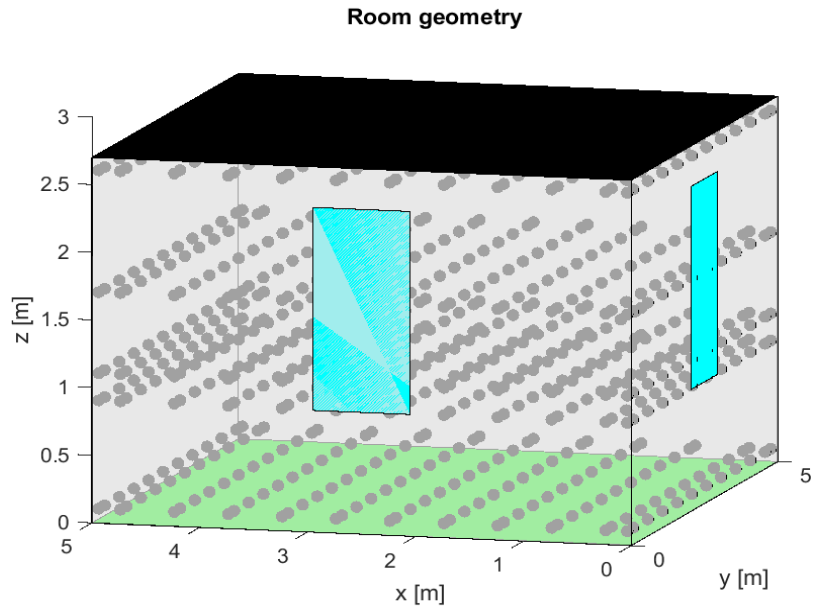
At the bottom of the form, there are three buttons: "SAVE" (cyan), "Reset" (gray), and "CLOSE" (red).



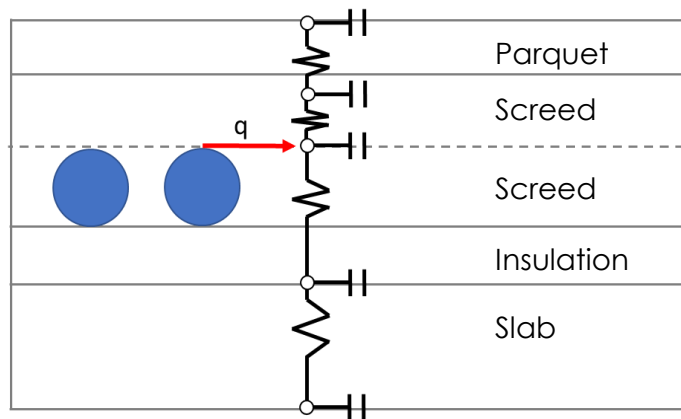
Simulink model: automatic implementation



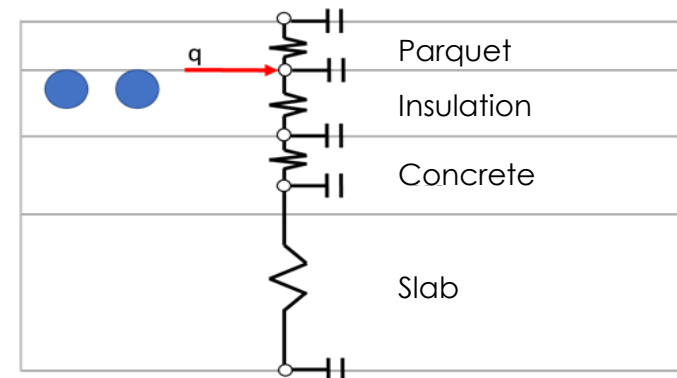
ALMABuild: an application case study on radiant floor heating



- Location: **Bologna**
- Thermal design load: **756 W**
- Set-point temperature: **20°C** (DB=0.5 K)
- 5 typologies of emitter:
 - **radiator**
 - **radiant ceiling**



Traditional radiant floor heating (**high inertia**)



Low-inertia radiant floor heating

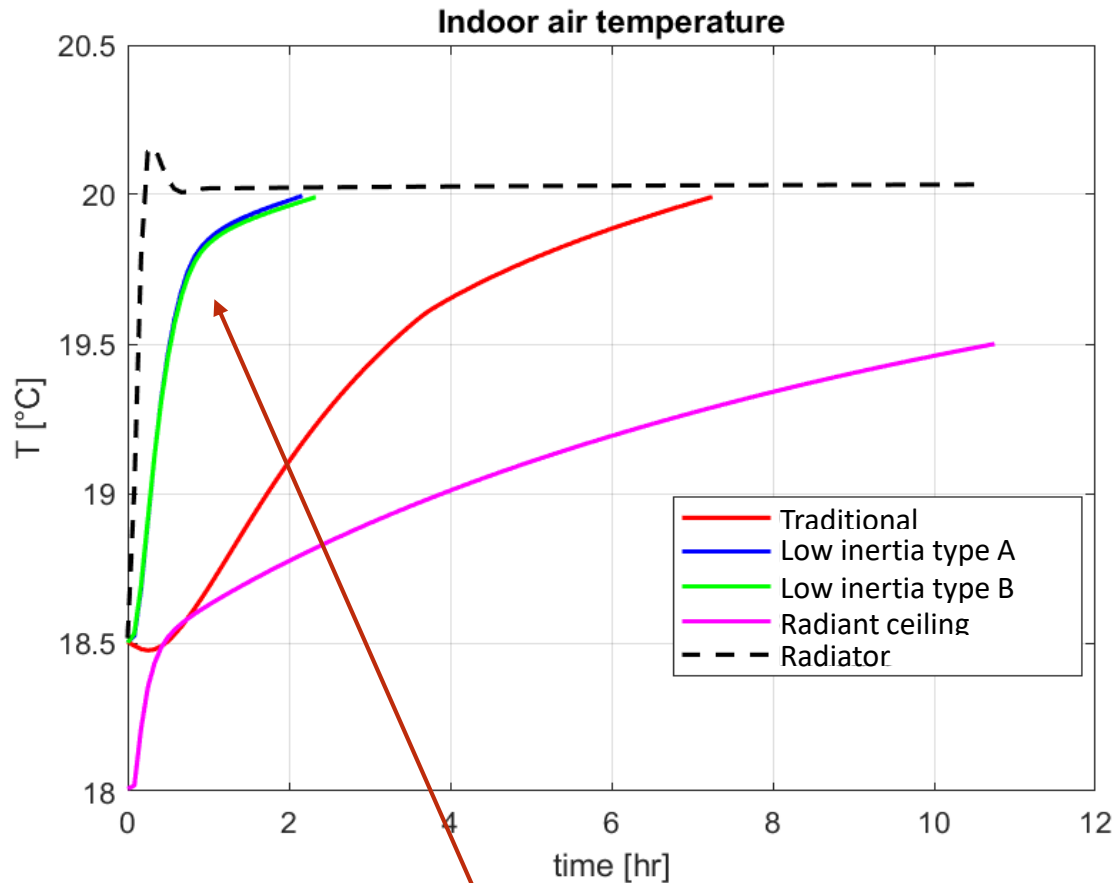
Type A: insulation = 0.1 cm

Type B: insulation = 3.2 cm

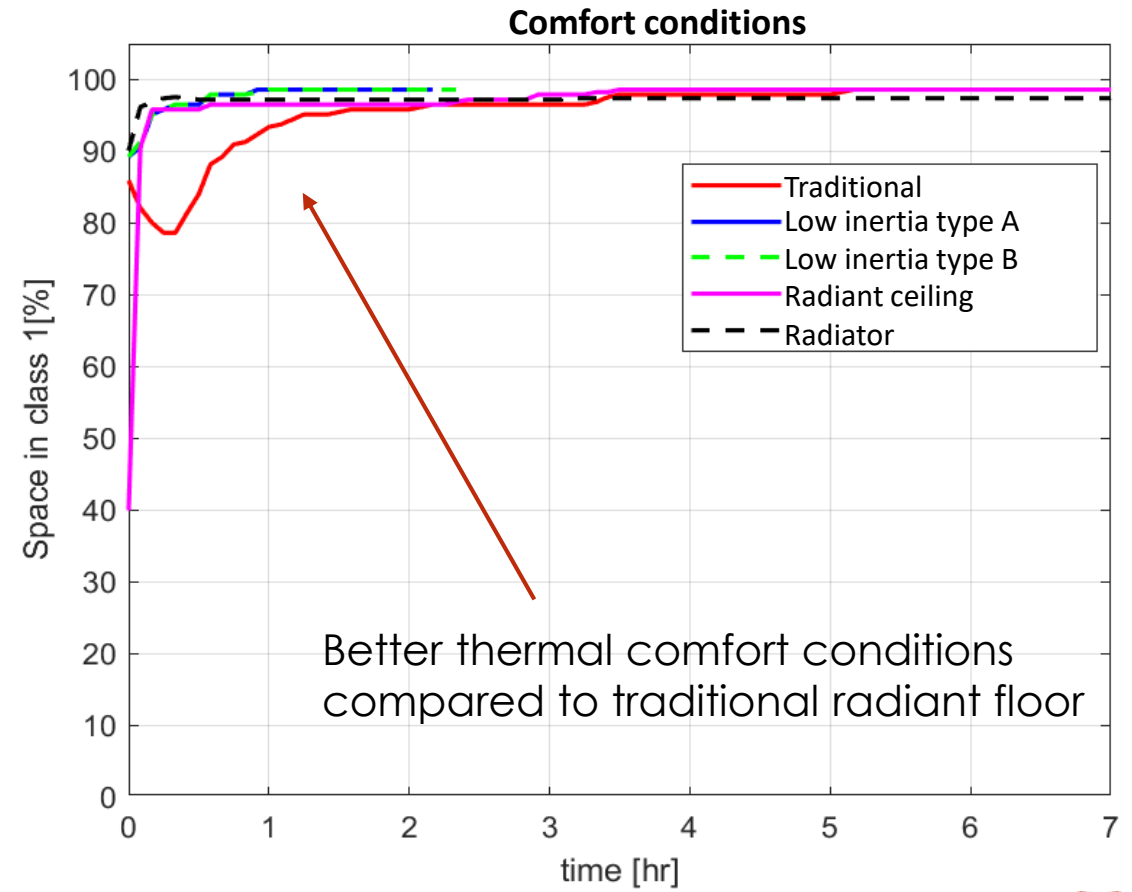


ALMABuild: an application case study on radiant floor heating

Start-up transient (ambient design temperature, no solar gains)



Very fast response low-inertia
radiant floor surfaces

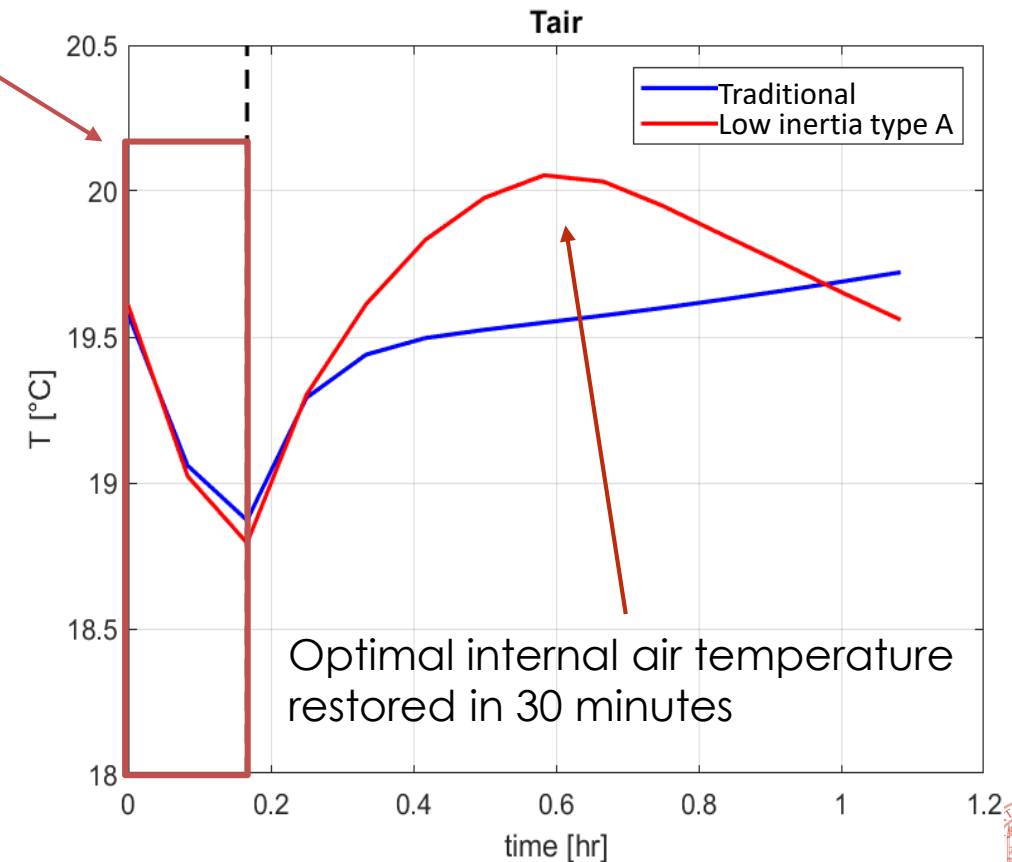
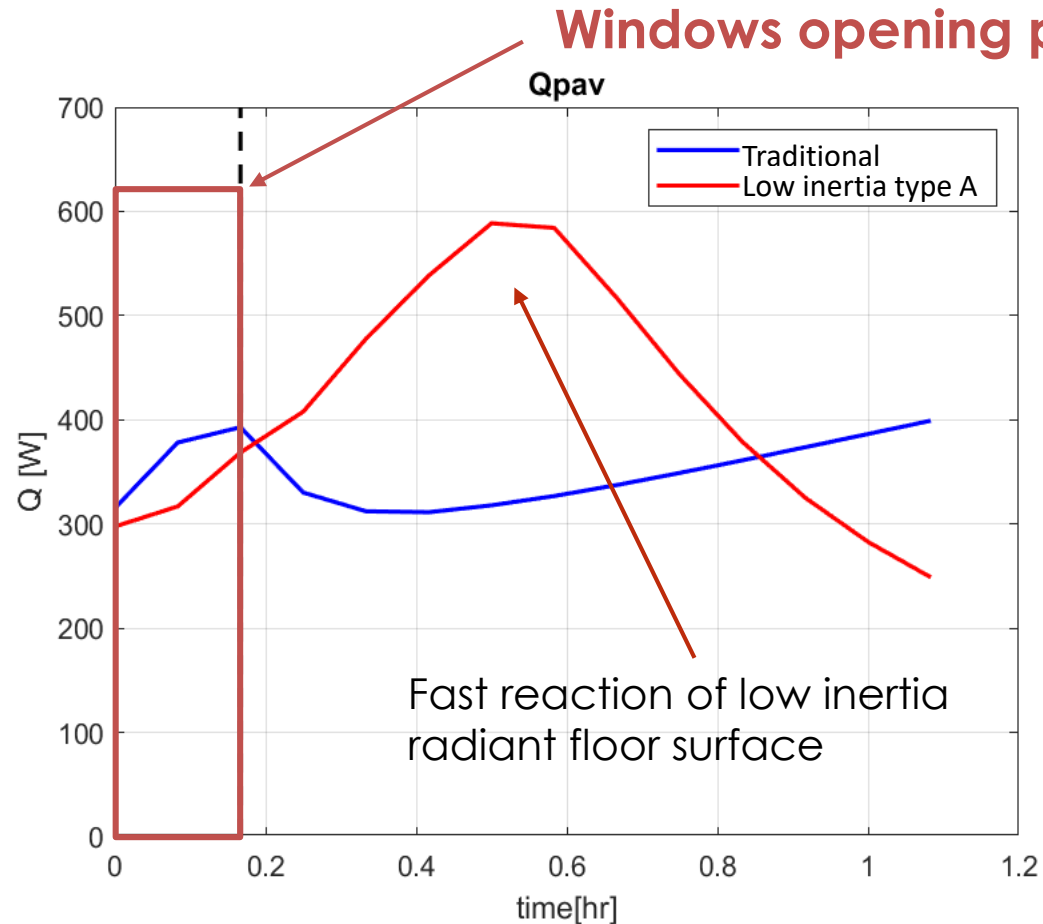


Better thermal comfort conditions
compared to traditional radiant floor



ALMABuild: an application case study on radiant floor heating

Transient with increase thermal load (windows opening, air change rate from 0.3 to 1 vol/hr)



ALMABuild: an application case study on radiant floor heating

Seasonal results with **intermittent operating mode** (space heating active between 7-23)



System	Percentage of heating season with optimal comfort conditions	Percentage of heating season with low temperature	Room energy demand compared to traditional system
Traditional radiant floor	37.4%	5.7%	0%
Low-inertia radiant floor – Type A	62.4%	2.9%	-6.2%
Low-inertia radiant floor – Type B	62.2%	2.9%	-9.7%

Better comfort conditions along the season
and decrease of room energy demand



Conclusions

- Tool **ALMABEST** (ALMABuild + ALMAHVAC):
 - ALMABuild: **detailed 3D modeling** (Google SketchUp) and **automatic import**
 - ALMABuild: **automatic implementation** of the building model with GUIs
 - ALMAHVAC: **compatibility with CARNOT**
 - ALMAHVAC: **automatic implementation** of the HVAC system with GUIs





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Thanks for your attention!

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