Demand side detailed models

Deliverable Title	Demand side detailed models			
Deliverable number	D2.4			
Nature of the deliverable(1)	☒R	☐P	☐D	☐O
Dissemination level(2)	☒PU	☐PP	☐RE	☐CO
Due date	31/05/2017			
Status	Final Version			
Date of Submission	02/08/2017			

- **(1)** Please indicate the nature of the deliverable using one of the following codes (according to the DOA): Report (R), Prototype (P), Demonstrator (D), Other (O)
- **(2)** Please indicate the dissemination level using one of the following codes (according to the DOA):
  PU = Public
  PP = Restricted to other programme participants (including the Commission Services)
  RE = Restricted to a group specified by the consortium (including the Commission Services)
  CO = Confidential, only for members of the consortium (including the Commission Services)

This project has received funding from European Union´s Horizon 2020 research and innovation programme under grant agreement n° 696098

Authors

Responsible Authors and Entities	
Author	Institution
Raymond Sterling	National University of Ireland, Galway
Andrea Bassani	R2M solution
Andrea Costa	R2M solution
Pietro De Cinque	R2M solution
Francesco Passerini	R2M solution
Collaborating Authors and Entities	
Author	Institution
Jesús Febres	IK4-TEKNIKER

Document Control

VERSION	DATE	INSTITUTION	CHANGE
V0.1	17/04/2017	NUIG	First draft and ToC
V0.2	05/2017	NUIG	Adding AHU types
V0.3	12/06/2017	NUIG	Finished first draft of mechanical systems reporting
V0.4	28/06/2017	R2M	Building models
V0.5	30/06/2017	NUIG	Formatting and incorporation of comments by CSEM and TEK
V1.0	18/07/2017	IK4-TEKNIKER	Final version
V1.1	02/08/2017	NUIG	Adapted disclaimer to agreed license

Disclaimer

The opinion stated in this report reflects the opinion of the authors and not the opinion of the European Commission.

All INDIGO consortium members are also committed to publish accurate and up to date information and take the greatest care to do so. However, the INDIGO consortium members cannot accept liability for any inaccuracies or omissions nor do they accept liability for any direct, indirect, special, consequential or other losses or damages of any kind arising out of the use of this information.

Table of content

Nomenclature

DHC	District Heating and Cooling System
PHC	Post heating coil
PCC	Post cooling coil
AHU	Air handling unit
HVAC	heating ventilation and air conditioning system
FMU	Functional Mock-up Unit
FMI	Functional Mock-up Interface
H	Enthalpy
T	Temperature
RH	Relative humidity
X	Absolute humidity
Qs	Sensible heat flow
Ql	Latent heat flow

1 Introduction

INDIGO is a Horizon 2020 EU-funded project carried out by 6 partners from across Europe and 1 from the United Arab Emirates that aims to develop a more efficient, intelligent and economical generation of District Cooling (DC) systems by improving the existing system planning, control and management tools. This will be achieved through two specific objectives. The first one is to widen the use of DC systems and motivate the competitiveness of European DC market by the development of two open-source tools: a planning tool for DC systems with the aim of supporting their optimal design; and a modelling library with thermo-fluid dynamic models of DC System components which will provide the designers detailed information about their physical behaviour. The second objective is to reduce primary energy consumption. This will be addressed by a ground breaking DC system management strategy focused mainly on energy efficiency maximization and on energy cost minimization.

The main characteristic of this strategy is a predictive management capability. However, it will also address other challenges, such as the integration of different types of Energy Sources (including Renewables) and suitable coupling between generation, storage and demand. Intelligent and innovative component controllers (Predictive Controllers) will also be developed at all DC system levels. Some of them include embedded self-learning algorithms, allowing components to respond properly to the established set-points. In addition, open source tools and guidelines will be developed within the project in order to provide more confidence and, consequently, more openness when developing and using DC systems. INDIGO developments will be validated in a real District Heating and Cooling installation with appropriate conditions for testing the new functionalities. The project, coordinated by the Spanish institution IK4-TEKNIKER, started in March 2016 and will last three and a half years.

This report presents the work done on developing simulation models for the three buildings chosen as demonstration for the full detailed modelling in INDIGO. These buildings are all located in Basurto complex and correspond to: Aztarain, Areilza (also known as Surgical Block) and Gurtubay.

This report starts with the development of the Building models that represent the geometry, materials, weather, air infiltration and internal gains of the building which were developed in DesignBuilder and then exported into as Functional Mock-up Units (via EnergyPlus).

Following, section 3 shows the development of the air handling units in Modelica, the different zone types and the interconnection between Modelica models of the AHUs and the Building models in EnergyPlus.

Section 4 describes the integration work and how the real air conditioning and distribution system in the three buildings was replicated in simulation models.

This report contains the work done on modelling and simulating the building in Basurto. Model validation results will be presented in D6.5. These models serve two purposes: to provide a safe test-bed for testing the behaviour of the model predictive controllers being developed in WP3 and as data generator for model reduction (final models that are used by MPCs). As such, models were developed in close collaboration with the teams developing the controllers to meet their requirements as best as possible. However, it is understood that the delivered models are one possible representation of the actually systems working properly, which means that models are developed based on the documentation provided by partner Veolia and compiled in WP6, that simplifications has been made in order to reduce model complexity, that assumptions have been made where information was incomplete (e.g. control of the AHUs) and that deviation from measured data are expected and that the models may be further adjusted at a later stage to more closely resemble the measured data. Nevertheless, the models are suitable for the purposes previously mentioned.

Source code and FMUs of the models is annexed to this report. Reader is forewarned that the models require specific software to be executed: Dymola for AHU models and EnergyPlus for Building models. Alternatively, an FMU compliant software may be used to execute FMUs.

2 Building Models

2.1 General approach

All the geometrical models of the buildings are created considering the external dimensions. This approach influences the way in which the linear transmittances of the thermal bridges are calculated.

To create the model, the following information has been collected:

- Geometry of the building;
- Geometry and position of the shading objects (e.g. other buildings or trees) located around the modelled buildings;
- Distribution of the mechanical ventilation and the relative control;
- Position and properties of opaque and transparent elements (walls, roofs, windows, floors, internal partitions);
- Electrical consumption for the different buildings and for the main equipment that is installed in them, to estimate the internal gains.

For the development of the models relative to the buildings, the software EnergyPlus was used. It manages input files in .idf format, which can be edited in the IDF Editor (free available online) or in a text editor. The input data that the building model acquires from the HVAC system model, which is developed in Modelica, and the output data that the building model transfers to the HVAC system model are listed in the .idf file. The weather data are included in an .epw file (*EnergyPlus weather file*). The information included in the .idf file and that one included in the .epw file are combined in a file that is readable by Modelica, specifically in a .fmu file. The exportation to .fmu is done through a Python script. (LBNL, 2017)

In the building model, there are thermal zones in which the internal air conditions are considered uniform. The thermal zones were created based on the air conditioning system and of its control logics, to allow an accurate modelling of the HVAC systems, as it is needed by the INDIGO project. As general rule, the zones that are controlled by the same system and based on the same sensors are modelled as part of the same thermal zone.

2.1.1 Energy Plus

EnergyPlus is a whole building energy simulation software, whose development is funded by the U.S. Department of Energy – Building Technologies Office. It is free, open-source, and cross-platform. In EnergyPlus many physical-mathematical models relative to the building physics (as well as to the HVAC systems) are already available and validated.

The input data are inserted in EnergyPlus through “objects” that can be considered as vectors containing information, divided in alpha and numeric fields. The input information can be relative to the control for the simulation (e.g. calculation time steps), or to physical phenomena (e.g. air infiltration), or to elements (e.g. a wall).

Exhaustive information regarding EnergyPlus is free available online. The main documents are the Input/output Reference (U.S. Department of Energy, Input Output Reference, 2016), which describes the input and the output data that can be manages in EnergyPlus, and the Engineering reference, which describes the EnergyPlus calculation methods (U.S. Department of Energy, Engineering Reference, 2016).

2.1.2 Heat transmission through opaque surfaces

EnergyPlus allows the use of different methods for modelling the heat transmission through opaque surfaces (different methods can be selected for different surfaces):

- CTF (Conduction Transfer Functions)
- EMPD (Effective Moisture Penetration Depth with Conduction Transfer Functions)
- CondFD (Conduction Finite Difference)
- HAMT (Combined Heat And Moisture Finite Element)

(U.S. Department of Energy, Engineering Reference, 2016, p. 369)
For the INDIGO project, the CTF method was selected.
The basic method used in EnergyPlus for CTF calculations is known as the state space method (H.T. Ceylan et al., 1980, p. 115-120); (J.E. Seem et al., 1987); (K. Ouyang et al., 1991, p. 173-177).
"CTFs are very powerful as they relate the current surface heat flux and temperature values to previous surface heat flux and temperature values (ASHRAE 2009). Thus, with CTFs there is no need to calculate temperatures within the surface, which reduces computational requirements for the simulation. The main disadvantages of CTFs are that they assume constant thermal properties and provide no information about internal processes in a wall".
(P.C. Tabares- Velasco et al. , 2012, p. 42)

The model of the stratigraphy and of the material properties was made considering:

- Geometrical information that has been taken from architectural drawings
- Information about the materials that compose the structures present in documentation developed by the designers (the design documentation is available only for the newest buildings: Aztarain and Bloque Quirurgico).
- Analysing the data explained in the last point and when necessary correcting it or completing it using some regulations to obtain the most realistic structure as close as possible at the realistic structure of the existing building.
- Methods and libraries provided by technical standards:
    - **UNI 10355:1994** Walls and floors, values of thermal resistance, methods of calculation.
      It provides the values of unitary thermal resistances relating to the types of walls and attics most widespread in Italy. It is based on the results of laboratory tests and checks by calculation.
    - **ISO 10456:2007(E) Table-3** Design thermal values for materials in general building applications.
    - **ISO 6946:2007(E) Table-2** Thermal resistance of unventilated air layers with high emissivity surfaces.
    - **ISO 6946:2007(E)-6.2.1** Total thermal resistance RT, of a component constituted by layers homogeneous and heterogeneous.

The emissivity of the external bricks was evaluated using a thermographic camera: the supposed emissivity was adjusted until the surface temperature measured by the thermographic camera was equal to the surface temperature measured by a contact thermometer.

The properties of the materials are being reviewed in a calibration process to improve the agreement between output results and monitored data. It will be an iterative process. As D6.2 proposed in agreement with (Barlas 1996), output such as the heat flow rate on the indoor side of the wall will be analysed and compared with empirical data from the point of view of amplitude of peak, time between two peaks, minimum value, slope and the number of inflection points.

For surfaces in contact with the ground, a layer with the ground properties was added on the external side and as boundary conditions, on that side, monthly temperatures were calculated. The calculation considers the ground as a half-plane and the monthly outside air temperatures were approximated with a sinusoidal curve. The ground temperature at different depths was calculated and was assigned to the relative underground surfaces.

The calculation of the thermal bridges has been done using Therm (software for finite element calculation) (Lawrence Berkeley National Laboratory (LBNL), s.d.). The outside surface temperatures of the FEM model have been compared with those ones of the thermographic images.

The increase of the heat flow rate due to the thermal bridges was considered in EnergyPlus through a local increase of the thermal conductivity of the materials.

2.1.3 Heat transmission through convection

EnergyPlus allows the choice among different methods both for the inside convection and for the outside convection.

As for the inside convection algorithm, the TARP method was selected, which "correlates the convective heat transfer coefficient to the surface orientation and the difference between the surface and zone air temperatures. The algorithm is taken directly from Walton (1983)" (G.N. Walton et al., 1983). (U.S. Department of Energy, Engineering Reference, 2016, p. 119)

As for the outside convection algorithm, the DOE-2 method was selected. The calculation of the exterior convection is based on correlations that are based on empirical measurements. It considers the surface roughness, the surface and air temperatures, the surface orientation, the wind velocity and direction.

2.1.4 Heat transmission through radiation

The sky diffuse radiance distribution is based on an empirical model based on radiance measurements. (R. Perez et al., 1990)
In this model, the diffuse radiance of the sky (W/m^2) is composed by three parts:
- an isotropic part that covers the entire sky dome;
- a circumsolar brightening centred at the position of the sun;
- a horizon brightening.

The proportions of these distributions depend on the sky condition, which is characterized by two quantities, clearness factor and brightness factor, which are determined from sun position and solar radiation.

The shadowing factors are calculated separately for the different parts of the radiation.

During the annual simulation, the shading factors relative to isotropic part and to the horizon brightening are calculated once for each surface since they are independent of sun position.

The shading factors relative to the other parts of the solar radiation (such as sunlit areas of surfaces) are calculated, for every hour, as average values every 20 days. Calculating them with a shorter timestep would improve the accuracy but would slow down the simulation. (U.S. Department of Energy, Engineering Reference, 2016, p. 184-191)

Solar radiation reflected by shades is considered as diffuse. The ground reflectance is modeled as constantly equal to 0,2.

The fundamental zone model includes infrared (IR) radiation exchange among all surfaces within the zone. (U.S. Department of Energy, Engineering Reference, 2016, p. 124)

EnergyPlus calculates the horizontal infrared radiation intensity to the sky based on the Opaque Sky Cover and of the outside air temperature. (U.S. Department of Energy, Engineering Reference, 2016, p. 179)

2.1.5 Heat transmission through transparent surfaces

On the external side of the windows that are installed in the Basurto hospital there are reflective films. On site, a pyranometer has been used with different sky conditions to evaluate the ratio between the solar radiation flux density (W/m^2) entering through the windows and the solar radiation on a plane parallel to the window, on its external side. That ratio can be considered an estimation of the solar direct transmittance τ_e. (EN 410, 2011)

In EnergyPlus the window glass face temperatures are determined by solving the heat balance equations on each face of every glass layer every time step. The thermal inertia of the glass is neglected. The heat flow is considered perpendicular to the glass faces (one-dimensional) and the glass faces are considered as isothermal. The short-wave radiation absorbed in a glass layer is apportioned equally to the two faces of the layer. (U.S. Department of Energy, Engineering Reference, 2016, p. 358)

The optical properties of every glass layer are modeled as spectral averages for particular ranges (solar radiation, visible radiation, infrared radiation). Moreover, every glass layer is characterized by a thickness and a conductivity.

As for the heat transfer through the window frame, a thermal conductance is input (also the thermal inertia of the frame is neglected).

The model of the windows and of the skylights was made considering:

- Geometrical information that has been taken from architectural drawings
- Information about the materials that compose the transparent surfaces present in documentation developed by the designers
- Analysing the data explained in the last point and when necessary completing it using data from libraries
- On-site visit and measurements.

The frame and dividers of windows and skylights were modelled considering the same points showed previously for the transparent surfaces and an Italian technical standard to complete the structures and build it as close as possible at the real frame and dividers of the building (UNI/TS 11300-1, 2014, p. 49 Tab. B.2).

2.1.6 Internal gains

The electric consumption of the buildings is going to be measured in the next monitoring campaign. The consumption due to the internal equipment, excluding the HVAC systems (that are modelled explicitly in Modelica), is going to be estimated and to be considered as internal gain for the building. The internal thermal loads that are removed by an extraction system directly are not going to be considered as internal gains.

2.1.6.1 Electric equipment and lights

The modelled internal gains due to electric equipment and lighting are compared with the monitored electric consumption. During the monitoring campaign, new data are going to be collected to improve the accuracy of the modelled internal gains.

The lights are considered on during the hours were not enough natural daylighting is available (for underground rooms that do not have windows, lights are considered on also when outdoor solar daylighting is available if they are occupied). During the night in in-patient

rooms and in offices the lights are considered off, while they are considered partially on in corridors or in some rooms (during the night the power density of the lights is lower than the power density that the same lights have during the day).
The behaviour of the lighting into the building is regulated by a schedule to simulate the presence of the artificial light into the zones of the building during the hours of the day.

2.1.6.2 People

The occupation of the different zones was modelled considering the number of seats or beds represented in the architectural drawings. Typical schedules were considered for the different kinds of room. For every person, an amount of latent gain and sensible gain was input based on the activity that is carried out typically in those rooms.

Table 1. Activity Level [W/person] (ASHRAE FUNDAMENTALS, 2009, p. 174 Tab.4).

Activity	Activity Level [W/person]
Resting	
Sleeping	72
Reclining	81
Seated, quiet	108
Walking (on level surface)	
4.3 km/h (1.2 m/s)	270
Office Activities	
Filing, seated	126

The behaviour of the people in the building is regulated by schedules to simulate the presence and the activity of the people during the hours of the day.

2.1.7 Zones

The zones were created considering for each building the criteria that are exposed in the following paragraphs.

2.1.7.1 Different AHUs

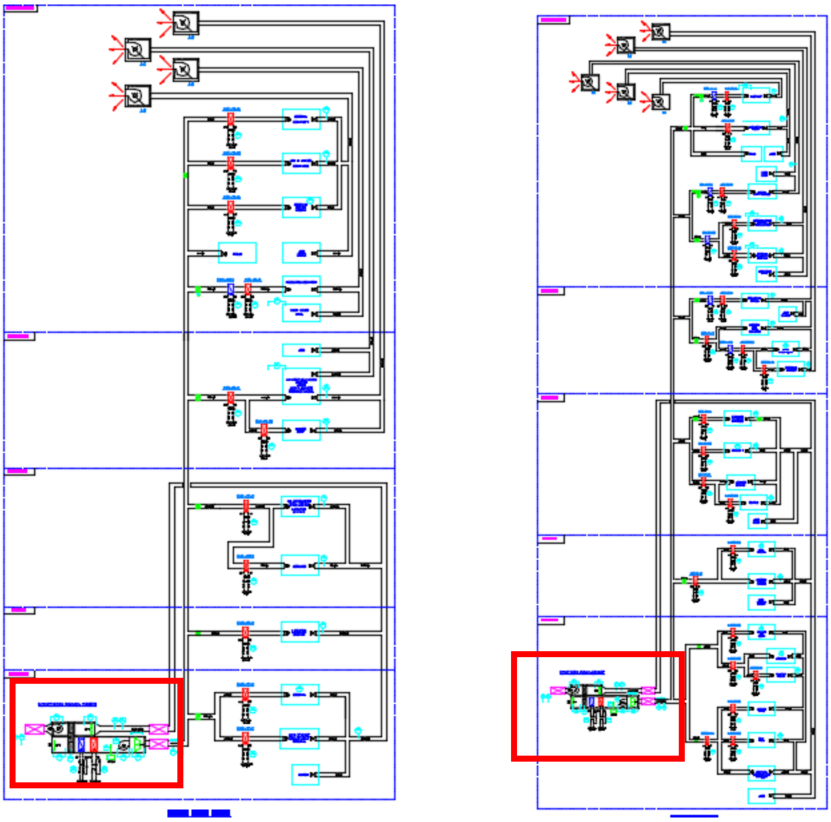


Figure 1. Air distribution plant of Gurtubay building

As it is possible to see in the picture, if two parts of the same building are served by different AHUs the two parts will be modelled separately.

2.1.7.2 Distribution of the air ducts and coils

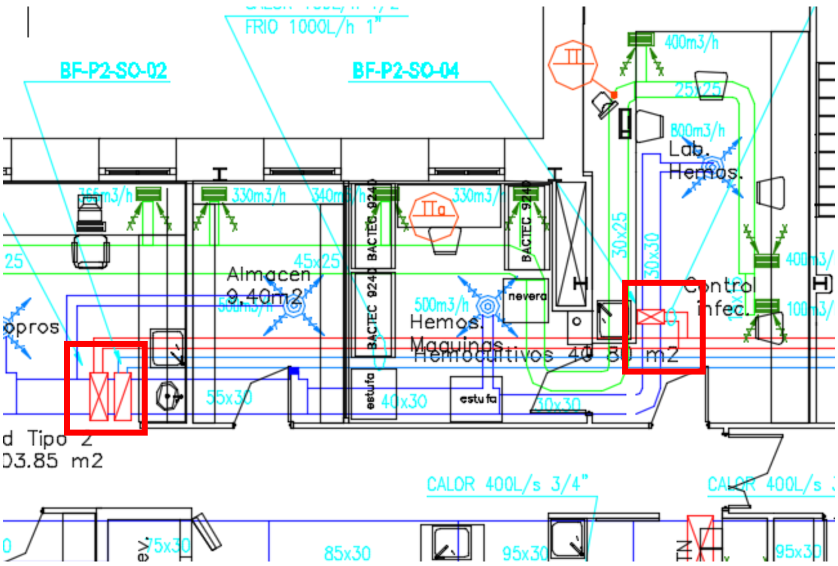


Figure 2. Post heating coils

The creation of the zones considers the **location of the coils**, to define if the conditions of some rooms are controlled by a post-heating or by a post-cooling coil.

The post-heating coils modify the characteristic of the injected air and consequently the served zone will be considered separated.

2.1.7.3 Location of temperature sensors

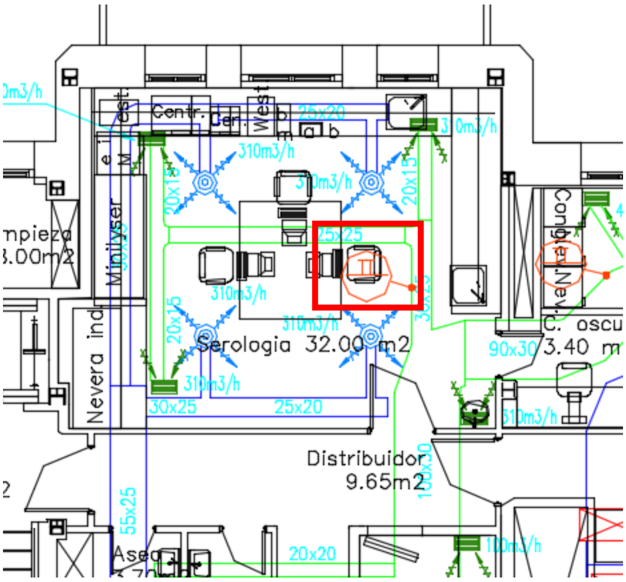


Figure 3. Sensor located on the return duct from a room (Serologia)

The creation of the zones considers the **location of temperature sensors** within the air distribution scheme, to model as close as possible to the reality the control logic and the temperature of the sensors on which the control logic is based.

Rooms whose internal conditions are measured by a specific sensor (inside the room or in the return duct) are modelled separately.

The location of the sensor is important because a goal of the project is the improvement of the control system.

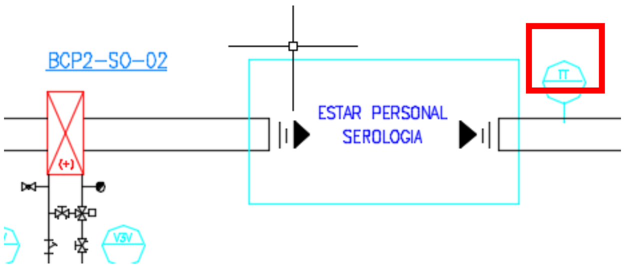


Figure 4. Sensor located on the return duct from a room (Serologia)

2.1.8 Air exchanges

The exchange of air has been modelled using three different objects of Energy Plus.
For the exchanges of air internal to the building:

- ZoneCrossMixing
- ZoneMixing

For the exchanges of air between the building and the external environment:

- ZoneVentilation:DesignFlowRate

2.1.8.1 ZoneCrossMixing

ZoneCrossMixing is an object of EnergyPlus that allows the model of an exchange of air between two zones (the both air flow rate is considered in both directions).
It allows to specify the air flow rate m^3/s and the temperature difference between both zones is below which the ZoneCrossMixing is shutoff.

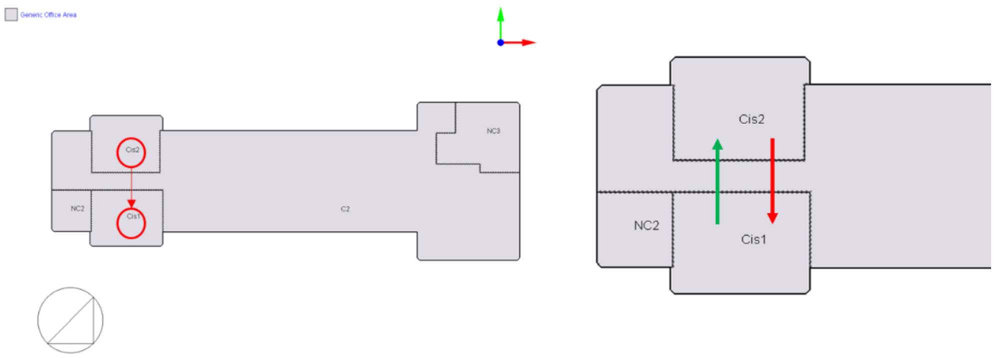


Figure 5. ZoneCrossMixing

Field	Units	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6	Obj7	Obj8
Name		Cis1-Cis2	Cis2-Cis1	Cis3-Cis4	Cis4-Cis3	SB1-SB2	SB2-SB1	SB2-SB3	SB3-SB2
Zone Name		1:Cis2	1:Cis1	2:Cis4	2:Cis3	Basement:SB2	Basement:SB1	Basement:SB3	Basement:SB2
Schedule Name		On	On	On	On	On	On	On	On
Design Flow Rate Calculation Method		Flow/Zone	Flow/Zone	Flow/Zone	Flow/Zone	Flow/Zone	Flow/Zone	Flow/Zone	Flow/Zone
Design Flow Rate	m3/s	3	3	3	3	3	3	3	3
Flow Rate per Zone Floor Area	m3/s-m2								
Flow Rate per Person	m3/s-person								
Air Changes per Hour	1/hr	12	12	12	12	12	12	12	12
Source Zone Name		1:Cis1	1:Cis2	2:Cis3	2:Cis4	Basement:SB1	Basement:SB2	Basement:SB2	Basement:SB3
Delta Temperature	deltaC	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Delta Temperature Schedule Name									
Minimum Zone Temperature Schedule Name									
Maximum Zone Temperature Schedule Name									
Minimum Source Zone Temperature Schedule Name									
Maximum Source Zone Temperature Schedule Name									
Minimum Outdoor Temperature Schedule Name									
Maximum Outdoor Temperature Schedule Name									

Figure 6. The ZoneCrossMixing object

2.1.8.2 ZoneMixing

This method is used to model a unidirectional flux of air from a zone to another.
This is important when two adjacent zones have different internal pressure. In that case the flux of air will pass from the zone having a higher pressure to the zone having a lower pressure (e.g. from over-pressure zones to equi-pressure zones).

2.1.8.3 ZoneVentilation:DesignFlowRate

The flux of air that is attracted directly into a zone of the building from the external environment has been modelled using this object.

2.1.8.4 Open-spaces zones

The open-space rooms served by different AHUs have been divided in different zones depending on the location of the supply vent and a ZoneCrossMixing or a ZoneMixing has been inserted in Energy Plus to simulate the exchange of air between the two zones.

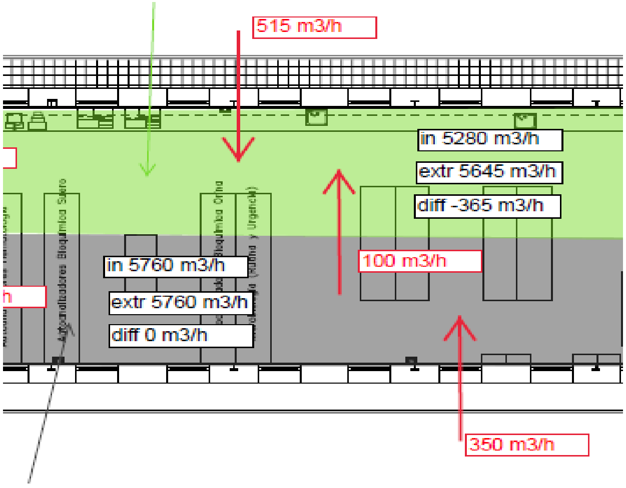


Figure 7. Open space zone

2.1.8.5 Zones served by the same AHU and duct but physically distant

Between zones served by the same AHU and duct but physically distant an air exchange was modelled with the ZoneCrossMixing object. it has been modelled a strong exchange of air between the two zones and consequently the internal condition of the two zones will be very similar. In this way in Modelica the model of only one zone will be necessary. In the real plant, the mixing of air happens into the return duct, while it has been modelled at the rooms level but the result will be the same.

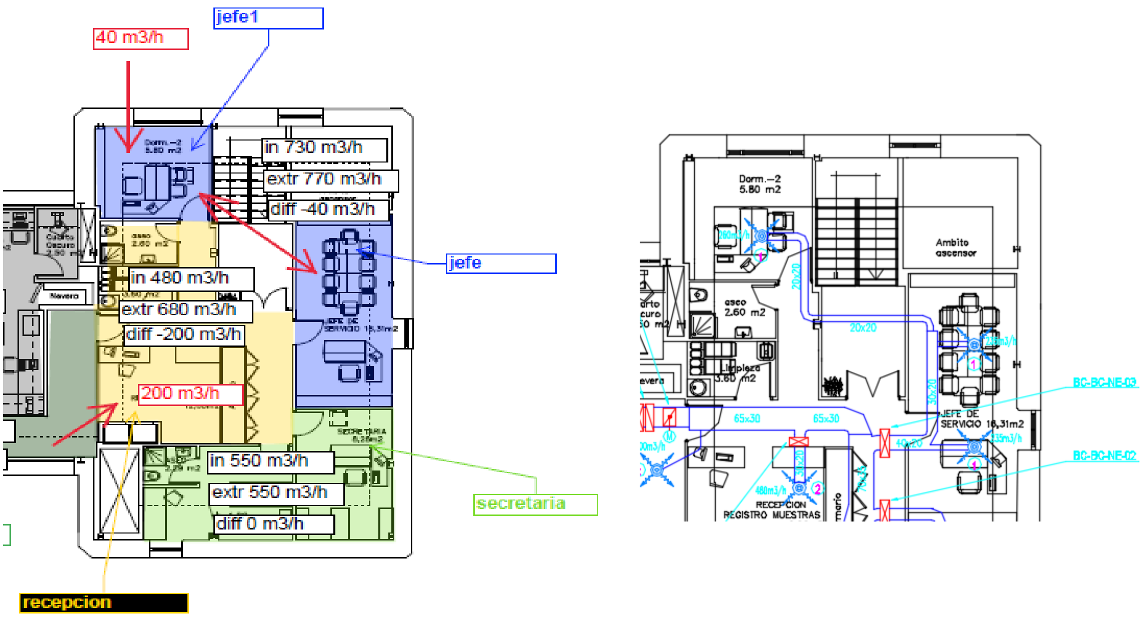


Figure 8. The zones jefe and jefe1 are served by the same AHU and heating coil but are physically distant

2.1.8.6 Zones in depression without supply vent

The **zones with the extraction vent** that are adjacent to a conditioned zone attract air inside them because they are in depression. Those zones have been studied separately to understand if they could be considered conditioned zones or not conditioned zone.

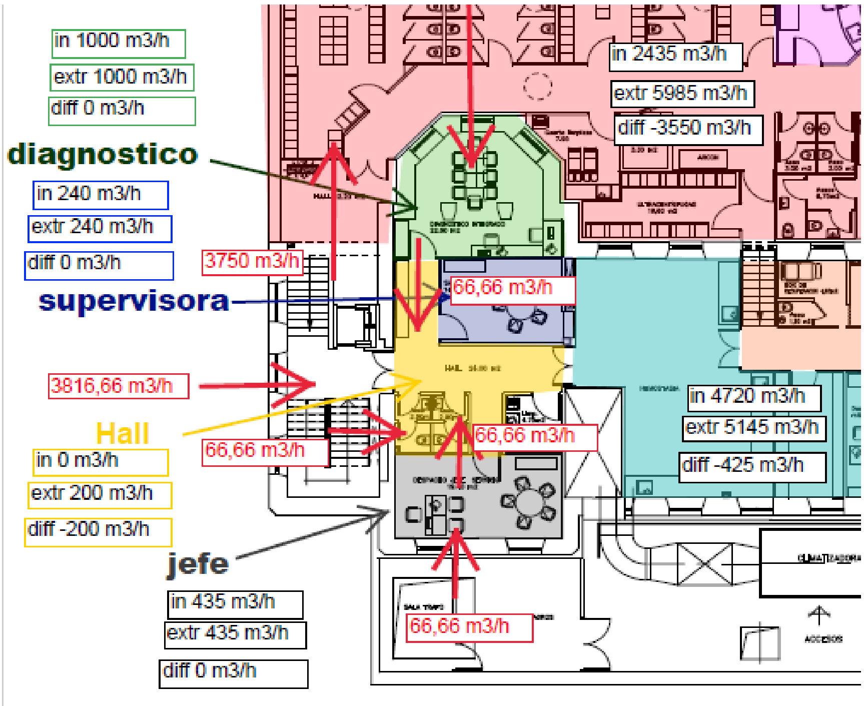


Figure 9. The zone Hall is in depression without supply vent

2.1.8.7 Zones in depression without supply vent

For some zones, **the extracted air is recirculated in the AHUs**. Those zones have been modelled in EnergyPlus and in Modelica.

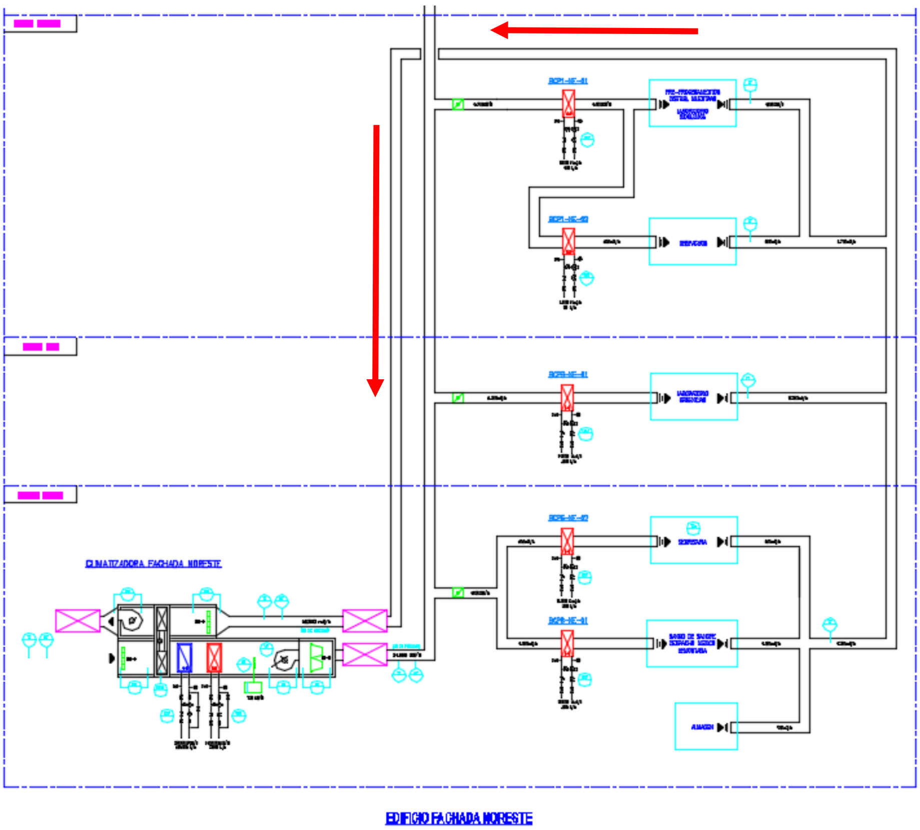


Figure 10. Zones in depression without supply vent

2.1.8.8 Zones in depression without supply vent

The zones from where the extracted air is rejected to the outdoor environment without a sensor that measures its properties are modelled only in EnergyPlus. In Modelica they are not modelled because they do not influence the control.

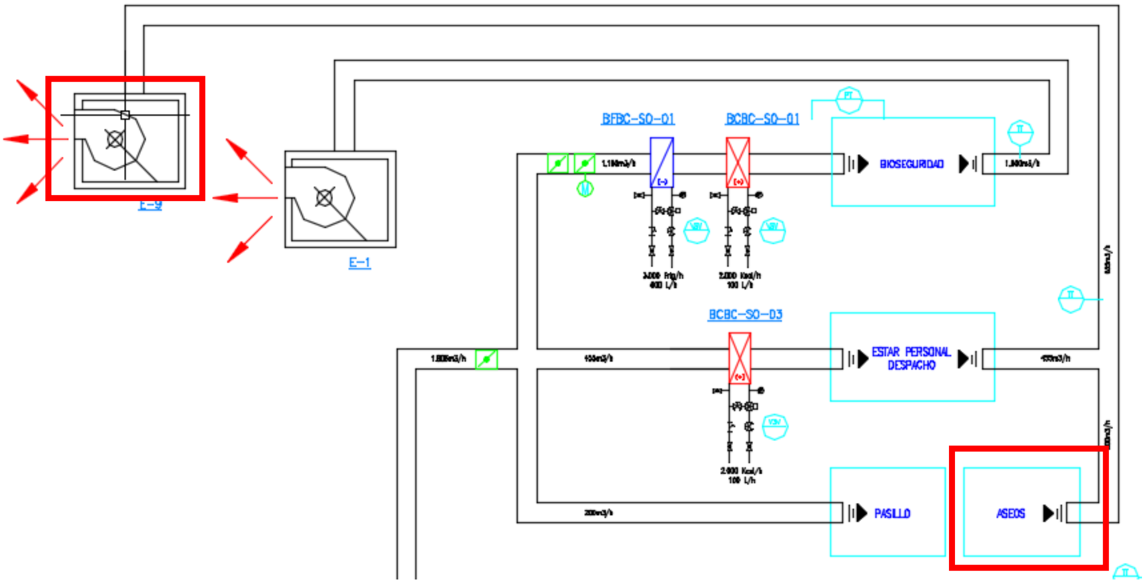


Figure 11. Zone in depression without supply vent

2.1.9 Infiltrations

Infiltrations have been calculated considering as first step the exchanges of air between the building and the external environment and the exchanges of air between the interior zones of the building due to the mechanical system.
For every zone in equi-pressure that has windows facing the external environment and that does not here exchange of air with other adjacent zones a value of 0,3 air changes per hour has been considered.
This infiltration has been modelled using the EnergyPlus object ZoneInfiltration:DesignFlowRate.

2.1.10 Other parameters

The simulation covers a full year.

The zone timestep was imposed equal to 12 per hour (i.e. 5 minutes), like for the HVAC system in the model developed in Modelica.

During the next monitoring campaign, the window openings (magnetic sensors) and the CO_2 concentration are going to be measured. The correlation between the opening of the windows and other parameters (e.g. CO_2 concentration, indoor and outdoor temperatures) will be investigated to improve the model of the natural ventilation.

2.1.11 Weather data

The weather data regarding dry air temperature (°C) and relative humidity (%) are taken on site while all the other data (solar radiation, wind velocity, wind direction, pressure) are taken from the weather station of “C039 - Deusto” of the Basque agency of meteorology (“Agencia vasca de meteorología”) (http://www.euskalmet.euskadi.net/s07-

5853x/es/meteorologia/estacion.apl?e=5&campo=C039). The weather station is in the Bilbao city, 2,5 km far away from the hospital.

The global radiance on a flat surface expressed in [W/m^2] information included in the weather file. A method provided by Reindl, D.T. et al. (1990) was used to estimate the diffuse radiation and the direct radiation from the global one. The method was validated for 5 localities in America and in Europe having very different climates (latitudes from 28.4°N to 59.56°N). (D.T. Reindl et al., 1990)

The sun position is evaluated based on the geographical position of the building.

2.1.12 Input data from Modelica

To create the possibility of communication between EnergyPlus and Modelica the use of the EnergyPlus object “ExternalInterface” is necessary.

2.1.12.1 ExternalInterface

This object activates the external interface of EnergyPlus.
Currently, the only valid entries are PtolemyServer, FunctionalMockupUnitImport, and FunctionalMockupUnitExport.
For the INDIGO project, the option “Export” was selected because the EnergyPlus file is exported as a FMU for co-simulation.

2.1.12.2 ExternalInterface:FunctionalMockupUnitExport:To:Schedule

These objects declare all the data that Modelica will provides to EnergyPlus.

The data that Modelica communicates to EnergyPlus are:

1) **Sensible load [Qs]** (W) due to the air supplied by the mechanical ventilation (for every zone of the building)
2) **Latent load [Ql]** (W) due to the air supplied by the mechanical ventilation (for every zone of the building)

EnergyPlus considers those loads in the same way as it considers the internal thermal gains.

Field	Units	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6
Schedule Name		1:Cis1_sensible	1:Cis1_latent	2:Cis3_sensible	2:Cis3_latent	0:C1_sensible	0:C1_latent
Schedule Type Limits Names		Any Number	Any Number	Any Number	Any Number	Any Number	Any Number
FMU Variable Name		Qs_1C	Ql_1C	Qs_2C	Ql_2C	Qs_P0	Ql_P0
Initial Value		0	0	0	0	0	0

Figure 12. ExternalInterface:FunctionalMockupUnitExport:To:Schedule

Field	Units	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6
Name		1:Cis1s	1:Cis1l	2:Cis3s	2:Cis3l	0:C1s	0:C1l
Fuel Type		None	None	None	None	None	None
Zone or ZoneList Name		1:Cis1	1:Cis1	2:Cis3	2:Cis3	0:C1	0:C1
Schedule Name		1:Cis1_sensible	1:Cis1_latent	2:Cis3_sensible	2:Cis3_latent	0:C1_sensible	0:C1_latent
Design Level Calculation Method		EquipmentLevel	EquipmentLevel	EquipmentLevel	EquipmentLevel	EquipmentLevel	EquipmentLevel
Design Level	W	1	1	1	1	1	1
Power per Zone Floor Area	W/m2						
Power per Person	W/person						
Fraction Latent		0	1	0	1	0	1
Fraction Radiant							

Figure 13. OtherEquipment

The use of heat flows instead of typical state variables (T, mflow, etc.) in the data exchange from Modelica to the building FMU is motivated by modelling simplifications whereby it was decided to exchange heat rather than set-up and air-flow exchange in the EnergyPlus model which would significantly increase the computational effort without providing advantages over the selected procedure.

2.1.13 Output data to Modelica

2.1.13.1 ExternalInterface:FunctionalMockupUnitExport:From:Variable

This object declares all the data that EnergyPlus communicates to Modelica. They are:

1) **Temperature [T]**
    a) Site Outdoor Air Dry-Bulb Temperature (°C)
    b) Zone Mean Air Temperature (°C) (for every zone of the building)
2) **Relative humidity [RH]**
    a) Site Outdoor Air Relative Humidity (%)
    b) Zone Mean Air Relative Humidity (%) (for every zone of the building)
3) **Humidity ratio [X]**
    1) Site Outdoor Air Humidity Ratio (kg_{Water}/kg_{DryAir})
    2) Zone Mean Air Humidity Ratio (kg_{Water}/kg_{DryAir}) (for every zone of the building)

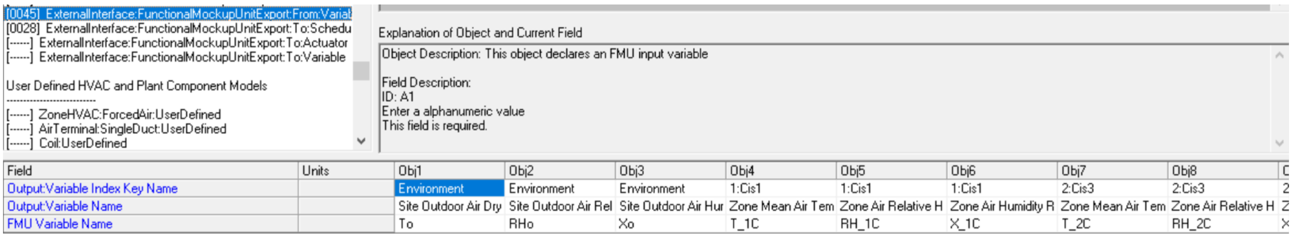


Figure 14. ExternalInterface:FunctionalMockupUnitExport:From:Variable

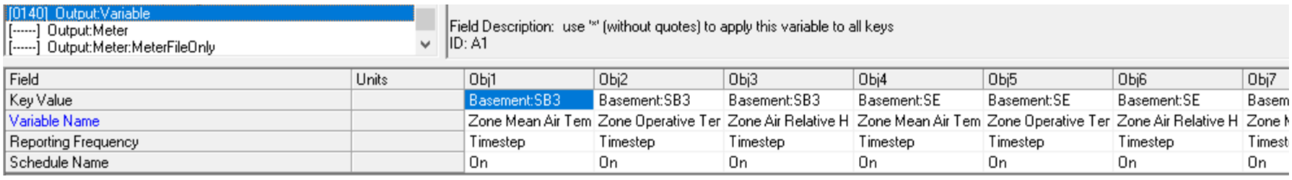


Figure 15. Output:Variable

To calculate the heat flows between the HVAC system and the building, Modelica requires knowledge of the temperature and humidity conditions of the zones. Therefore, these are the variables selected to be exchanged from the FMU to Modelica.

2.2 Aztarain

2.2.1 3D geometry

Architectural drawings and the schemes relative to the air distribution were available for the consortium. The rooms are collected in thermal zones. Generally, a thermal zone collects more than a room, to simplify the model without losing accuracy of the model of the control logics of the HVAC system. Other buildings and trees were modelled as shading elements.

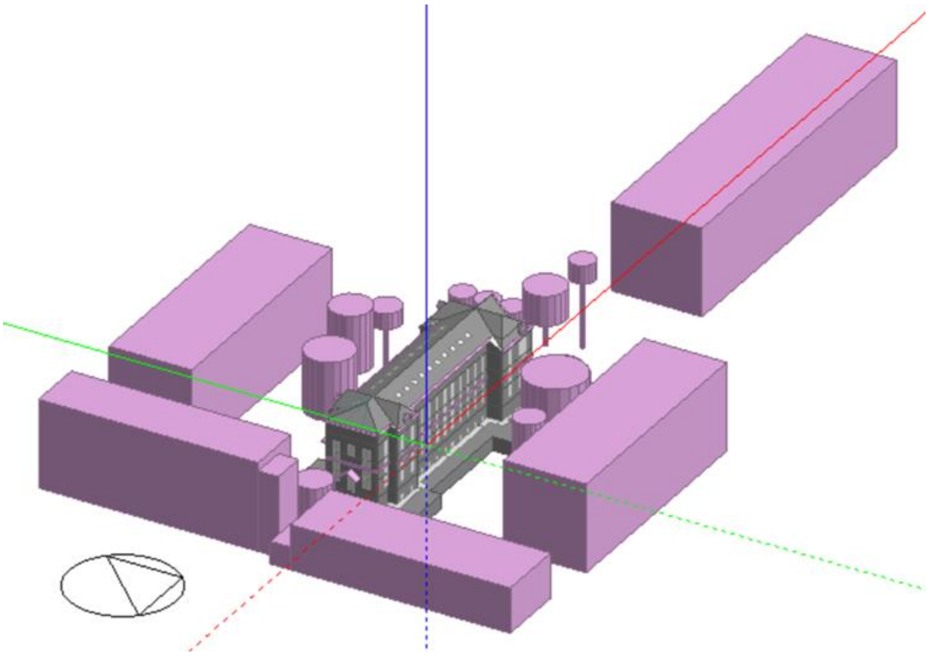


Figure 16. Aztarain model (DesignBuilder)

2.2.2 Zones and exchanges of air

If the zones where no supply vent but an extraction vent is present are adjacent to a cooled zone, they are considered as part of the conditioned zone (cooled) because since they are in depression they attract cooled air and the return temperature is influenced by their temperature.

To estimate the exchange of air between the internal zones of the building, the amount of air injected and extracted in every single zone has been calculated.

MECHANICAL VENTILATION AZTARAIN:					
ZONE	Air in [m3/h]	Air out [m3/h]	Normal pression	Overpressure	Depression
Aislamiento	2900	2900	X		
SA	3000	2541		X	
SB	4500	4600			X
SE	3000	3000	X		
SC	4500	4500	X		
SH	4500	4500	X		
SF	3000	3000	X		
SJ	4500	4676			X
SK	3000	2824		X	
Floor 0	5214	4411		X	
Floor 1	2558	2333		X	
Floor 2	2558	2333		X	
Bajo Cubierta	1422	1086		X	

Figure 17. Mechanical ventilation in Aztarain

Since for the underground floor of the Aztarain building the indoor conditions are controlled by re-heating and re-cooling coils that are installed in the supply ducts, for that floor the division has considered also the distribution of the re-heating/re-cooling boxes. Temperature sensors (or temperature and humidity sensors) are installed in every zone of the underground floor.

As for the other floors, the rooms have been divided in thermal zones gathering together all the rooms of a floor that are supplied by the same AHU.

The building has three different types of zones:

- Not cooled (identified with NC in the name)
- Cooled
- Specially purpose cooled zones (Aislamiento, identified with Cis in the name), which are conditioned by a specific AHU because in those rooms the requested conditions are different.

The Aislamiento zones are conditioned by a specific AHU because in those rooms the requested conditions are different.

The basement is composed by a part underground and a part over the level of the ground.
The two parts are connected (the zones include both the levels).
In the first part of the names of the zones of the underground floor the prefix “Basement” is always present.

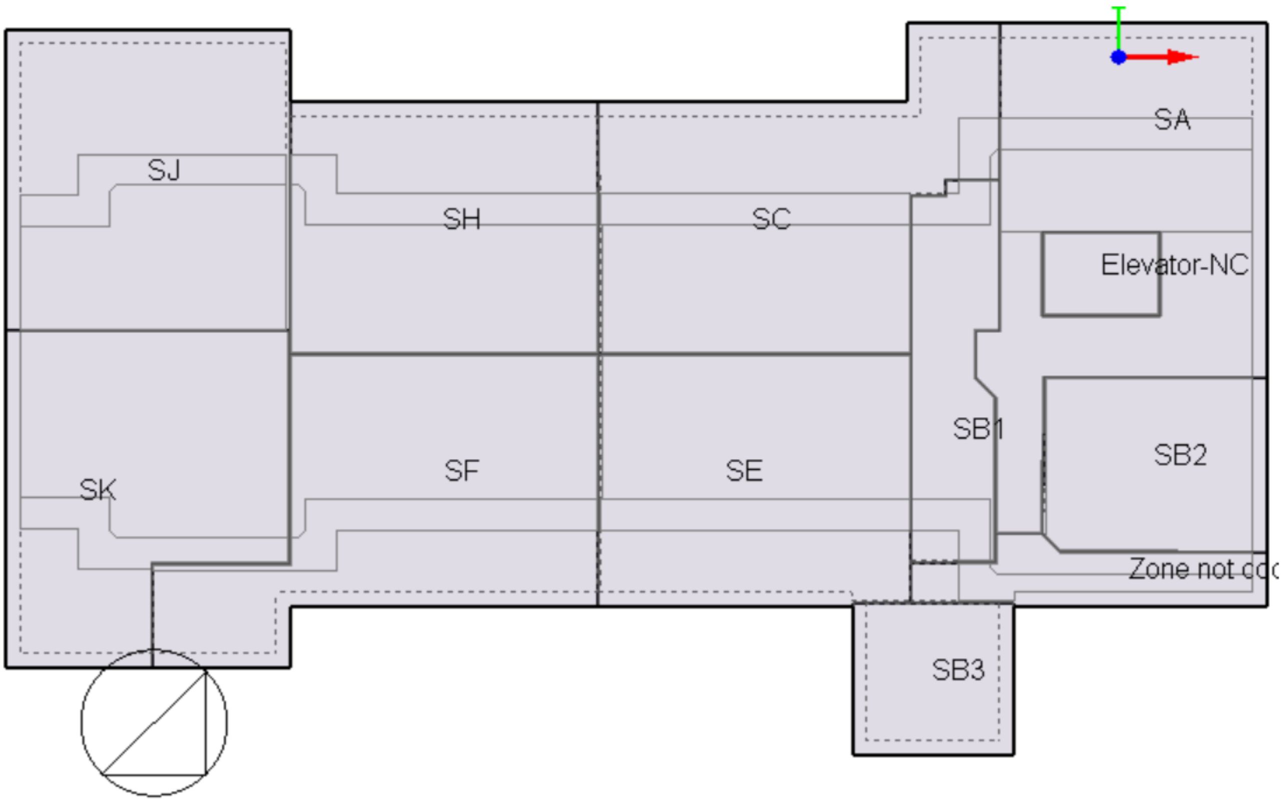


Figure 18. Lower part of the Aztarain basement

Upper part of the basement:

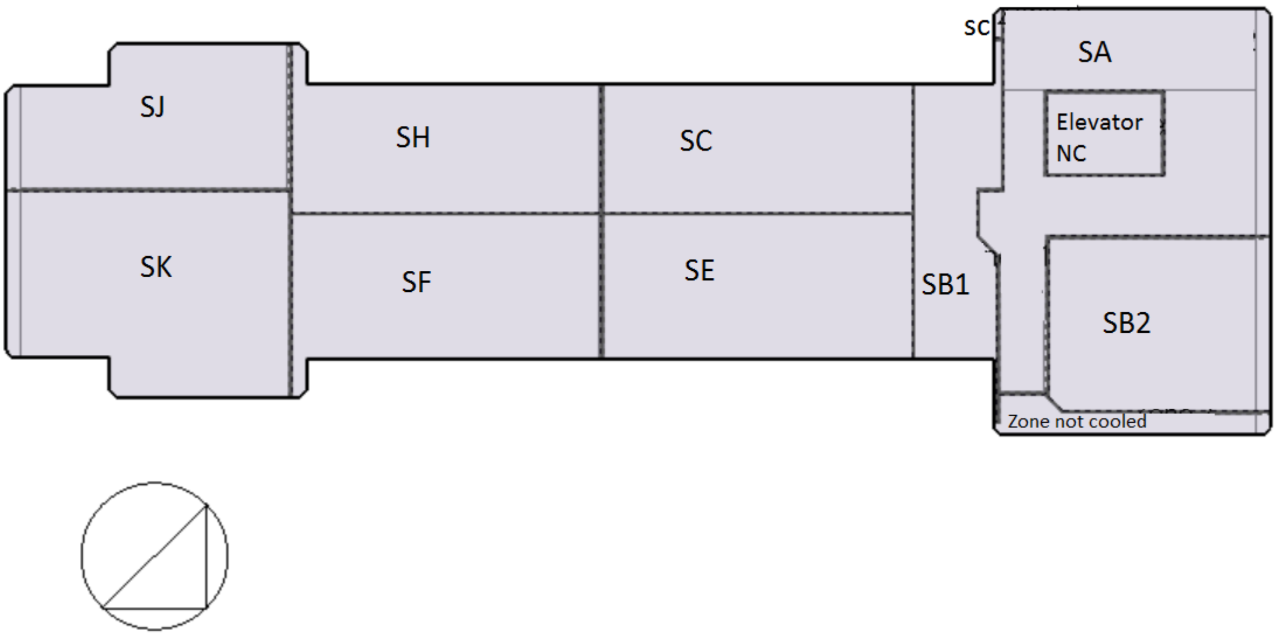


Figure 19. Upper part of the Aztarain basement

The ground floor (whose zones are named with the prefix “0” in the model):

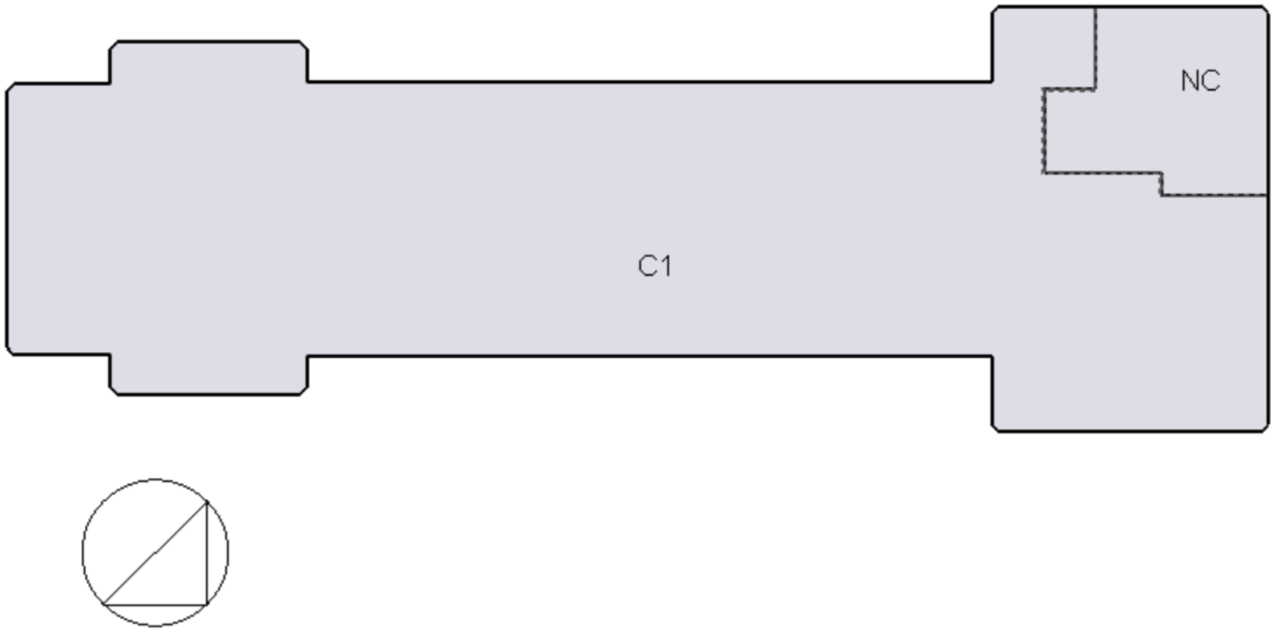


Figure 20. Aztarain ground floor

The first floor “1”:

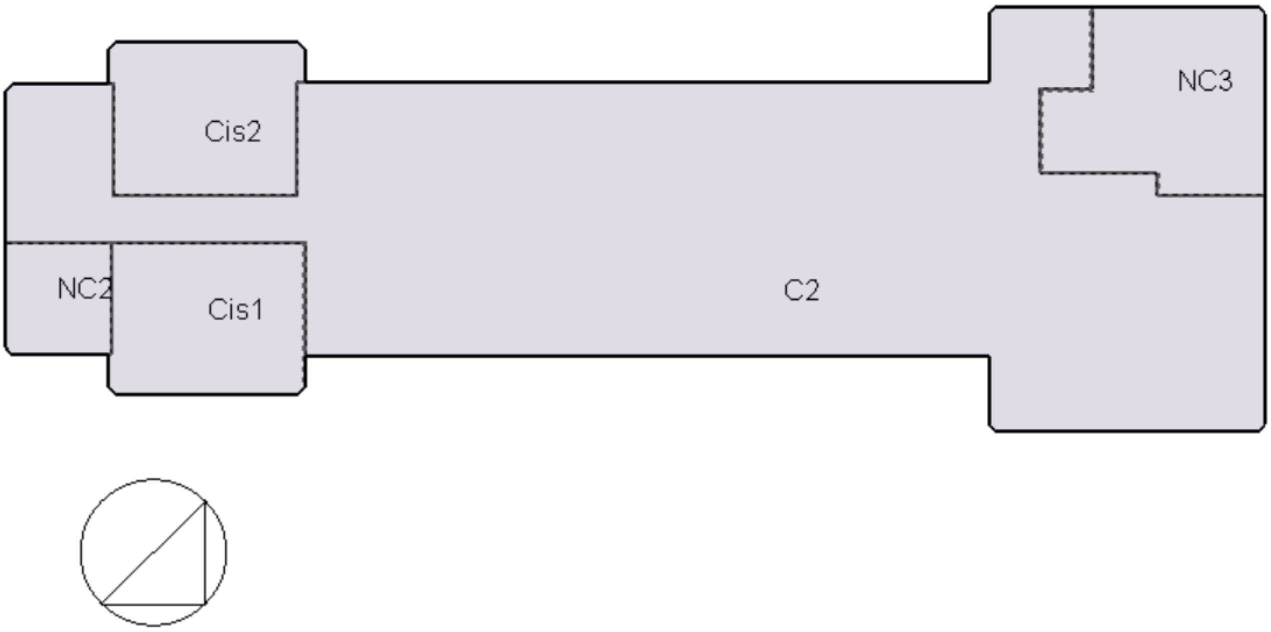


Figure 21. Aztarain first floor

Cis1 and Cis2 are supplied by the Aislamiento AHU.

The second floor “2”:

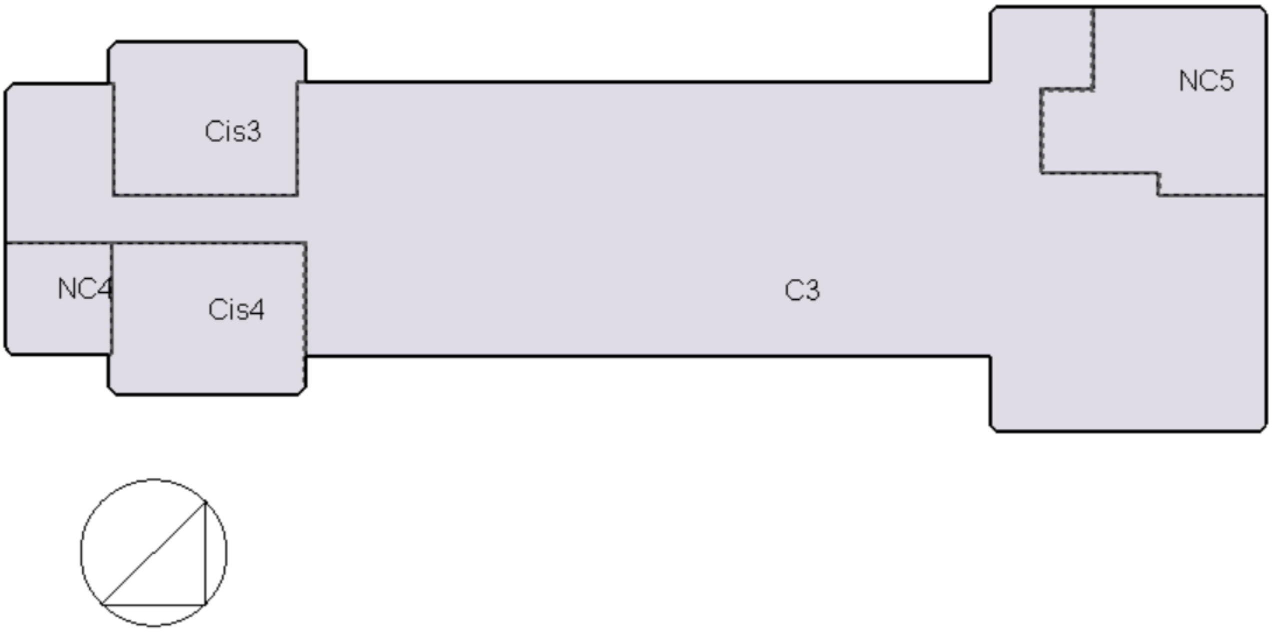


Figure 22. Aztarain second floor

Cis3 and Cis4 are supplied by the Aislamiento AHU.

The third floor “3”:

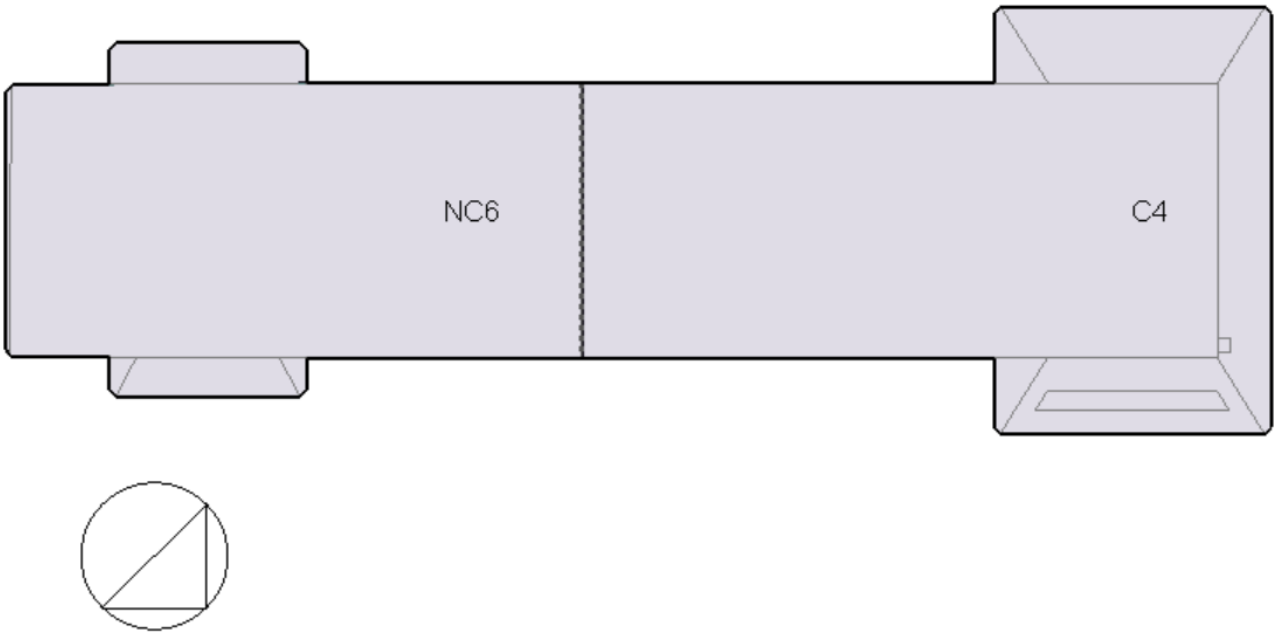


Figure 23. Aztarain third floor

2.2.3 Stratigraphy of opaque surfaces

Some measurements relative to the building envelope have started in summer 2016.

The thermographic camera has been used for detecting irregularities in the building envelope. In this way, the best position for the heat flow meter can be evaluated. The heat flow meter was used to measure the heat flow rate through the roof and the external walls of the Aztarain building. During the same period the outdoor and the indoor air temperature, the outdoor and the indoor surface temperature were measured (Figure 24). The data relative to the solar radiation and to the wind velocity and direction are available through the weather station “C039 - Deusto”.

Generally, the measurements made through the heat flow meter are indicative when there is an important difference (at least 10°C) for some consecutive days between the indoor temperature and the outdoor temperature. Normally this happens during the winter season. Nevertheless, in this case the measurements were carried out in summer because the research is interested in modelling the cooling demand and therefore in analysing the behaviour of the structures in hot conditions and when they are stricken by a high solar radiation.

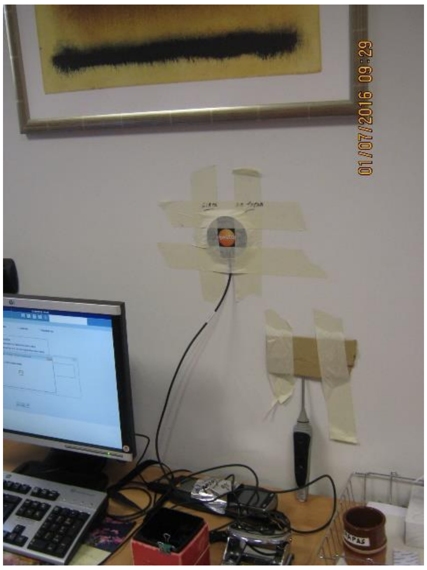


Figure 24. Internal measurement equipment for heat flow rate, surface temperature, and air temperature (Francesco Passerini, 2016)

Figure 25. External measurement equipment for surface temperature (Francesco Passerini, 2016)

Figure 26. External measurement equipment for air temperature (Francesco Passerini, 2016)

The validation of the models of the walls and of the roof is considering: amplitude of peak, time between two peaks, minimum, maximum and mean values, slope and number of inflection points, attenuation factor relative to the external and to the internal oscillations, time delay between external surface temperature and internal surface temperature or internal heat flow rate.

The surface emissivity is being evaluated through a thermographic camera: the surface temperature is measured at the same time with a thermographic camera and with a surface thermometer and the emissivity considered by the thermographic camera is adjusted until it measures the same value measured by the surface thermometer.

The surface solar absorptance considered in the model is adjusted to have an acceptable agreement between measured and calculated outside surface temperatures. The results obtained with different models of the outdoor convection coefficient are going to be compared with measured data to select the most appropriate one for the analysed case.

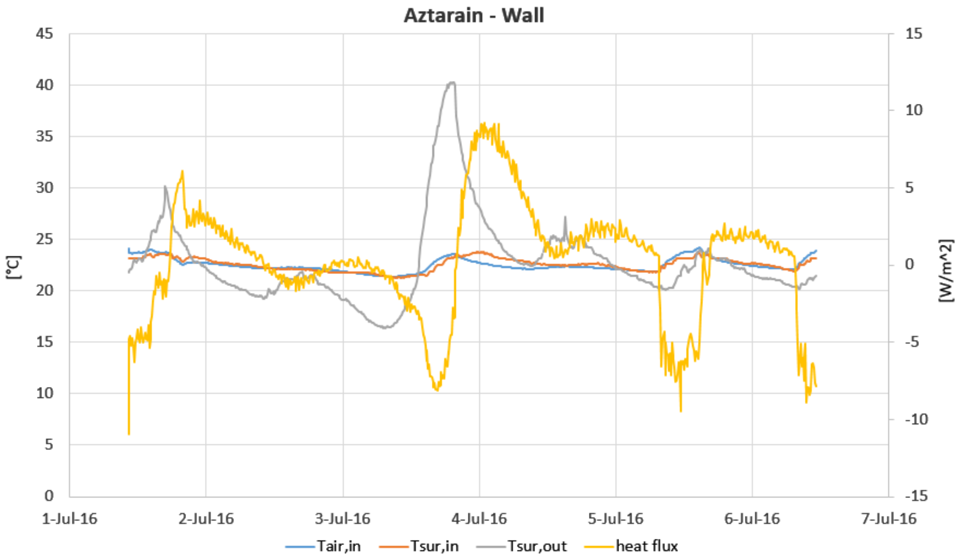


Figure 27. Elaboration of measured data relative to an external wall of Aztarain building (Francesco Passerini, 2016)

2.2.4 Features of glass surfaces

The following values of the solar radiation were measured for the skylights:

- External side: 638 W/m^2
- Internal side: 435 W/m^2

The solar direct transmittance (for the total amount of direct and diffuse radiation) is calculated equal to τ_e = 0,68

As for the vertical windows:

- External side: 58 W/m^2
- Internal side: 5,8 – 6,1 – 5,9 W/m^2. Average value: 5,9 W/m^2

The solar direct transmittance (for the total amount of direct and diffuse radiation) is calculated equal to τ_e = 0,10

The measurements are going to be repeated in the next months, during another measurement campaign, to improve the accuracy of the estimation, through measurements with different sky conditions.

2.2.5 Calculation of thermal bridges

The thermal bridges are calculated in Therm and then reviewed comparing the surface temperature values with the thermographic images.

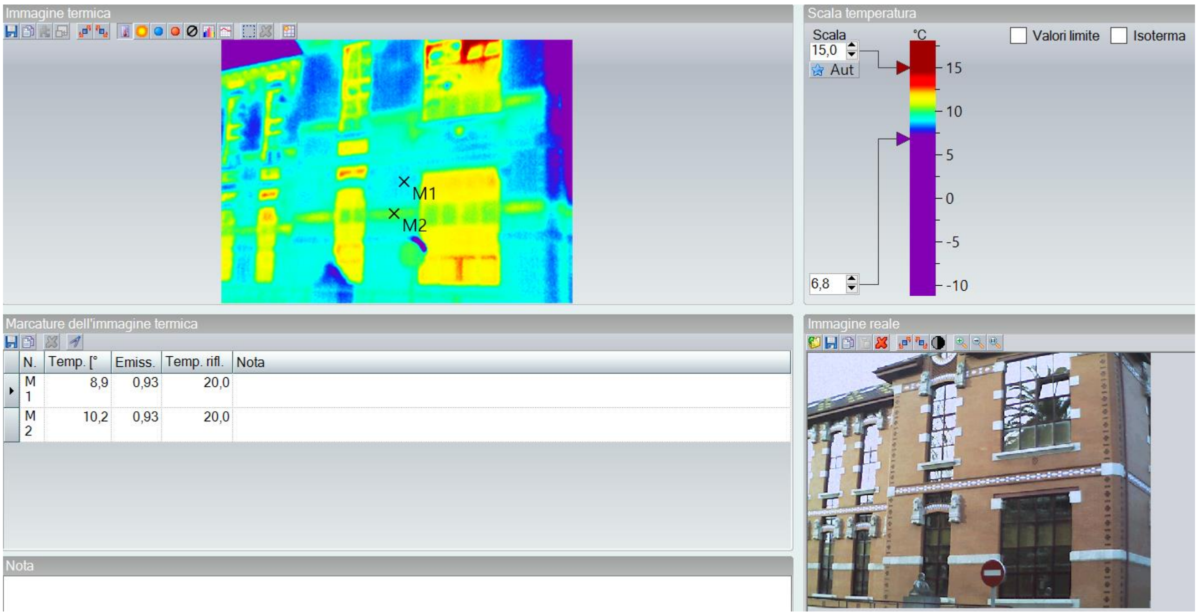


Figure 28. Thermographic images

2.3 Gurtubay

2.3.1 3D geometry

The structure of the building is similar to the structure of Aztarain but there are some important differences:

- The basement of Gurtubay has a different geometrical structure and is not all at the same depth underground.

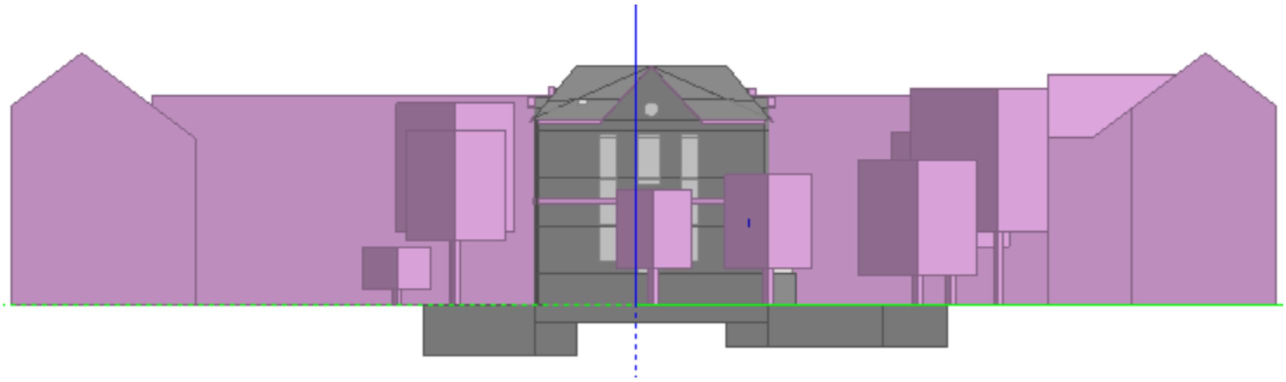


Figure 29. Gurtubay model (DesignBuilder)

- In Gurtubay there are more windows, in particular in the third floor, and the windows on the roof are smaller than in Aztarain.
- A porch connected to the building of Gurtubay that is not present in Aztarain.
- The distribution of the internal spaces is different
- There are no in-patient rooms but many laboratories are present and therefore the schedules relative to the internal gains are very different.

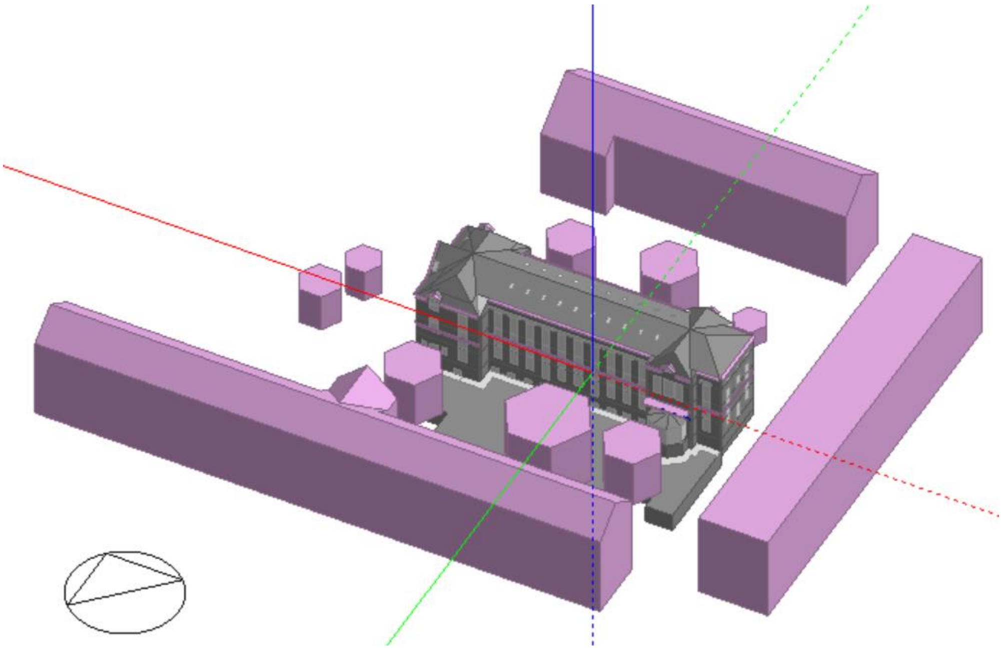


Figure 30. Gurtubay model (DesignBuilder)

2.3.2 Zones and exchanges of air

The following images show:

- The internal division in zones
- The exchanges of air
- The different object used in EnergyPlus to model the exchanges of air.
  a) Unidirectional red arrow between two internal zones = ZoneMixing
  b) Bidirectional red arrow = ZoneCrossMixing
  c) Unidirectional red arrow from the external environment to the internal zones of the building = ZoneVentilation:DesignFlowRate

Basement:

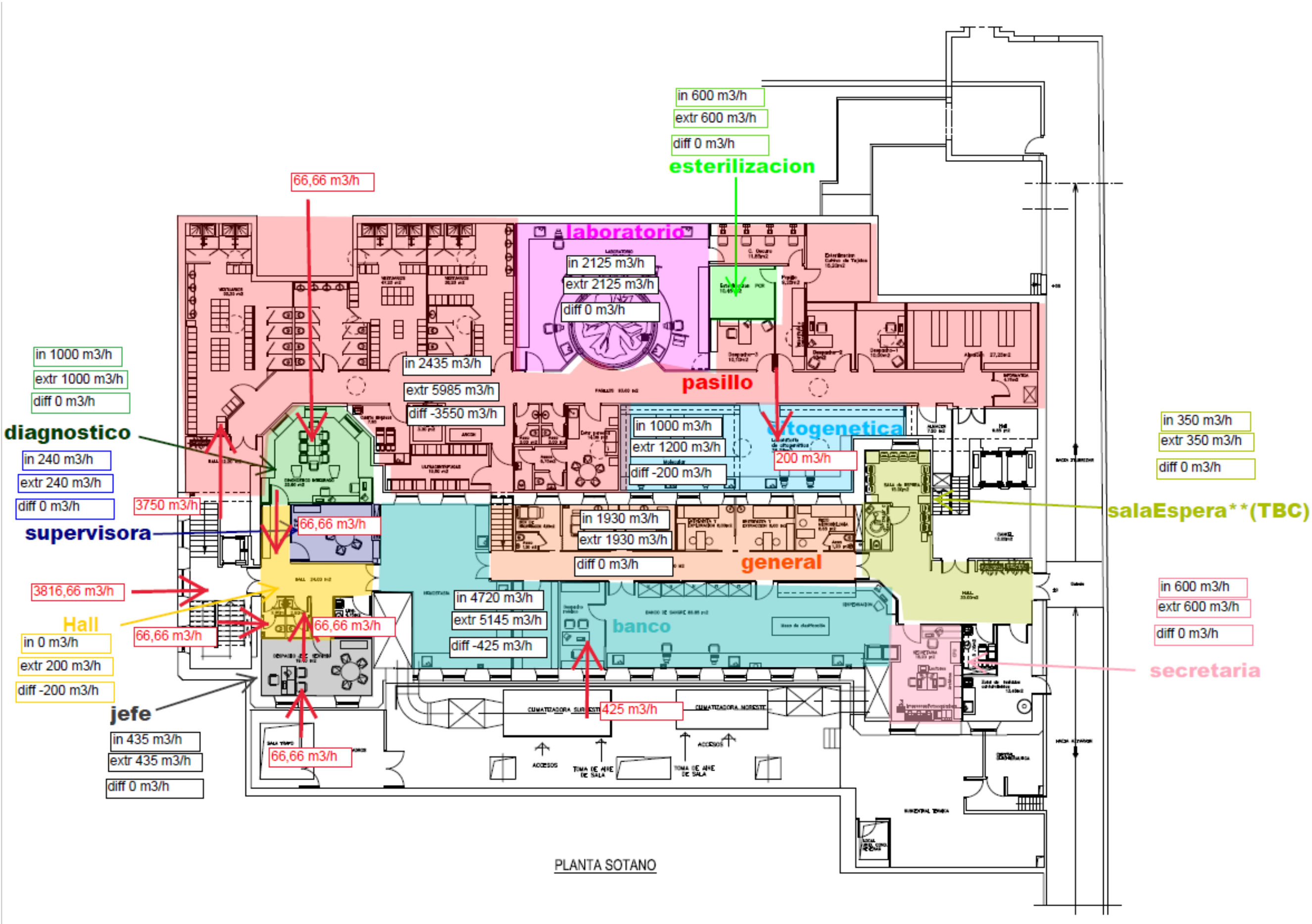


Figure 31. Lower part of the Gurtubay basement

In the following image, the upper part of the basement is showed. The zones are the same of the bottom part.

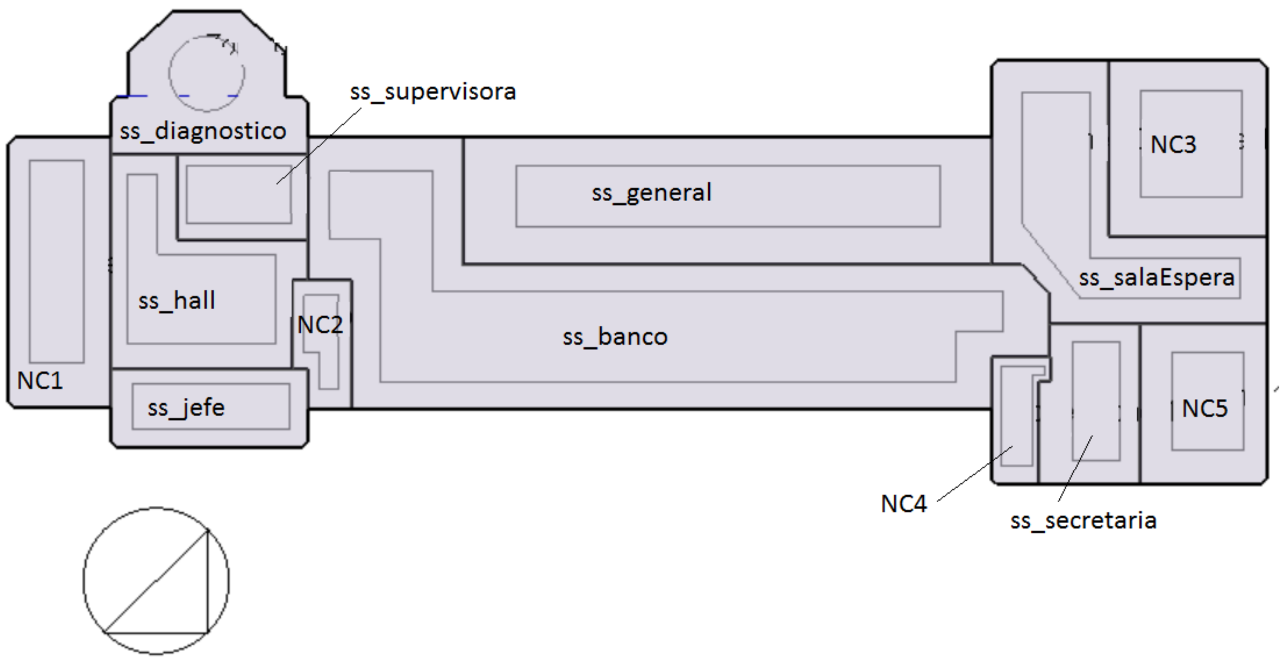


Figure 32. Upper part of the Gurtubay basement

Ground floor “0 Baja”:

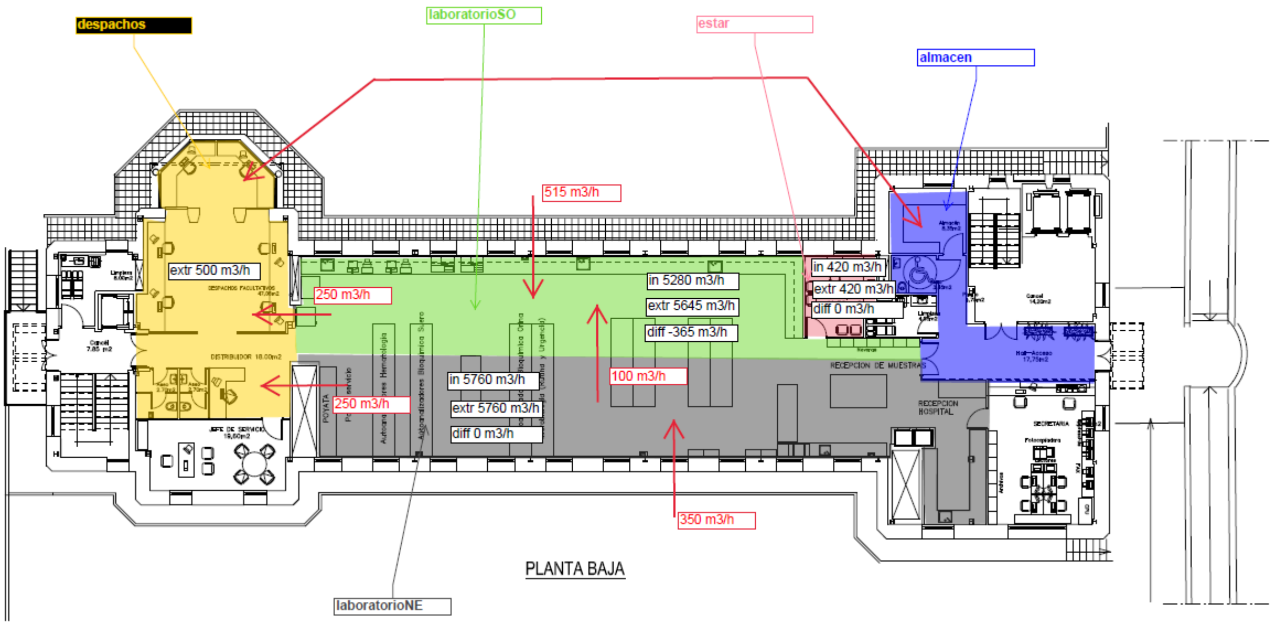


Figure 33. Gurtubay ground floor

First floor “1 Planta Primera”:

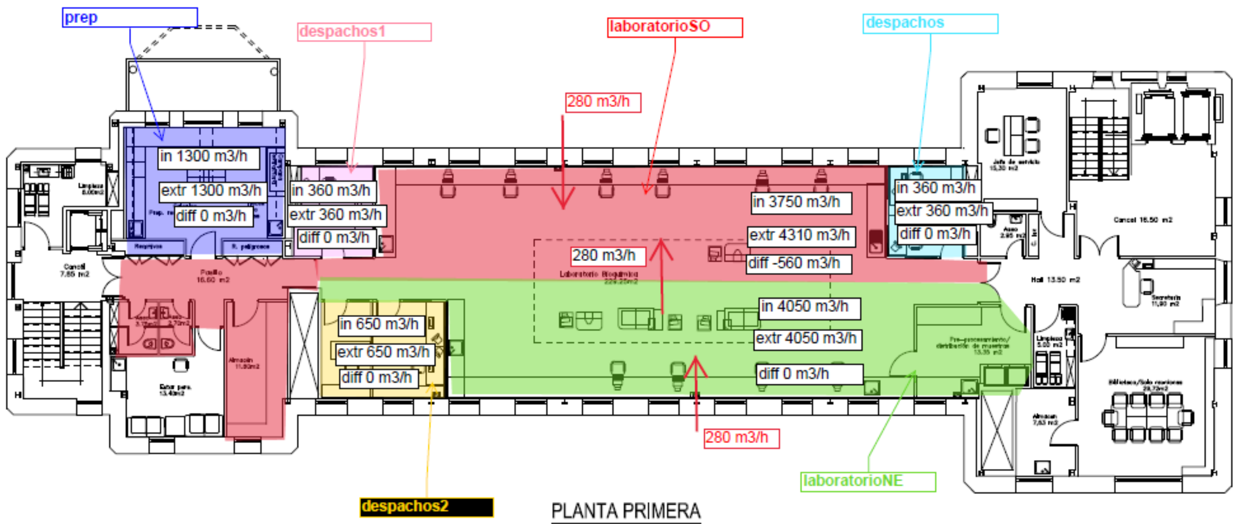


Figure 34. Gurtubay first floor

Second floor “2 Planta Segunda”:

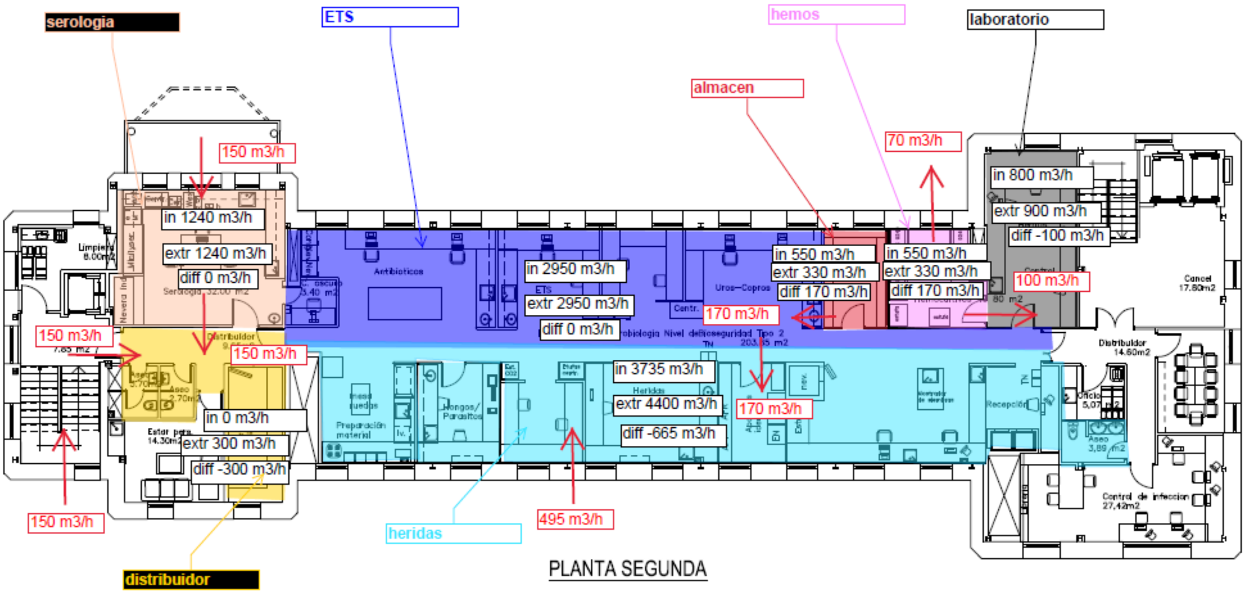


Figure 35. Gurtubay second floor

Third floor “3 Bajo Cubierta”:

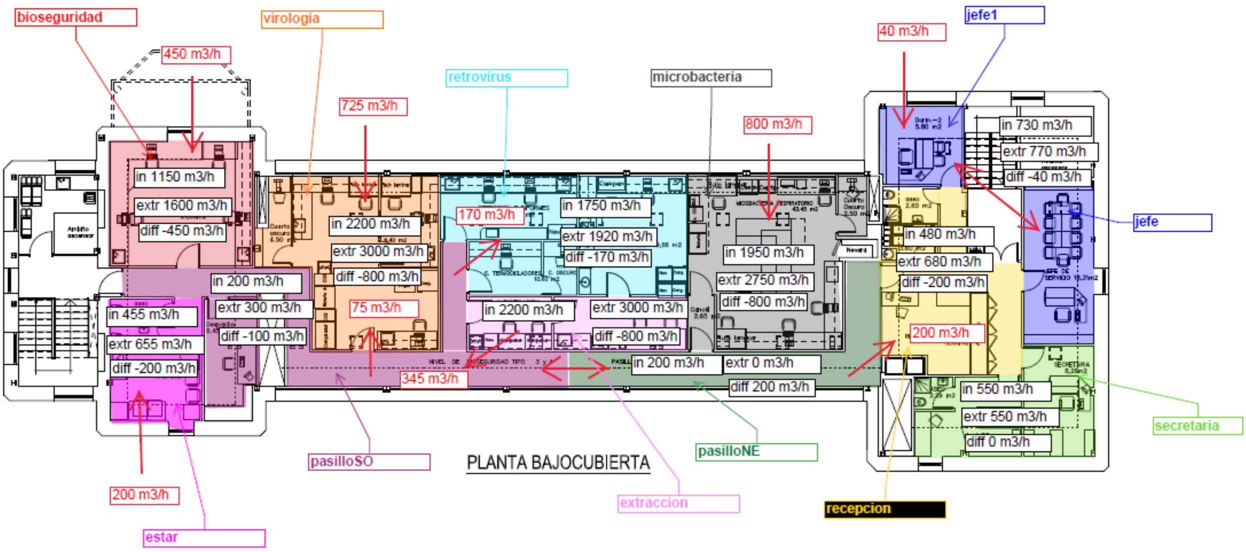


Figure 36. Gurtubay third floor

2.4 Areilza (Surgical Block)

2.4.1 3D geometry

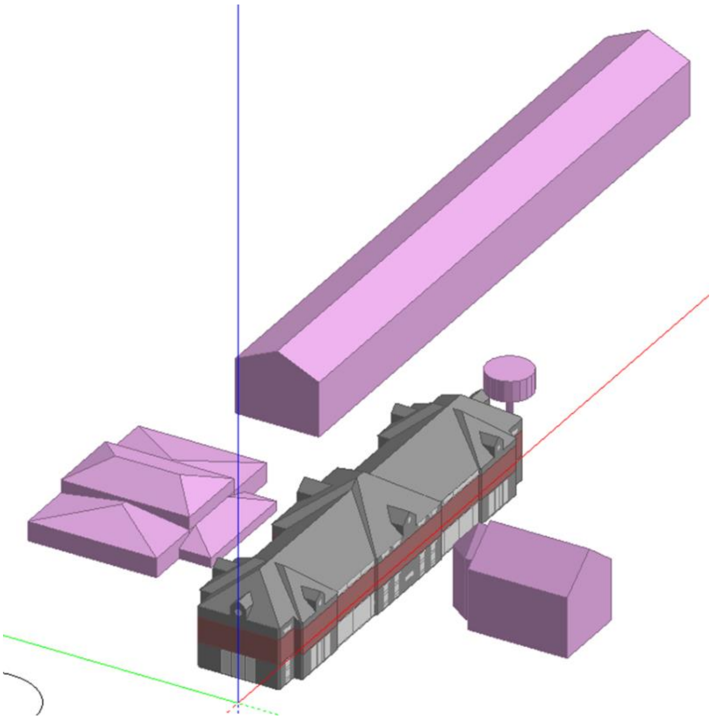


Figure 37. Areilza model (DesignBuilder)

In this case only the part of the building served by the AHU CL1 (2nd floor) and that one supplied by AHU CL3 (4th floor, named Bajocubierta) were modelled.
The third floor and the second floor were built like adiabatic floors.

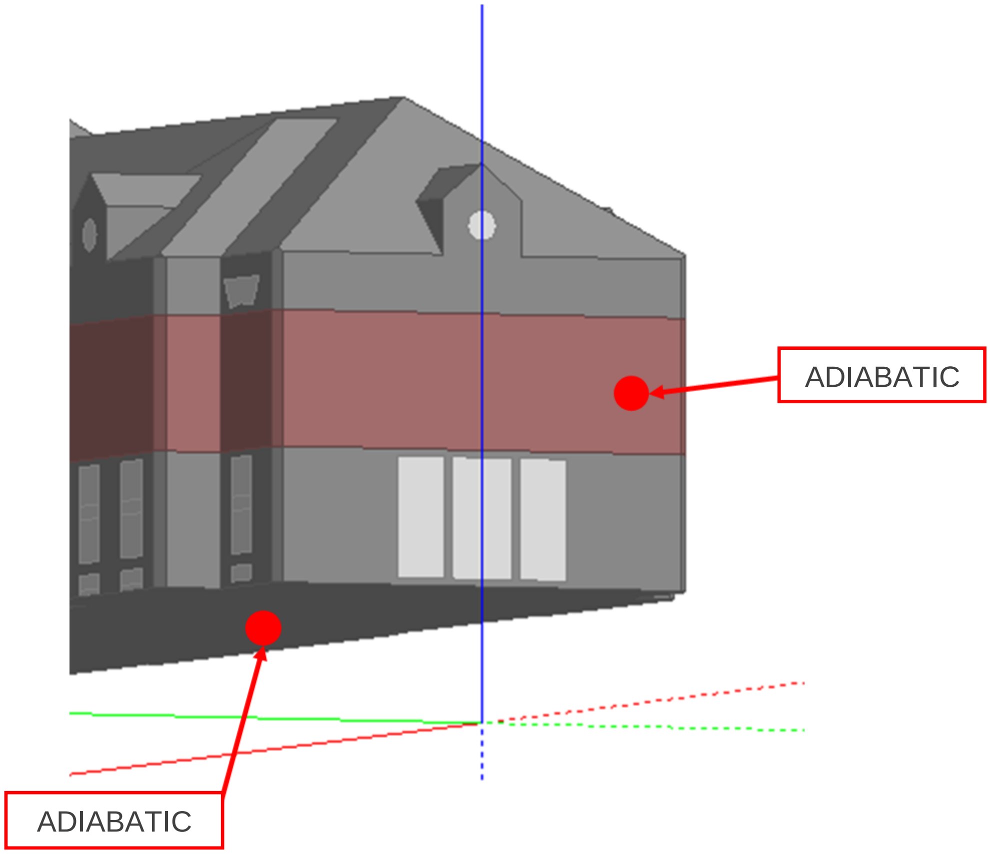


Figure 38. Areilza adiabatic boundary conditions (DesignBuilder)

2.4.2 Zones

Second floor:

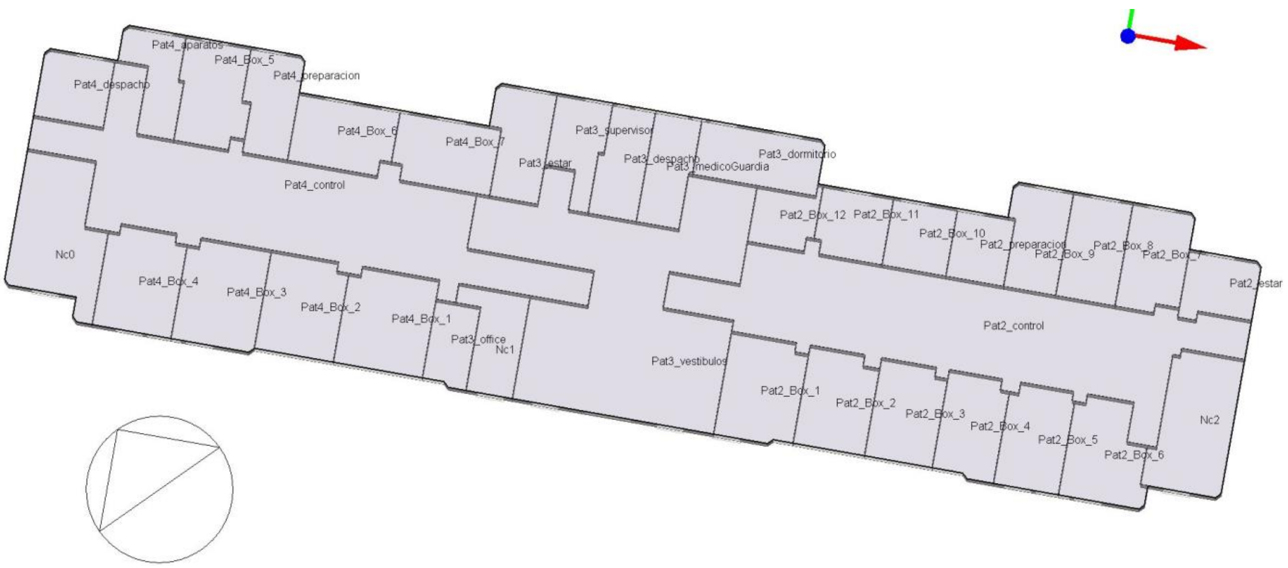


Figure 39. Areilza second floor

Fourth floor:

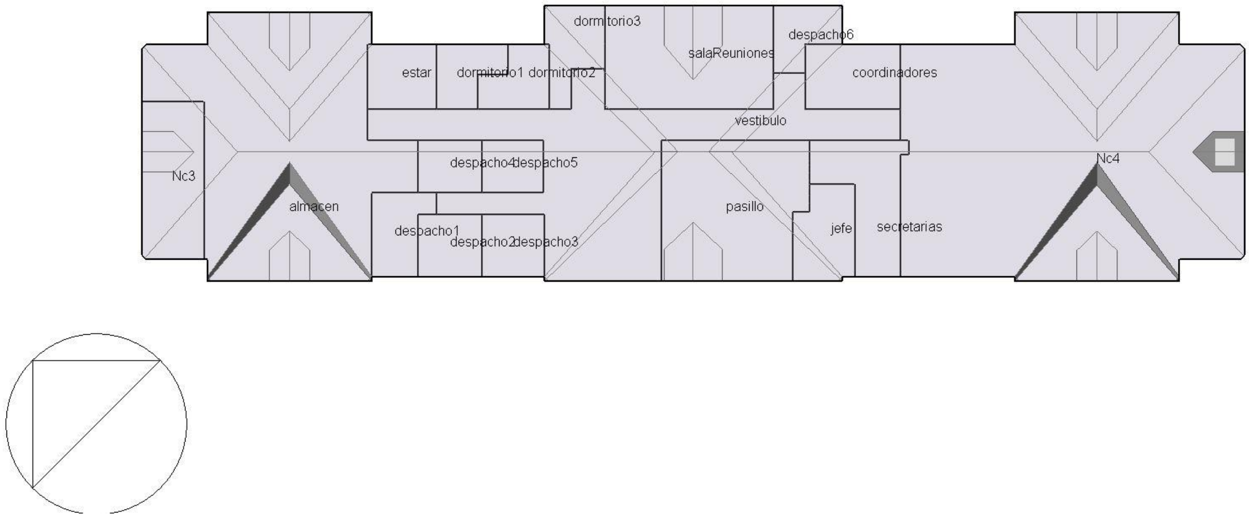


Figure 40. Areilza fourth floor

2.4.3 Stratigraphy of opaque surfaces

The international technical standard **ISO 6946:2007(E)-6.2.1 "**Total thermal resistance RT, of a component constituted by layers homogeneous and heterogeneous" has been used for the calculation of the thermal resistance of the roof of Areilza, where the thermal insulation is located among the elements of the metal structure.

The density of the "equivalent layer" that considers the combination of insulation and metal structure was calculated as a weighted average, using as weights the volumes of the different materials present in the structure. The specific heat was calculated as a weighted average using as weights the mass of the different materials present in the structure.

The external walls of Areilza are made of reinforced masonry. Its C value (thermal conductance, W/(m^{2}K)) was calculated through the FEM software THERM.

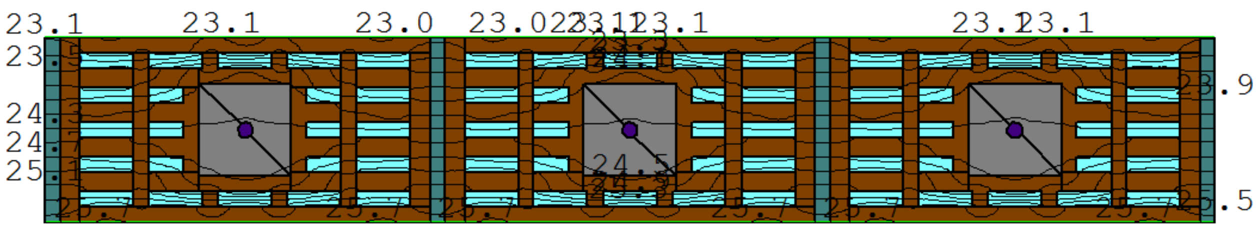


Figure 41. Reinforced masonry (THERM)

2.4.4 Features of glass surfaces

On the external side of glass, a reflective film is installed and on site it has been used a pyranometer to evaluate the ratio between the solar radiation flux density (W/m^2) entering through the window and the external solar radiation on a plane parallel to the window.

External solar radiation: 46 – 38,5 – 47 W/m^2. Mean value: 43,8 W/m^2

Internal solar radiation: 11 – 11 – 7,5 W/m^2. Mean value: 9,8 W/m^2

For diffuse radiation τ_e = 0,22

In the future other measurements will be made, with other sky conditions.

3 Heating, ventilation and air conditioning models

In this section, the building blocks of the models of the mechanical system is presented alongside a description of the interaction between the two modelling tools involved in the developed of the whole building detailed energy models. The different types of air handling units that can be found in Basurto and the different types of local zone control are also described in the following sections.

3.1 Interfacing via FMU and zone types

EnergyPlus[1] is a well-established, whole building energy simulation tool that considers a broad range of different characteristics of the buildings. It is an optimal tool to simulate the long-term (days, months and years) energy performance of the buildings. However, the implementation of the HVAC systems within EnergyPlus doesn't account for dynamics of diverse elements of such systems (heat exchangers, ducts, boilers, etc.) making this tool poorly accurate for short-term (minutes and hours) simulations. To overcome this issue, INDIGO has decided to integrate an EnergyPlus model of the buildings (geometry, materials, weather, internal gains) with HVAC models developed in Modelica via the Functional Mock-up Interface[2]. Figure 42. Modelica/EnergyPlus data exchange diagram shows the data exchange, at each time-step, between HVAC model in Modelica and each zone in the EnergyPlus building model.

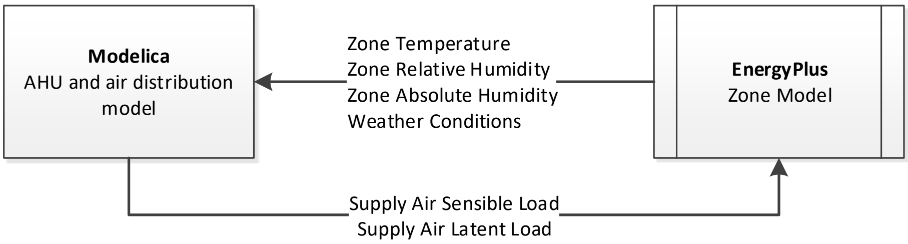


Figure 42. Modelica/EnergyPlus data exchange diagram

For the Aztarain building, this interconnection was done directly as the air coming from the main AHU was either supplied directly to the zone ('Aislamiento') or supplied to one of the 8 AHU_Type 2 units ('Salas'). However, given the size of the air distribution, the complexity of the air distribution system, the fact that each main AHU has different types of post-heating/cooling units and the possibilities for repetition in Areilza and Gurtubay, typical 'zone types' where developed in Modelica to enable a standardised interconnection and control between building models in EnergyPlus and HVAC in Modelica. Zone types represent the different ways local components and controls (not AHUs) are used in the buildings to maintain indoor environmental conditions.

These zone types are explained in the following paragraphs; however, some common characteristics are:

- All zone types have an 'enabling' signal (zoneHab). This means that zoneHab is true, a fixed air-flow is supplied and conditions controlled and when is false there is no supply air mass flow rate into the zone.
- The zone types with fan-coil units will have an additional fancoilHab signal for the fancoil.

[1] https://energyplus.net/
[2] http://fmi-standard.org/

- All zones types take as inputs from EnergyPlus: Zone Temperature (ºC), Zone Relative Humidity (%) and zone Temperature set-point (ºC).
- All zones types provide as outputs into EnergyPlus sensible heat flow (W) and latent heat flow (W).
- All zone types provide as outputs supply air temperature (ºC).
- All zone types with active elements (fancoils and heat exchangers) will have implemented a simple proportional-integral feed-back control.

3.1.1 zonePHC

zonePHC is a zone type where the air coming from the main AHU passes through a post-heating coil (PHC) before being delivered into the zone. Air from the zone is extracted through one path (port_b).

Modelica representation of zonePHC can be seen in Figure 43.

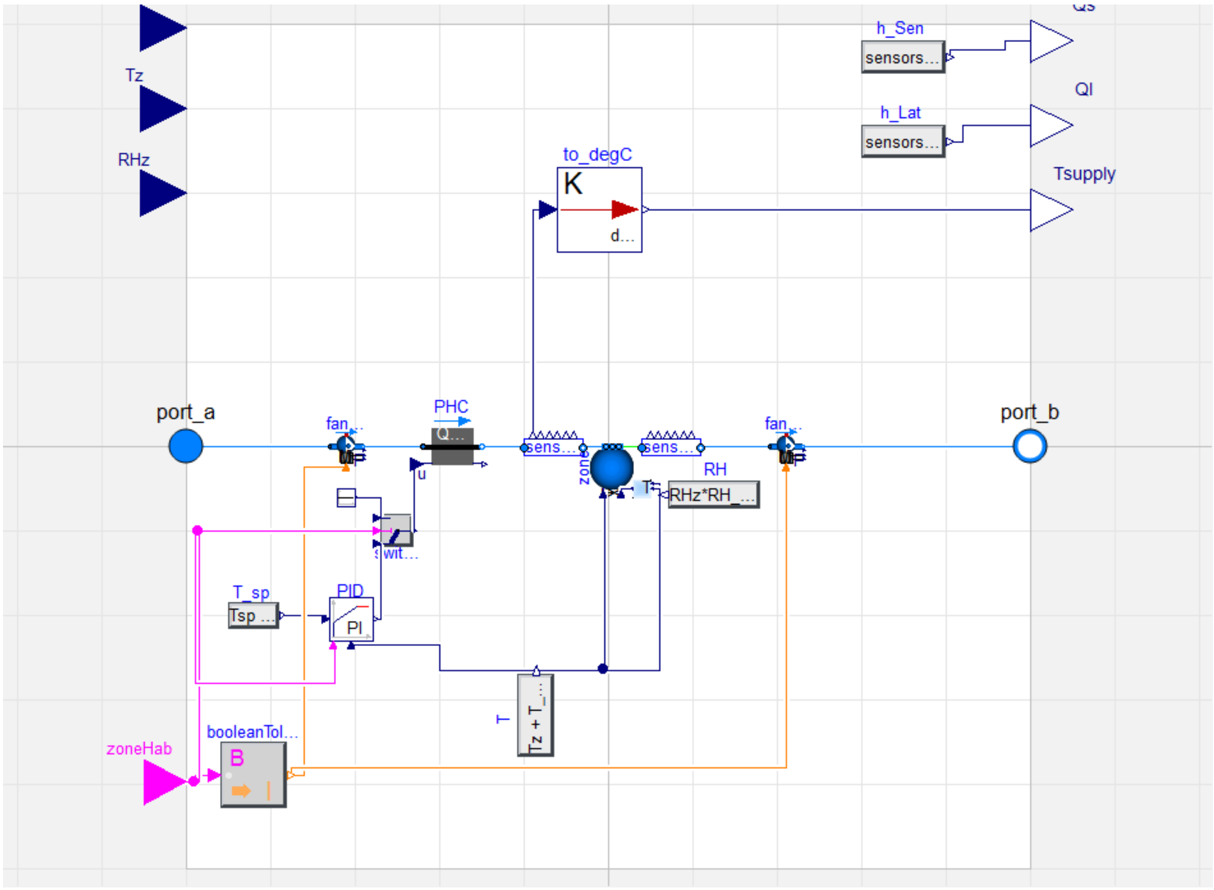


Figure 43. zonePHC Modelica model

3.1.2 zonePHCe

zonePHCe is a zone type where the air coming from the main AHU passes through a post-heating coil (PHC) before being delivered into the zone. Only difference with zonePHCe is that part of the return air goes into a different air path (e.g. exhaust – port_c). Air from the zone is extracted through two paths (port_b and port_c).

Modelica representation of zonePHCe can be seen in Figure 44.

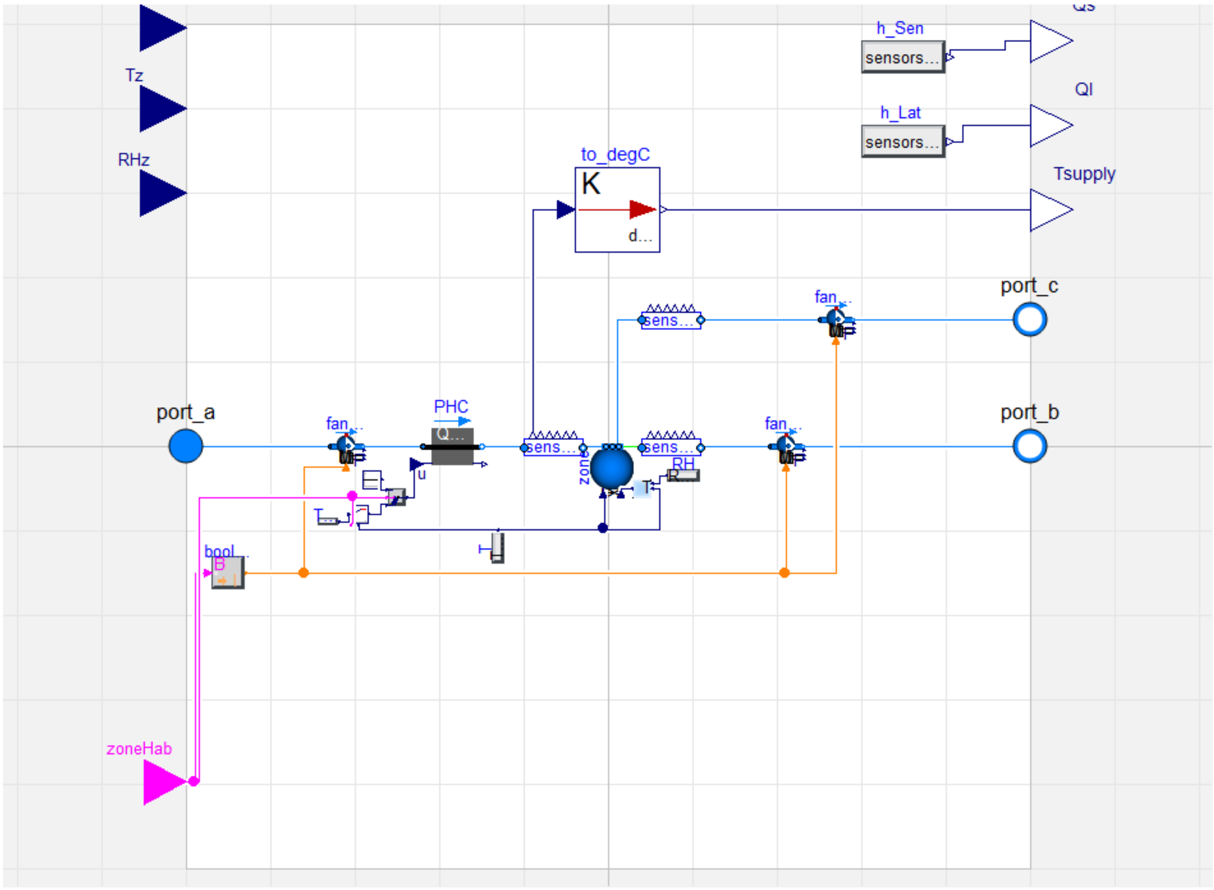


Figure 44. zonePHCe Modelica model

3.1.3 zonePHC_splitSupply

zonePHC_splitSupply is a zone type where the air coming from the main AHU passes through a post-heating coil (PHC) and then it is split into two air-flows, on being delivered into the zone and another following a different path (port_c). Air from the zone is extracted through one path (port_b).

Modelica representation of zonePHC_splitSupply can be seen in Figure 45.

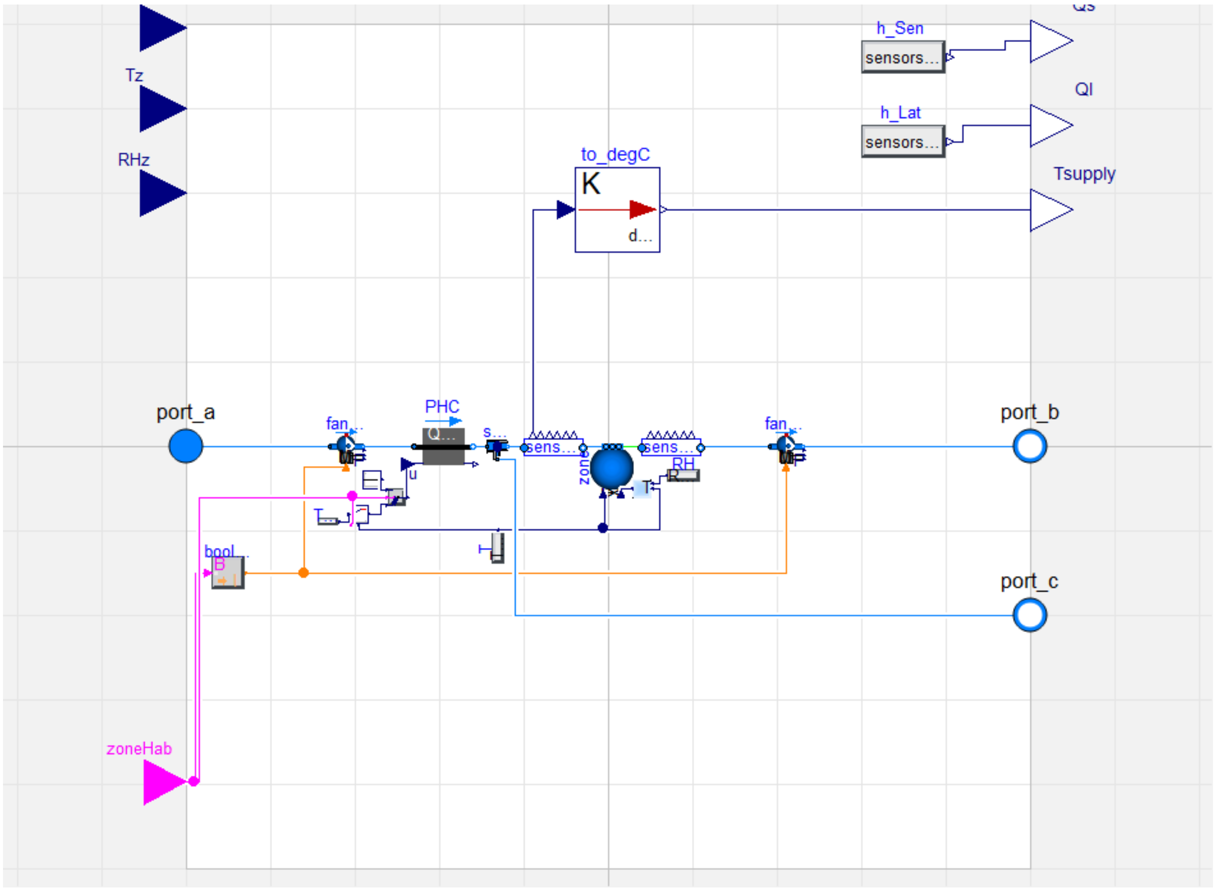


Figure 45. zonePHC_splitSupply Modelica model

3.1.4 zonePHC_PCC

zonePHC_PCC is a zone type where the air coming from the main AHU passes through a post-heating coil (PHC) and a post-cooling coil on being delivered into the zone. Air from the zone is extracted through one path (port_b)

Modelica representation of zonePHC_PCC can be seen in Figure 46.

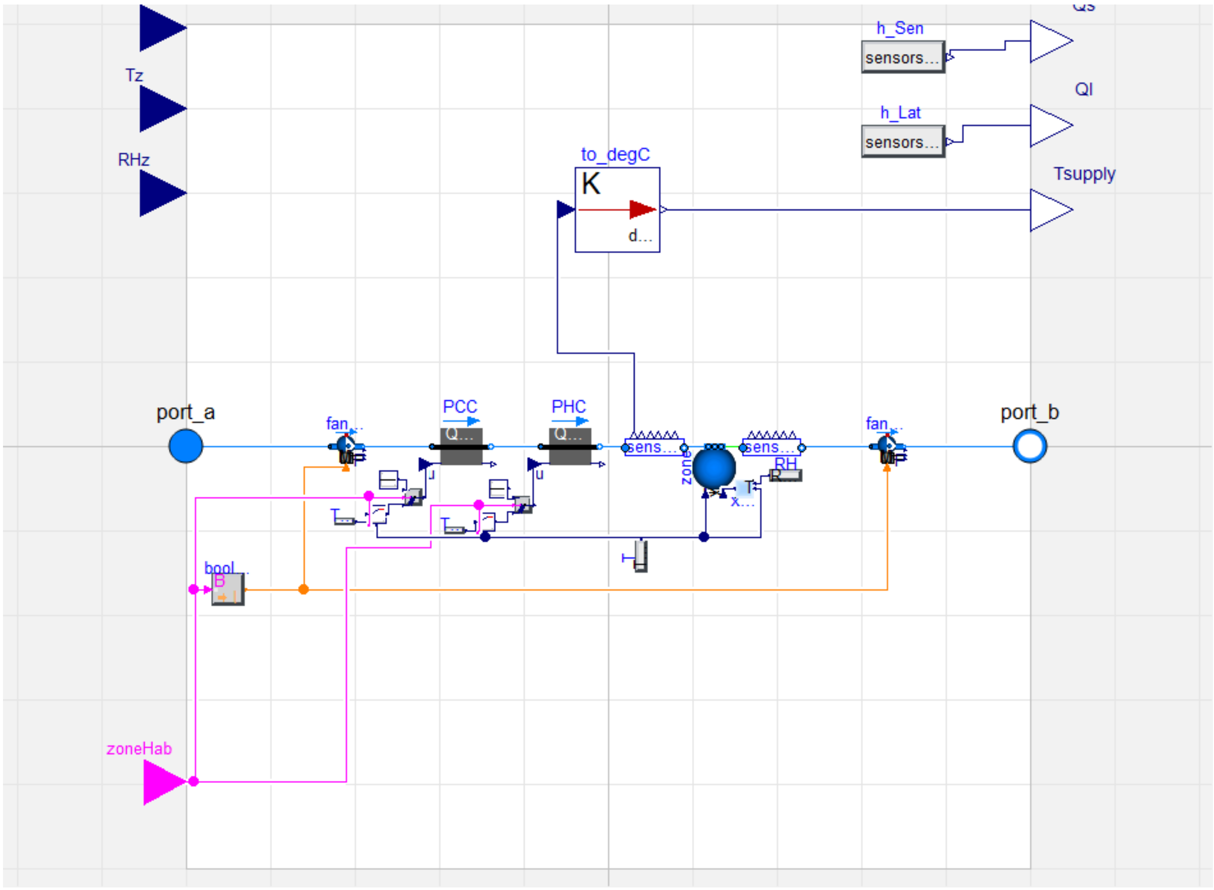


Figure 46. zonePHC_PCC Modelica model

3.1.5 zonePHC_PCC_splitSupply

zonePHC_PCC_splitSupply is a zone type where the air coming from the main AHU passes through a post-heating coil (PHC), then through a post-cooling coil and then it is split into two air-flows, on being delivered into the zone and another following a different path (port_c). Air from the zone is extracted through one path (port_b)

Modelica representation of zonePHC_PCC_splitSupply can be seen in Figure 47.

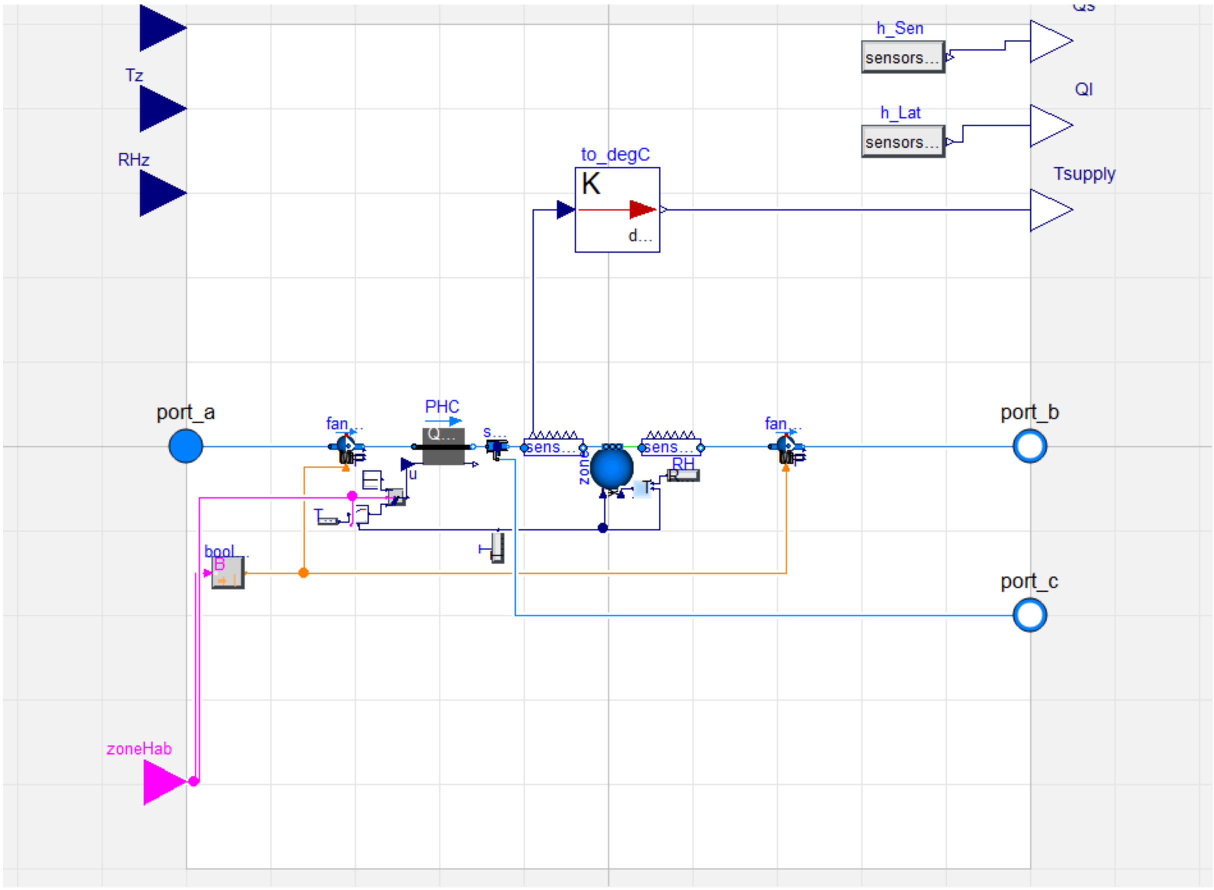


Figure 47. zonePHC_PCC_splitSupply Modelica model

3.1.6 zoneFancoil

zoneFancoil is a zone type where the air coming from the main AHU is delivered directly to the zone where a fancoil unit controls the environmental conditions (via recirculation of air). Air from the zone is extracted through one path (port_b)

Modelica representation of zoneFancoil can be seen in Figure 48.

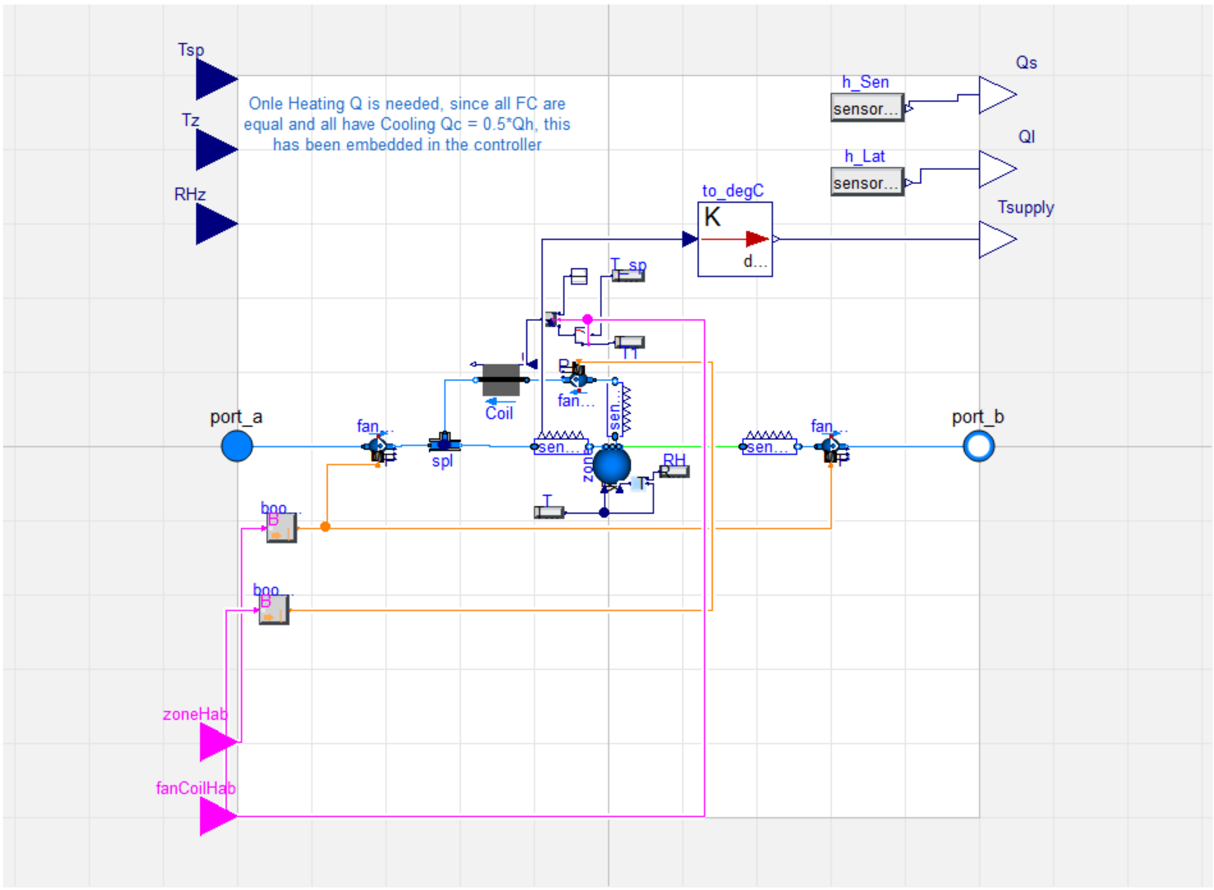


Figure 48. zoneFancoil modelica model

3.1.7 zoneFancile

zoneFancile is a zone type where the air coming from the main AHU is delivered directly to the zone where a fancoil unit controls environmental conditions (via recirculation of air). Air from the zone is extracted from two different paths (port_b and port_c)

Modelica representation of zoneFancile can be seen in Figure 49.

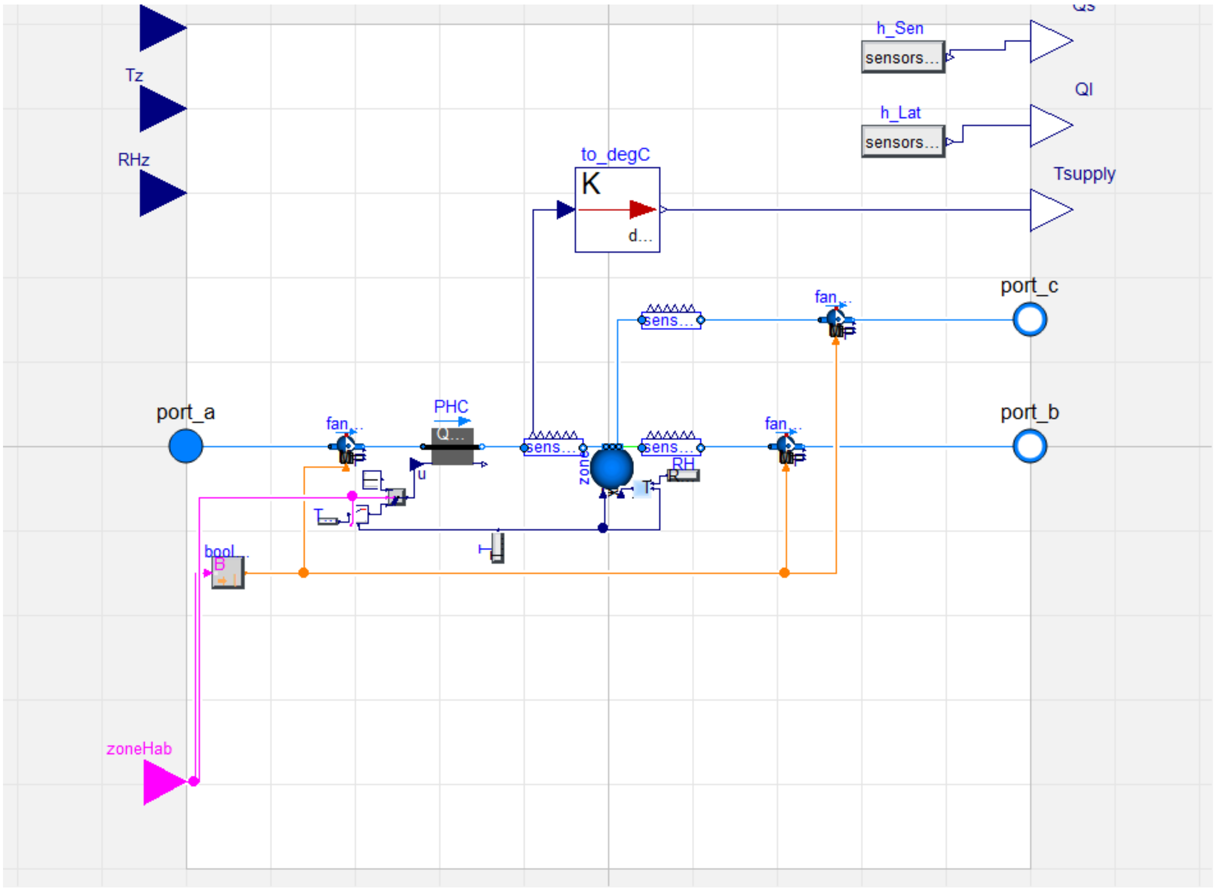


Figure 49. zoneFancile Modelica model

3.1.8 zoneVAV

zoneVAV is a zone type where the air coming from the main AHU is delivered directly to the zone. Air from the zone is extracted from one path (port_b). Environmental control is achieved through Variable Air Volume (VAV) Boxes in the supply and extract air paths which are controlled using standard configuration for this type of system (by controlling air-flow).

Modelica representation of zoneVAV can be seen in Figure 50.

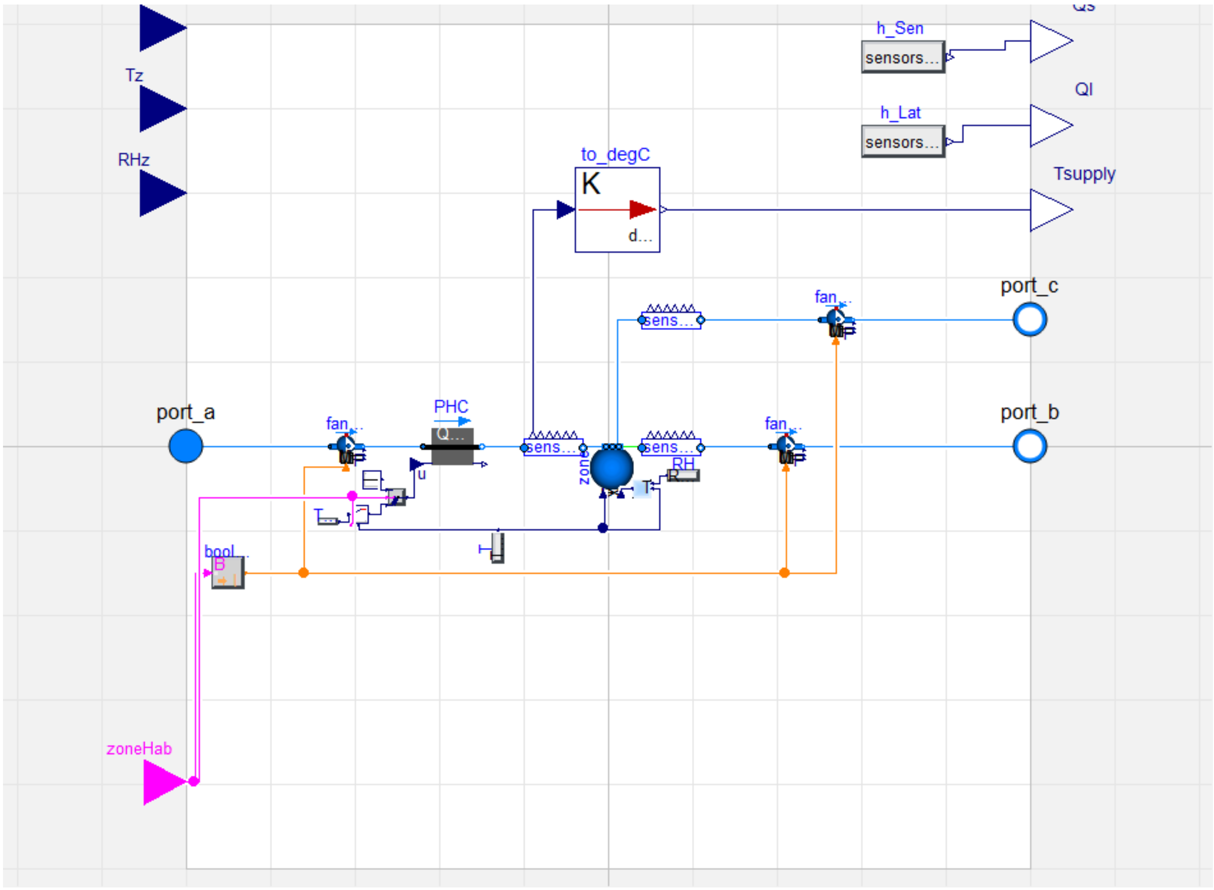


Figure 50. zoneVAV Modelica model

3.2 Air handling unit types and Modelica models

In Basurto, six types of air handling units were identified. These units are described below. Modelica models use components based on the Modelica.Fluid library to replicate the schematic of the units.

All units will have fresh (port_F) and supply (port_S) port connections. For those units with return air, return (port_R) and exhaust (port_E) port connection are added.

All units will output the heat flow of each active component (e.g. heating coils and cooling coils)

Since not information about the input conditions on the water side of the cooling coils is being gathered by the BMS, in the cooling coil models, conditions matching the nominal design conditions have been imposed. Such conditions correspond with constant input water temperature and constant maximum mass flow rate achieved when valve opening is at 100%.

In this section, schematics and general characteristics of the models are presented. For full information of the models, please revise the code.

3.2.1 Type 0/Fan coil

3.2.1.1 Brief description

This is a small unit consisting of a heat exchanger (CC) element and optionally a fan element.

3.2.1.2 Schematic

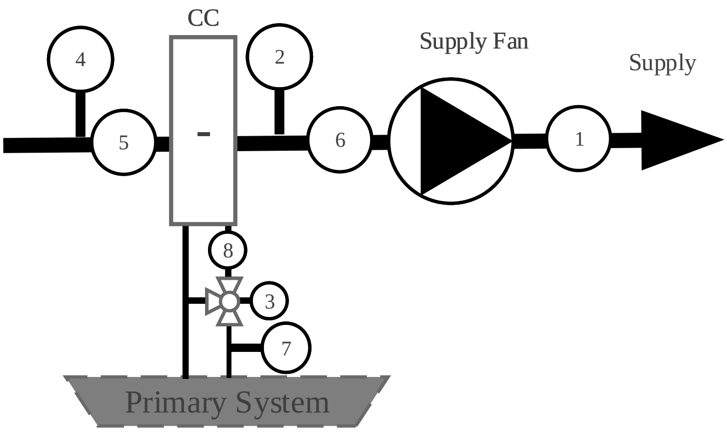


Figure 51. Type 0/Fan coil schematic.

3.2.1.3 Modelica model schematic

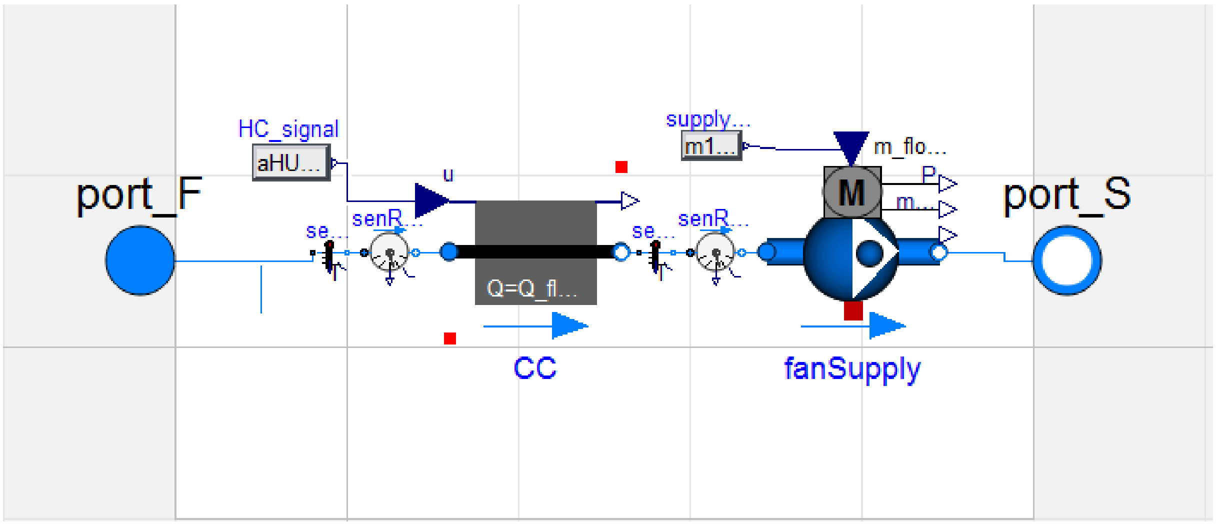


Figure 52. AHU Type 0/Fan coil Modelica model.

3.2.1.4 Input/output variables

Table 2. Input/output variables for AHU Type 0/Fan coil.

Component	Variable	Type	# in schematic
Fan Supply	air mass flow rate	Measurement	1
Heat Exchanger (CC)	Air output temperature	Measurement	2
Heat Exchanger (CC)	Valve position	Input	3
Heat Exchanger (CC)	Air input temperature	Measurement	4
Heat Exchanger (CC)	Air input relative humidity	Measurement	5
Heat Exchanger (CC)	Air output relative humidity	Measurement	6
Heat Exchanger (CC)	Water input temperature	Measurement	7
Heat Exchanger (CC)	Water mass flow rate	Measurement	8

3.2.1.5 Parameters needed to run the model

Table 3. Parameters needed to run model AHU Type 0/Fan coil.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Cooling Coil	Nominal air input temperature
Cooling Coil	Nominal air output temperature
Cooling Coil	Nominal air temperature difference
Cooling Coil	Nominal air input relative humidity
Cooling Coil	Nominal air output relative humidity
Cooling Coil	Nominal air mass flow rate
Cooling Coil	Nominal water input temperature
Cooling Coil	Nominal water output temperature
Cooling Coil	Nominal water output difference
Cooling Coil	Nominal water mass flow rate
Cooling Coil	Nominal power

3.2.2 Type 1

3.2.2.1 Brief description

This is full-sized air handling unit type and one of the most used in Basurto. It is composed of:

- Heat recovery (HR): two heat exchangers interconnected via a water circuit
- Cooling Coil (CC)
- Heating Coil (HC)

- Fans
- Humidifier (H)

3.2.2.2 Schematic

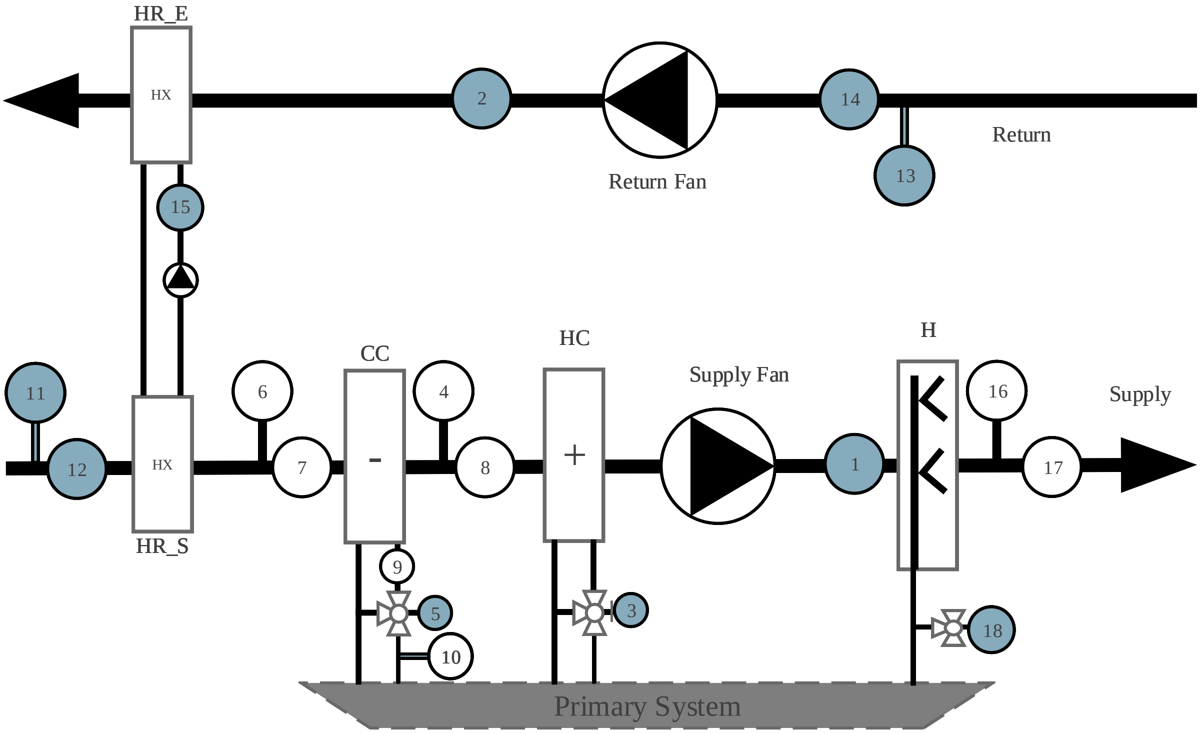


Figure 53. Type 1 schematic.

3.2.2.3 Modelica model schematic

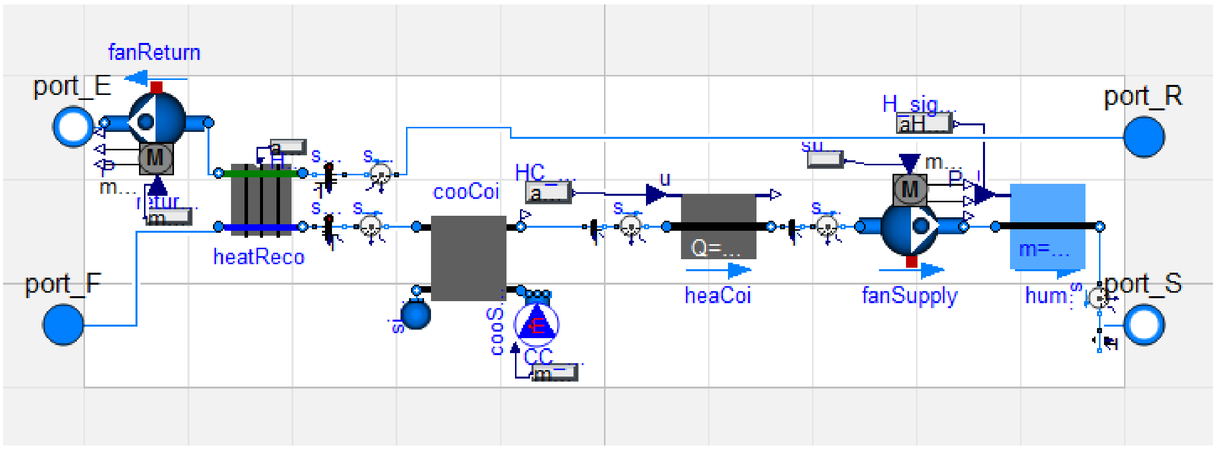


Figure 54. AHU Type 1 Modelica model.

3.2.2.4 Input/output variables

Table 4. Input/output variables for AHU Type 1.

Component	Variable	Type	# in schematic
Fan Supply	air mass flow rate	Measurement	1
Fan Return	air mass flow rate	Measurement	2
Heating Coil	Valve position	Input	3
Cooling Coil	Air output temperature	Measurement	4
Cooling Coil	Valve position	Input	5
Cooling Coil	Air input temperature	Measurement	6
Cooling Coil	Air input relative humidity	Measurement	7

Cooling Coil	Air output relative humidity	Measurement	8
Cooling Coil	Water mass flow rate	Measurement	9
Cooling Coil	Water input temperature	Measurement	10
Heat Recovery Supply Path	Air input temperature	Measurement	11
Heat Recovery Supply Path	Air input relative humidity	Measurement	12
Heat Recovery Exhaust Path	air input temperature	Measurement	13
Heat Recovery Exhaust Path	Air input relative humidity	Measurement	14
Heat Recovery Exhaust Path	water mass flow rate	Measurement	15
Humidifier	Air output temperature	Measurement	16
Humidifier	Air output relative humidity	Measurement	17
Humidifier	Valve position	Input	18
Heat Recovery Exhaust Path	Air output temperature	Measurement	19
Heat Recovery Exhaust Path	Air output relative humidity	Measurement	20
Heat Recovery water Path	Pump differential pressure	Measurement	21
Heating Coil	Air output temperature	Measurement	22
Heating Coil	Air output relative humidity	Measurement	23
Heating Coil	Water input temperature	Measurement	24
Cooling Coil	Water output temperature	Measurement	25
Fan Supply	Pump differential pressure	Measurement	26
Fan Return	Pump differential pressure	Measurement	27

3.2.2.5 Parameters needed to run the model

Table 5. Parameters needed to run model AHU Type 1.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Fan Return	Nominal air mass flow rate
Fan Return	Nominal power
Heating Coil	Nominal air mass flow rate
Heating Coil	Nominal power
Cooling Coil	Nominal air input temperature
Cooling Coil	Nominal air output temperature
Cooling Coil	Nominal air temperature difference
Cooling Coil	Nominal air input relative humidity
Cooling Coil	Nominal air output relative humidity
Cooling Coil	Nominal air mass flow rate
Cooling Coil	Nominal water input temperature
Cooling Coil	Nominal water output temperature
Cooling Coil	Nominal water output difference
Cooling Coil	Nominal water mass flow rate
Cooling Coil	Nominal power
Heat Recovery Supply Path	Nominal air input temperature
Heat Recovery Supply Path	Nominal air output temperature
Heat Recovery Supply Path	Nominal air temperature difference
Heat Recovery Supply Path	Nominal air input relative humidity
Heat Recovery Supply Path	Nominal air output relative humidity
Heat Recovery Supply Path	Nominal air mass flow rate
Heat Recovery Supply Path	Nominal water input temperature
Heat Recovery Supply Path	Nominal water output temperature
Heat Recovery Supply Path	Nominal water output difference
Heat Recovery Supply Path	Nominal water mass flow rate
Heat Recovery Supply Path	Nominal power
Heat Recovery Exhaust Path	Nominal air input temperature
Heat Recovery Exhaust Path	Nominal air output temperature
Heat Recovery Exhaust Path	Nominal air temperature difference
Heat Recovery Exhaust Path	Nominal air input relative humidity
Heat Recovery Exhaust Path	Nominal air output relative humidity
Heat Recovery Exhaust Path	Nominal air mass flow rate
Heat Recovery Exhaust Path	Nominal water input temperature
Heat Recovery Exhaust Path	Nominal water output temperature
Heat Recovery Exhaust Path	Nominal water output difference
Heat Recovery Exhaust Path	Nominal water mass flow rate
Heat Recovery Exhaust Path	Nominal power
Humidifier	Maximum steam mass flow rate
Humidifier	Steam temperature

3.2.3 Type 2

3.2.3.1 Brief description

Similar to Type 0 but adding an extra heat exchanger so the unit can heat (HC), cool and dehumidify (CC).

3.2.3.2 Schematic

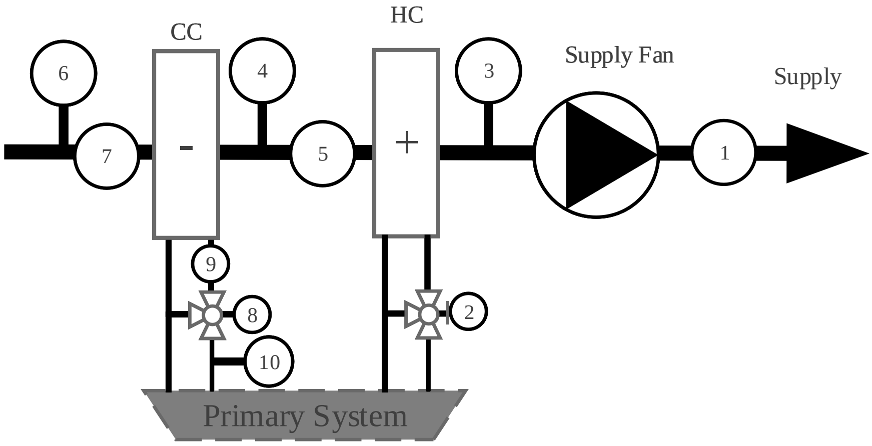


Figure 55. Type 2 schematic.

3.2.3.3 Modelica model schematic

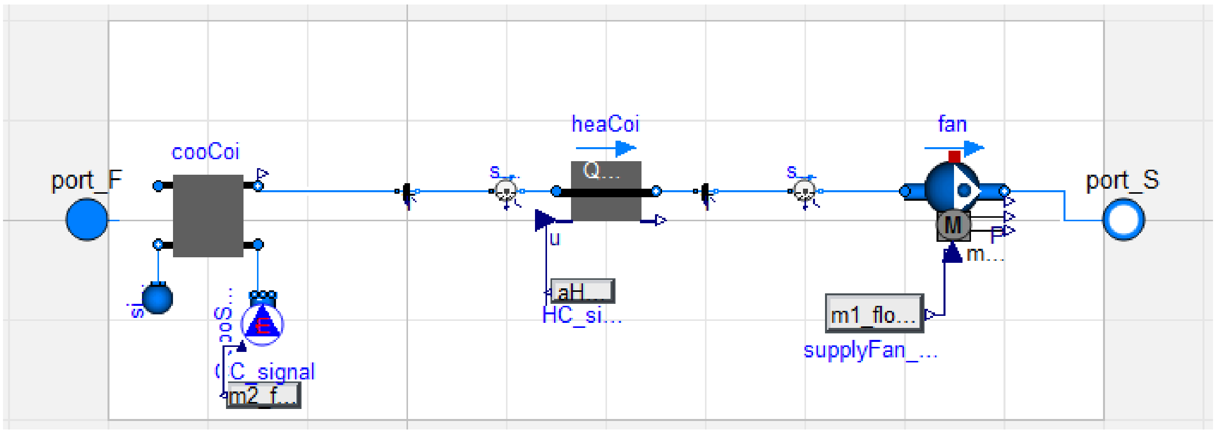


Figure 56. AHU Type 2 Modelica model.

3.2.3.4 Input/output variables

Table 6. Input/output variables for AHU Type 2.

Component	Variable	Type	# in schematic
Fan Supply	air mass flow rate	Measurement	1
Heating Coil	Valve position	Input	2
Heating Coil	air output temperature	Measurement	3
Cooling Coil	air output temperature	Measurement	4
Cooling Coil	Air output relative humidity	Measurement	5
Cooling Coil	air input temperature	Measurement	6
Cooling Coil	air input relative humidity	Measurement	7
Cooling Coil	Valve position	Input	8
Cooling Coil	water mass flow rate	Measurement	9
Cooling Coil	Water input temperature	Measurement	10
Heating Coil	Air output relative humidity	Measurement	11
Cooling Coil	Water output temperature	Measurement	12

3.2.3.5 Parameters needed to run the model

Table 7. Parameters needed to run model AHU Type 2.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Cooling Coil	Nominal air input temperature
Cooling Coil	Nominal air output temperature
Cooling Coil	Nominal air temperature difference
Cooling Coil	Nominal air input relative humidity
Cooling Coil	Nominal air output relative humidity
Cooling Coil	Nominal air mass flow rate
Cooling Coil	Nominal water input temperature
Cooling Coil	Nominal water output temperature
Cooling Coil	Nominal water output difference
Cooling Coil	Nominal water mass flow rate
Cooling Coil	Nominal power
Heating Coil	Nominal air mass flow rate
Heating Coil	Nominal power

3.2.4 Type 3

3.2.4.1 Brief description

This unit is composed of:

- Heat recovery (HR)
- Cooling Coil 1 (CC_1)
- Cooling Coil 2 (CC_2)
- Fans
- Humidifier
- Heating Coil (HC)

No Modelica model has yet been developed for this unit type as it is not present in the buildings selected for model development.

3.2.4.2 Schematic

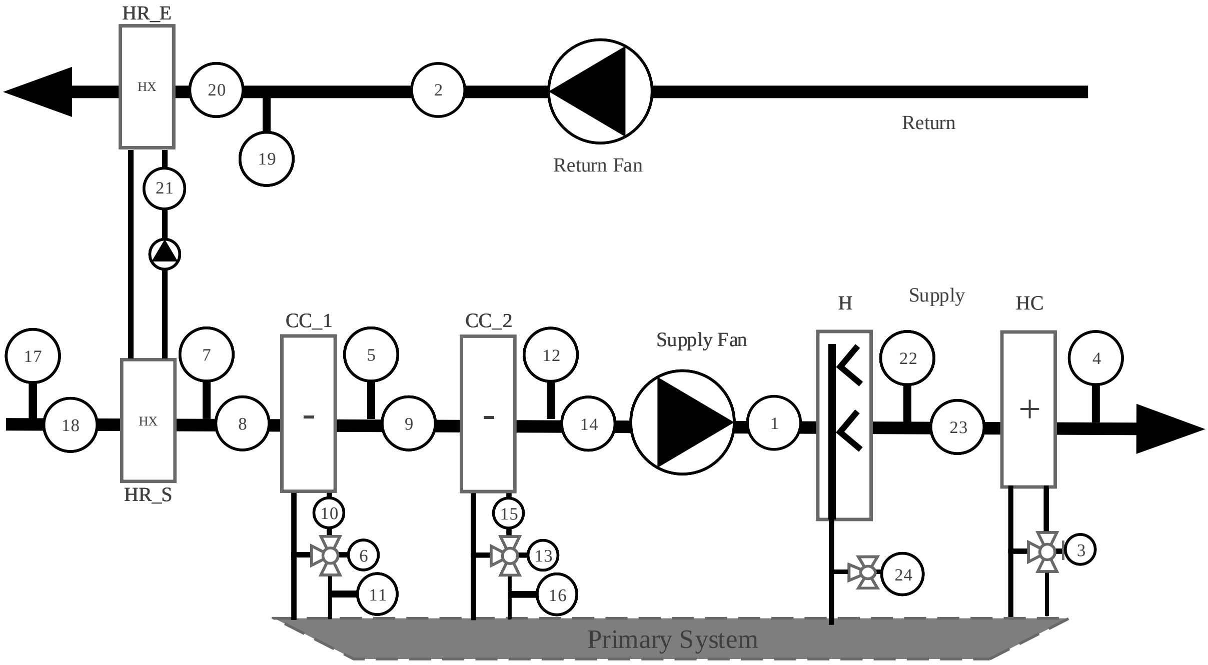


Figure 57. Type 3 schematic.

3.2.4.3 Modelica model schematic

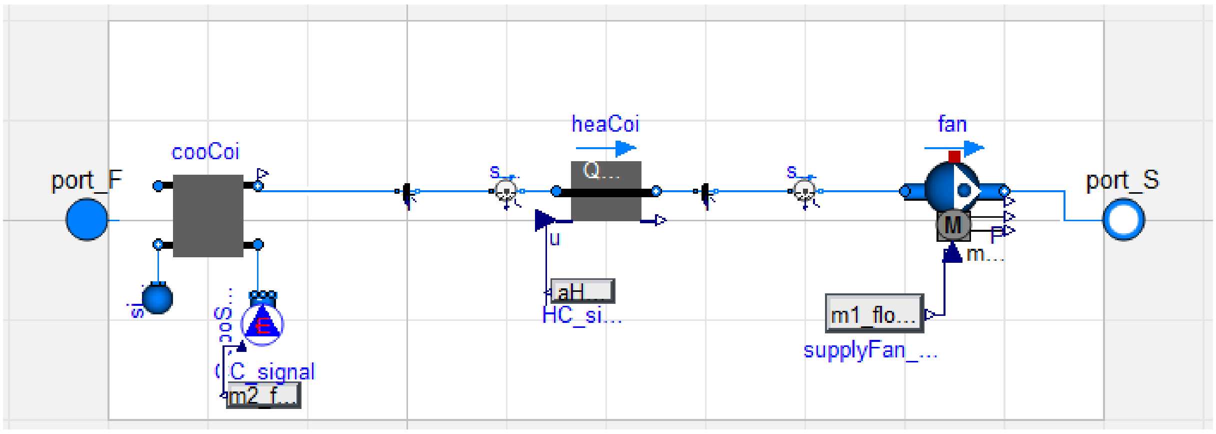


Figure 58. AHU Type 3 Modelica model.

3.2.4.4 Input/output variables

Table 8. Input/output variables for AHU Type 3.

Component	Variable	Type	# in schematic
Fan Supply	air mass flow rate	Measurement	1
Fan Return	air mass flow rate	Measurement	2
Heating Coil	Valve position	Input	3
Heating Coil	Air output temperature	Measurement	4
Cooling Coil 1	Air output temperature	Measurement	5
Cooling Coil 1	Valve position	Input	6
Cooling Coil 1	Air input temperature	Measurement	7
Cooling Coil 1	Air input relative humidity	Measurement	8
Cooling Coil 1	Air output relative humidity	Measurement	9
Cooling Coil 1	Water mass flow rate	Measurement	10
Cooling Coil 1	Water input temperature	Measurement	11
Cooling Coil 2	Air output temperature	Measurement	12
Cooling Coil 2	Valve position	Input	13
Cooling Coil 2	Air output relative humidity	Measurement	14
Cooling Coil 2	Water mass flow rate	Measurement	15
Cooling Coil 2	Water input temperature	Measurement	16
Heat Recovery Supply Path	Air input temperature	Measurement	17
Heat Recovery Supply Path	Air input relative humidity	Measurement	18
Heat Recovery Exhaust Path	air input temperature	Measurement	19
Heat Recovery Exhaust Path	Air input relative humidity	Measurement	20
Heat Recovery Exhaust Path	water mass flow rate	Measurement	21
Humidifier	Air output temperature	Measurement	22
Humidifier	Air output relative humidity	Measurement	23
Humidifier	Valve position	Input	24

3.2.4.5 Parameters needed to run the model

Table 9. Parameters needed to run model AHU Type 3.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Fan Return	Nominal air mass flow rate
Fan Return	Nominal power
Heating Coil	Nominal air mass flow rate
Heating Coil	Nominal power
Cooling Coil 1	Nominal air input temperature
Cooling Coil 1	Nominal air output temperature
Cooling Coil 1	Nominal air temperature difference
Cooling Coil 1	Nominal air input relative humidity
Cooling Coil 1	Nominal air output relative humidity
Cooling Coil 1	Nominal air mass flow rate
Cooling Coil 1	Nominal water input temperature

Cooling Coil 1	Nominal water output temperature
Cooling Coil 1	Nominal water output difference
Cooling Coil 1	Nominal water mass flow rate
Cooling Coil 1	Nominal power
Cooling Coil 2	Nominal air input temperature
Cooling Coil 2	Nominal air output temperature
Cooling Coil 2	Nominal air temperature difference
Cooling Coil 2	Nominal air input relative humidity
Cooling Coil 2	Nominal air output relative humidity
Cooling Coil 2	Nominal air mass flow rate
Cooling Coil 2	Nominal water input temperature
Cooling Coil 2	Nominal water output temperature
Cooling Coil 2	Nominal water output difference
Cooling Coil 2	Nominal water mass flow rate
Cooling Coil 2	Nominal power
Heat Recovery Supply Path	Nominal air input temperature
Heat Recovery Supply Path	Nominal air output temperature
Heat Recovery Supply Path	Nominal air temperature difference
Heat Recovery Supply Path	Nominal air input relative humidity
Heat Recovery Supply Path	Nominal air output relative humidity
Heat Recovery Supply Path	Nominal air mass flow rate
Heat Recovery Supply Path	Nominal water input temperature
Heat Recovery Supply Path	Nominal water output temperature
Heat Recovery Supply Path	Nominal water output difference
Heat Recovery Supply Path	Nominal water mass flow rate
Heat Recovery Supply Path	Nominal power
Heat Recovery Exhaust Path	Nominal air input temperature
Heat Recovery Exhaust Path	Nominal air output temperature
Heat Recovery Exhaust Path	Nominal air temperature difference
Heat Recovery Exhaust Path	Nominal air input relative humidity
Heat Recovery Exhaust Path	Nominal air output relative humidity
Heat Recovery Exhaust Path	Nominal air mass flow rate
Heat Recovery Exhaust Path	Nominal water input temperature
Heat Recovery Exhaust Path	Nominal water output temperature
Heat Recovery Exhaust Path	Nominal water output difference
Heat Recovery Exhaust Path	Nominal water mass flow rate
Heat Recovery Exhaust Path	Nominal power
Humidifier	Maximum steam mass flow rate
Humidifier	Steam temperature

3.2.5 Type 4

3.2.5.1 Brief description

This unit is composed of:

- Heat recovery 1 (HR_1)
- Cooling Coil (CC, composed of two coils in parallel)
- Heat recovery 1 (HR_1)
- Heating Coil (HC)
- Fans
- Humidifier

3.2.5.2 Schematic

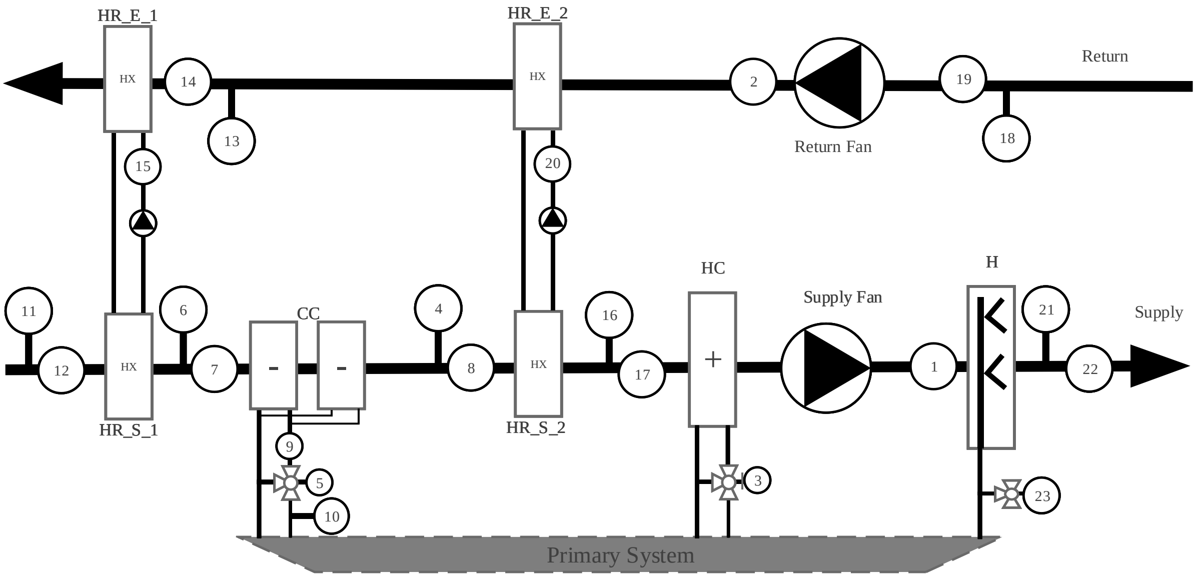


Figure 59. Type 4 schematic.

3.2.5.3 Modelica model schematic

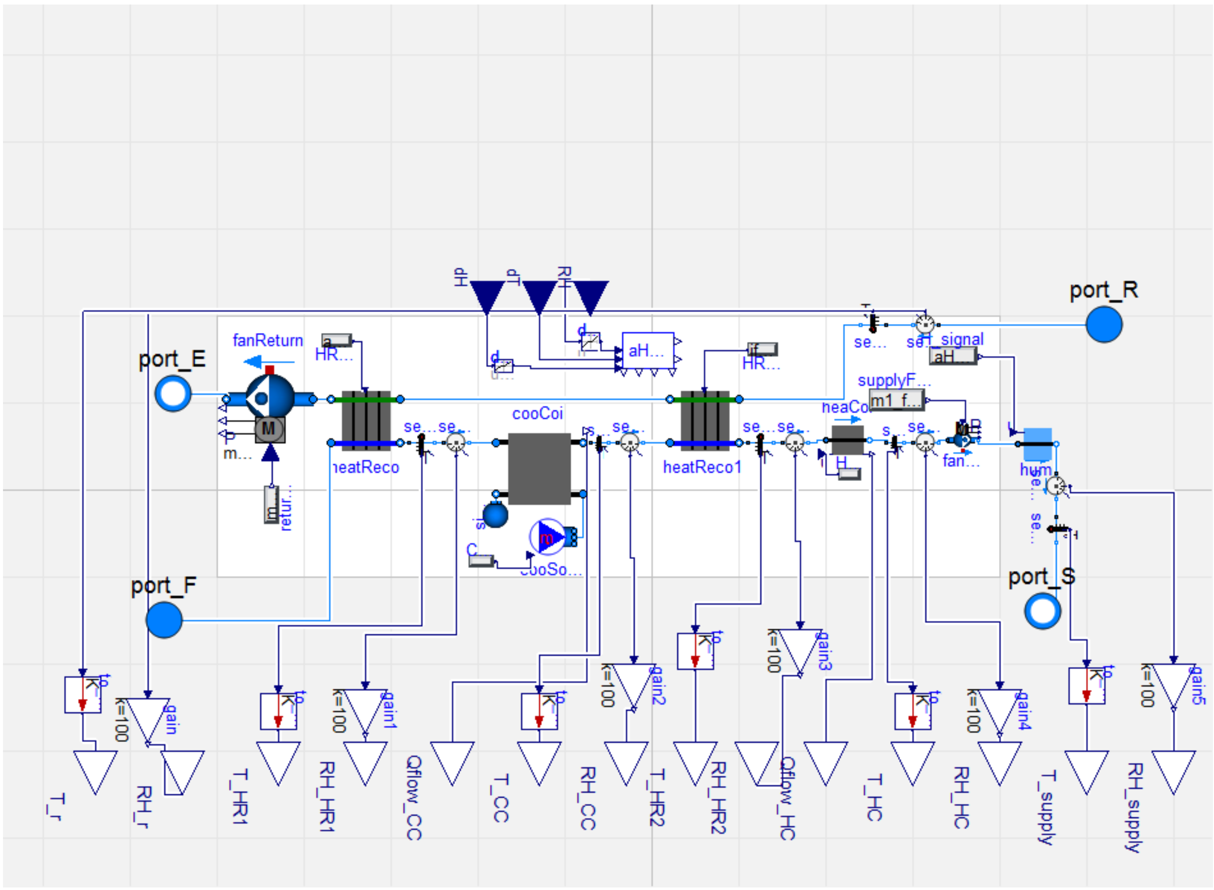


Figure 60. AHU Type 4 Modelica model.

3.2.5.4 Input/output variables

Table 10. Input/output variables for AHU Type 4.

Component	Variable	Type	# in schematic
Fan Return	air mass flow rate	Measurement	2
Heating Coil	Valve position	Input	3
Cooling Coil	Air output temperature	Measurement	4
Cooling Coil	Valve position	Input	5
Cooling Coil	Air input temperature	Measurement	6
Cooling Coil	Air input relative humidity	Measurement	7
Cooling Coil	Air output relative humidity	Measurement	8
Cooling Coil	Water mass flow rate	Measurement	9
Cooling Coil	Water input temperature	Measurement	10
Heat Recovery Supply Path 1	Air input temperature	Measurement	11
Heat Recovery Supply Path 1	Air input relative humidity	Measurement	12
Heat Recovery Exhaust Path 1	air input temperature	Measurement	13
Heat Recovery Exhaust Path 1	Air input relative humidity	Measurement	14
Heat Recovery Exhaust Path 1	water mass flow rate	Measurement	15
Heat Recovery Supply Path 2	Air output temperature	Measurement	16
Heat Recovery Supply Path 2	Air output relative humidity	Measurement	17
Heat Recovery Exhaust Path 2	air input temperature	Measurement	18
Heat Recovery Exhaust Path 2	Air input relative humidity	Measurement	19
Heat Recovery Exhaust Path 2	water mass flow rate	Measurement	20
Humidifier	Air output temperature	Measurement	21
Humidifier	Air output relative humidity	Measurement	22
Humidifier	Valve position	Input	23
Heat Recovery Exhaust Path 2	Air output temperature	Measurement	24
Heat Recovery Exhaust Path 1	Air output relative humidity	Measurement	25
Fan supply	Pump differential pressure	Measurement	26
Fan return	Pump differential pressure	Measurement	27

3.2.5.5 Parameters needed to run the model

Table 11. Parameters needed to run model AHU Type 4.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Fan Return	Nominal air mass flow rate
Fan Return	Nominal power
Heating Coil	Nominal air mass flow rate
Heating Coil	Nominal power
Cooling Coil	Nominal air input temperature
Cooling Coil	Nominal air output temperature
Cooling Coil	Nominal air temperature difference
Cooling Coil	Nominal air input relative humidity
Cooling Coil	Nominal air output relative humidity
Cooling Coil	Nominal air mass flow rate
Cooling Coil	Nominal water input temperature
Cooling Coil	Nominal water output temperature
Cooling Coil	Nominal water output difference
Cooling Coil	Nominal water mass flow rate
Cooling Coil	Nominal power
Heat Recovery 1 Supply Path	Nominal air input temperature
Heat Recovery 1 Supply Path	Nominal air output temperature
Heat Recovery 1 Supply Path	Nominal air temperature difference
Heat Recovery 1 Supply Path	Nominal air input relative humidity
Heat Recovery 1 Supply Path	Nominal air output relative humidity
Heat Recovery 1 Supply Path	Nominal air mass flow rate
Heat Recovery 1 Supply Path	Nominal water input temperature
Heat Recovery 1 Supply Path	Nominal water output temperature
Heat Recovery 1 Supply Path	Nominal water output difference
Heat Recovery 1 Supply Path	Nominal water mass flow rate
Heat Recovery 1 Supply Path	Nominal power
Heat Recovery 1 Exhaust Path	Nominal air input temperature
Heat Recovery 1 Exhaust Path	Nominal air output temperature
Heat Recovery 1 Exhaust Path	Nominal air temperature difference
Heat Recovery 1 Exhaust Path	Nominal air input relative humidity
Heat Recovery 1 Exhaust Path	Nominal air output relative humidity
Heat Recovery 1 Exhaust Path	Nominal air mass flow rate

Heat Recovery 1 Exhaust Path	Nominal water input temperature
Heat Recovery 1 Exhaust Path	Nominal water output temperature
Heat Recovery 1 Exhaust Path	Nominal water output difference
Heat Recovery 1 Exhaust Path	Nominal water mass flow rate
Heat Recovery 1 Exhaust Path	Nominal power
Heat Recovery 2 Supply Path	Nominal air input temperature
Heat Recovery 2 Supply Path	Nominal air output temperature
Heat Recovery 2 Supply Path	Nominal air temperature difference
Heat Recovery 2 Supply Path	Nominal air input relative humidity
Heat Recovery 2 Supply Path	Nominal air output relative humidity
Heat Recovery 2 Supply Path	Nominal air mass flow rate
Heat Recovery 2 Supply Path	Nominal water input temperature
Heat Recovery 2 Supply Path	Nominal water output temperature
Heat Recovery 2 Supply Path	Nominal water output difference
Heat Recovery 2 Supply Path	Nominal water mass flow rate
Heat Recovery 2 Supply Path	Nominal power
Heat Recovery 2 Exhaust Path	Nominal air input temperature
Heat Recovery 2 Exhaust Path	Nominal air output temperature
Heat Recovery 2 Exhaust Path	Nominal air temperature difference
Heat Recovery 2 Exhaust Path	Nominal air input relative humidity
Heat Recovery 2 Exhaust Path	Nominal air output relative humidity
Heat Recovery 2 Exhaust Path	Nominal air mass flow rate
Heat Recovery 2 Exhaust Path	Nominal water input temperature
Heat Recovery 2 Exhaust Path	Nominal water output temperature
Heat Recovery 2 Exhaust Path	Nominal water output difference
Heat Recovery 2 Exhaust Path	Nominal water mass flow rate
Heat Recovery 2 Exhaust Path	Nominal power
Humidifier	Maximum steam mass flow rate
Humidifier	Steam temperature

3.2.6 Type 5

3.2.6.1 Brief description

This unit is composed of:

- Heat recovery/Enthalpy Wheel (HR)
- Mixing Box (MB)
- Cooling Coil (CC)
- Heating Coil (HC)
- Fans
- Humidifier (H)

3.2.6.2 Schematic

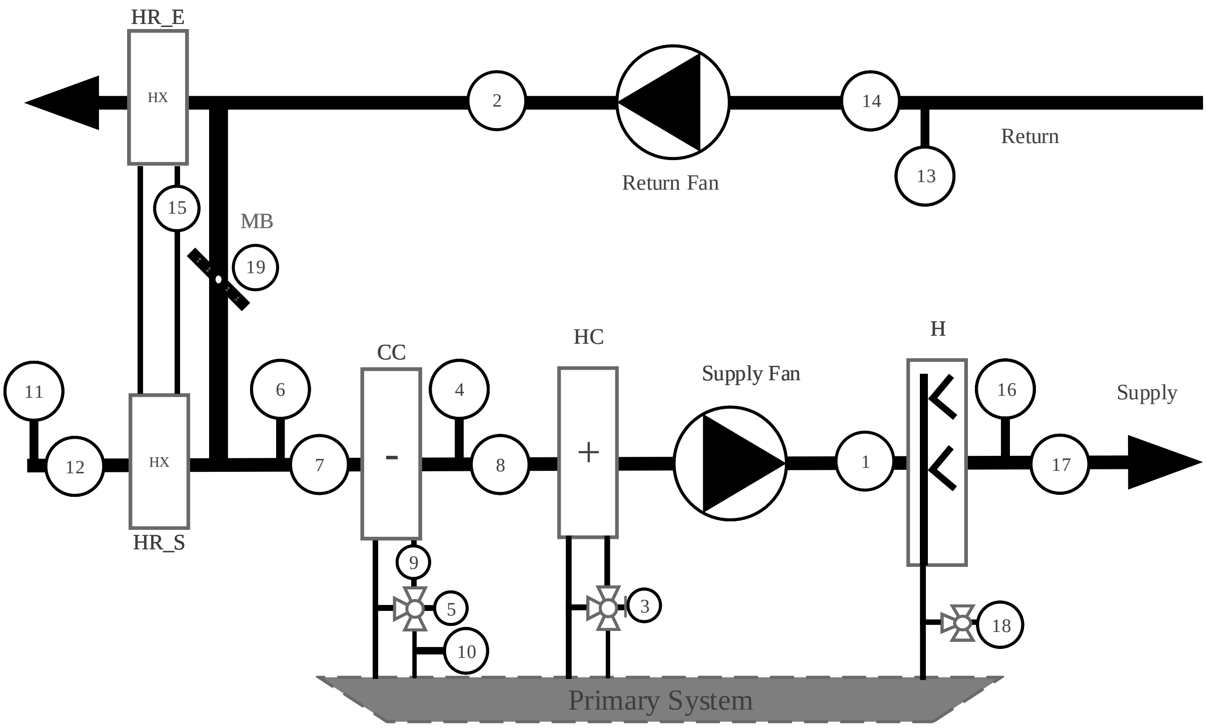


Figure 61. Type 5 schematic.

3.2.6.3 Modelica model schematic

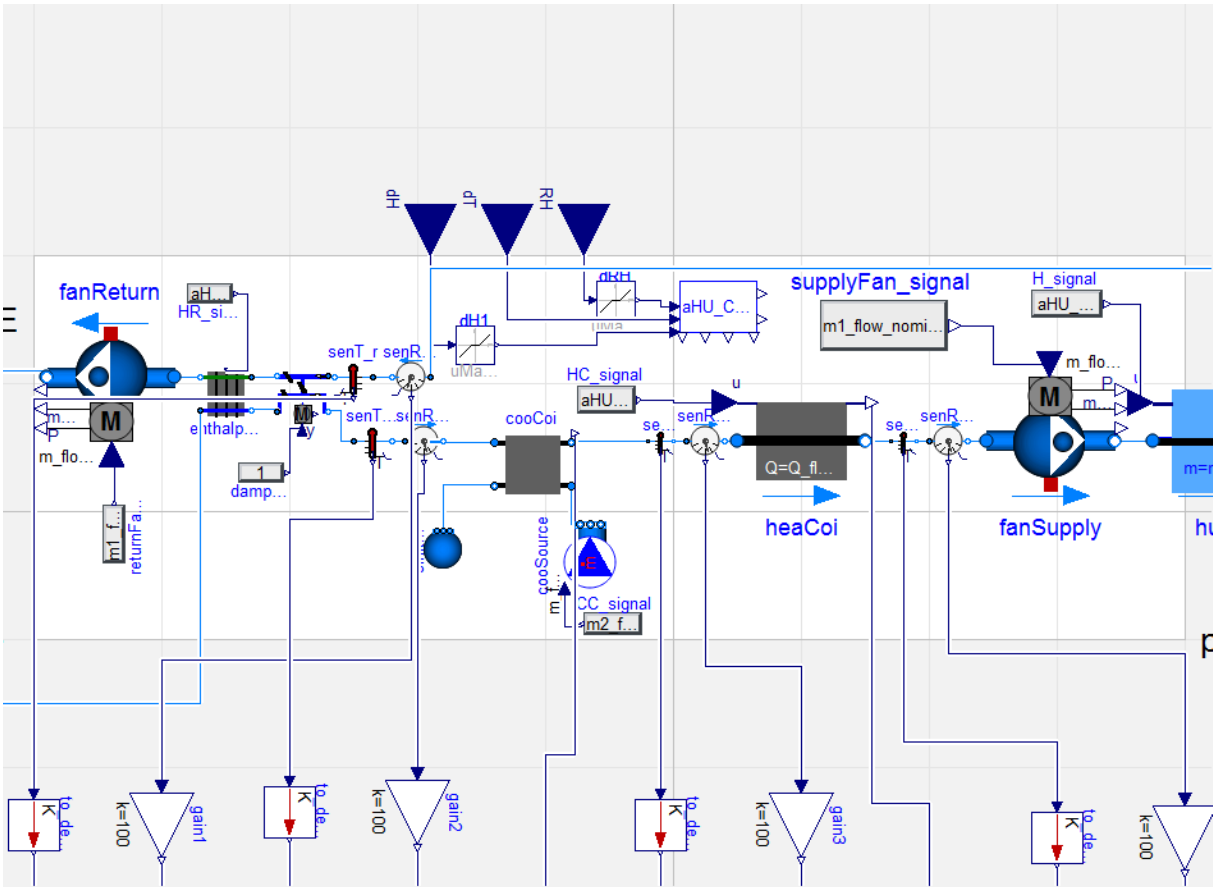


Figure 62. AHU Type 5 Modelica model.

3.2.6.4 Input/output variables

Table 12. Input/output variables for AHU Type 5.

Component	Variable	Type	# in schematic
Fan Return	air mass flow rate	Measurement	2
Heating Coil	Valve position	Input	3
Cooling Coil	Air output temperature	Measurement	4
Cooling Coil	Valve position	Input	5
Cooling Coil	Air input temperature	Measurement	6
Cooling Coil	Air input relative humidity	Measurement	7
Cooling Coil	Air output relative humidity	Measurement	8
Cooling Coil	Water mass flow rate	Measurement	9
Cooling Coil	Water input temperature	Measurement	10
Heat Recovery Supply Path	Air input temperature	Measurement	11
Heat Recovery Supply Path	Air input relative humidity	Measurement	12
Heat Recovery Exhaust Path	air input temperature	Measurement	13
Heat Recovery Exhaust Path	Air input relative humidity	Measurement	14
Heat Recovery Exhaust Path	Spinning speed	Input	15
Humidifier	Air output temperature	Measurement	16
Humidifier	Air output relative humidity	Measurement	17
Humidifier	Valve position	Input	18
Mixing Box	Damper Position	Input	19
Heat Recovery Exhaust Path	Air output temperature	Measurement	20
Heat Recovery Exhaust Path	Air output relative humidity	Measurement	21
Heat Recovery Exhaust Path or mixing box	air mass flow rate	Measurement	22
Fan Supply	Pump differential pressure	Measurement	23
Fan Return	Pump differential pressure	Measurement	24

3.2.6.5 Parameters needed to run the model

Table 13. Parameters needed to run model AHU Type 5.

Component	Parameter
Fan Supply	Nominal air mass flow rate
Fan Supply	Nominal power
Fan Return	Nominal air mass flow rate
Fan Return	Nominal power
Heating Coil	Nominal air mass flow rate
Heating Coil	Nominal power
Cooling Coil	Nominal air input temperature
Cooling Coil	Nominal air output temperature
Cooling Coil	Nominal air temperature difference
Cooling Coil	Nominal air input relative humidity
Cooling Coil	Nominal air output relative humidity
Cooling Coil	Nominal air mass flow rate
Cooling Coil	Nominal water input temperature
Cooling Coil	Nominal water output temperature
Cooling Coil	Nominal water output difference
Cooling Coil	Nominal water mass flow rate
Cooling Coil	Nominal power
Heat Recovery Supply Path	Nominal air input temperature
Heat Recovery Supply Path	Nominal air output temperature
Heat Recovery Supply Path	Nominal air temperature difference
Heat Recovery Supply Path	Nominal air input relative humidity
Heat Recovery Supply Path	Nominal air output relative humidity
Heat Recovery Supply Path	Nominal air mass flow rate
Heat Recovery Supply Path	Nominal water input temperature
Heat Recovery Supply Path	Nominal water output temperature
Heat Recovery Supply Path	Nominal water output difference
Heat Recovery Supply Path	Nominal water mass flow rate
Heat Recovery Supply Path	Nominal power
Heat Recovery Exhaust Path	Nominal air input temperature
Heat Recovery Exhaust Path	Nominal air output temperature
Heat Recovery Exhaust Path	Nominal air temperature difference
Heat Recovery Exhaust Path	Nominal air input relative humidity
Heat Recovery Exhaust Path	Nominal air output relative humidity
Heat Recovery Exhaust Path	Nominal air mass flow rate
Heat Recovery Exhaust Path	Nominal water input temperature
Heat Recovery Exhaust Path	Nominal water output temperature
Heat Recovery Exhaust Path	Nominal water output difference
Heat Recovery Exhaust Path	Nominal water mass flow rate
Heat Recovery Exhaust Path	Nominal power
Humidifier	Maximum steam mass flow rate
Humidifier	Steam temperature
Mixing Box	Max flow rate or duct size

3.2.7 Controllers Modelica model

3.2.7.1 Brief description

Each AHU type in the models has an associated control system (named AHU_controller) emulating the behaviour of the real system as closely as possible with the available data (e.g. O&M manuals from Basurto). The Modelica implementation of the AHU_controller can be seen in Figure 63. AHU_controller Dymola representation:

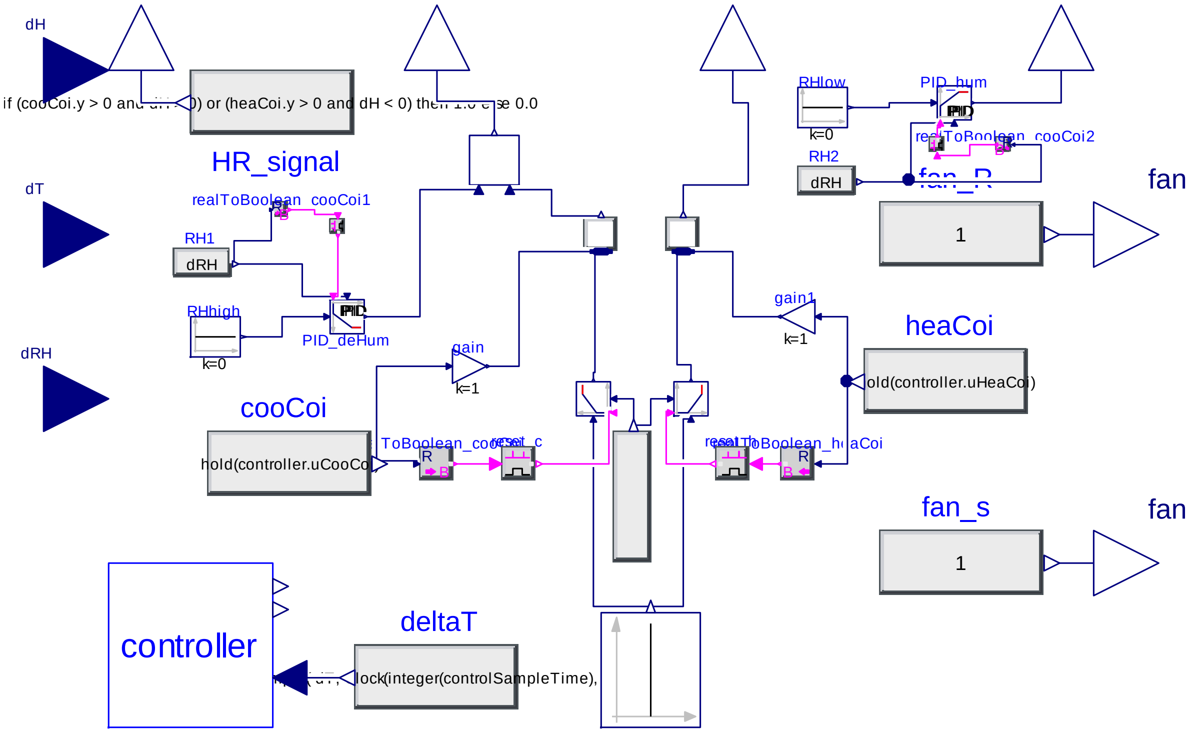


Figure 63. AHU_controller Dymola representation

The AHU_controller operates in a mode-switching hybrid system, i.e., it is a system that can operate in multiple modes, and can switch between these modes either through continuous- or discrete-valued signals. The AHU can operate in 2 nominal modes for temperature control: (1) when the controlled temperature is above its set-point + dead-band (T_ASP) and (2) when the controlled temperature is below its set-point – dead-band (T_BSP):

If T_ASP, the AHU_controller shall:

1. Modulate the opening signal valve of the Heating Coil towards the fully closed position.
2. Modulate the opening signal valve of the Cooling Coil towards the fully opened position.

If T_BSP, the AHU_controller shall:

1. Modulate the opening signal valve of the Cooling Coil towards the fully closed position.
2. Modulate the opening signal valve of the Heating Coil towards the fully opened position

All modulations are performed via PID control.

In this controller humidity control operates independently from the heating/cooling operation. For humidity control, the AHU can also operate in 2 nominal modes: (1) when the controlled relative humidity is above its set-point + dead-band (RH_ASP) and (2) when the controlled relative humidity is below its set-point – dead-band (RH_BSP).

If RH_ASP, the AHU_controller shall:

1. Modulate the opening signal valve of the Cooling Coil towards the fully opened position.
2. Modulate the opening signal valve of the Humidifier towards the fully closed position.

If RH_BSP, the AHU_controller shall:

1. Modulate the opening signal valve of the Cooling Coil towards the fully closed position.
2. Modulate the opening signal valve of the Humidifier Coil towards the fully opened position

All modulations are performed via PID control.

In this controller heat recovery control operates independently from the heating/cooling operation. Heat recovery operates in on/off mode as follows:

1. If (Cooling Coil valve > 0 and dH > 0) or (Heating Coil valve > 0 and dH < 0) then 1.0 else 0.0.

According to maintenance personnel from Basurto site, Fans operate at fixed mass flow rate 100%. Hence, in this controller, fan output is always true.

3.2.7.2 Input/output variables

The input/output variables are shown in Table 14.

Table 14. Input/output variables for Controllers Modelica model.

Type	Name	Description
output RealOutput	CC	Cooling Coil Signal
output RealOutput	HC	Heating Coil Signal
input RealInput	dT	delta Temperature (T - Tsp)
output RealOutput	HR	Heat Recovery Signal
output RealOutput	H	Humidifier Signal
output RealOutput	fanS	Supply Fan Signal
output RealOutput	fanR	Return Fan Signal
input RealInput	dRH	Controlled Relative Humidity
input RealInput	dH	delta enthalpy for heat recovery on/off

Aimed at making this component as flexible as possible with as less inputs as possible, instead of having separated temperature (T), enthalpy (H) and relative humidity(RH) controlled signals and set-points, the difference between controlled signal and set-point for each (dT, dH, dRH) I used.

3.2.7.3 Parameters needed to run the models

The component takes as a parameters those shown in the table below corresponding with the selection of controller type (P, PI, PID), and the associated constants. The controlSampleTime is also a parameter determining how often inputs are read and outputs updated.

Table 15. Parameters needed to run model Controllers Modelica model.

Type	Name	Default	Description
Time	controlSampleTime		Sampling time of the Controller [s]
		Humidity Control	
SimpleController	controllerType_hu		Type of controller
Real	k_hu	1	Gain of controller
Time	Ti_hu	0.5	Time constant of Integrator block [s]
Time	Td_hu	0.1	Time constant of Derivative block [s]
		Cooling Control	
SimpleController	controllerType_c	.	Type of controller
Real	k_c	1	Gain of controller
Time	Ti_c	0.5	Time constant of Integrator block [s]

Time	Td_c	0.1	Time constant of Derivative block [s]
Heating Control			
SimpleController	controllerType_h		Type of controller
Real	k_h	1	Gain of controller
Time	Ti_h	0.5	Time constant of Integrator block [s]
Time	Td_h	0.1	Time constant of Derivative block [s]

3.3 Substation models

3.3.1 Brief description

In Basurto Hospital, the ‘Substation’ is a hydraulic separator. The hydraulic separator is basically a cylinder or tank with 4 flanges, two are connected to the main cold-water distribution system, one for supply and one for return, and the other two are connected to the building cold water distribution system, again one for supply and another for return. Hydraulic separators are used in hydronic systems to allow a decoupling between primary and secondary flows while still allowing direct heat exchange between both. Figure 64 shows the schematic of the substation while Figure 65 provides a visual example of how heat flows are affected by mass flow rates between primary and secondary sides.

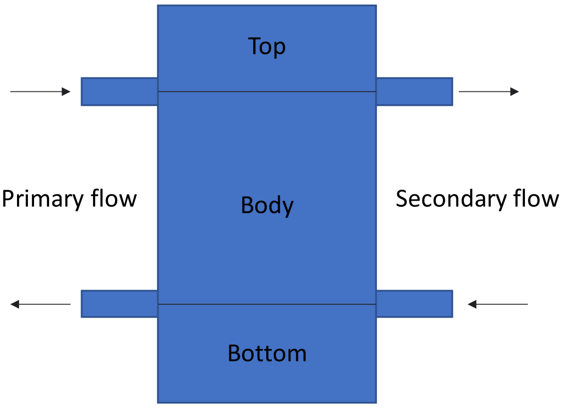


Figure 64. Substation Schematic

Depending on the relation between mass flow rates between the two sides, heat and mass can be transferred from the primary to the secondary or vice-versa as shown in figures below.

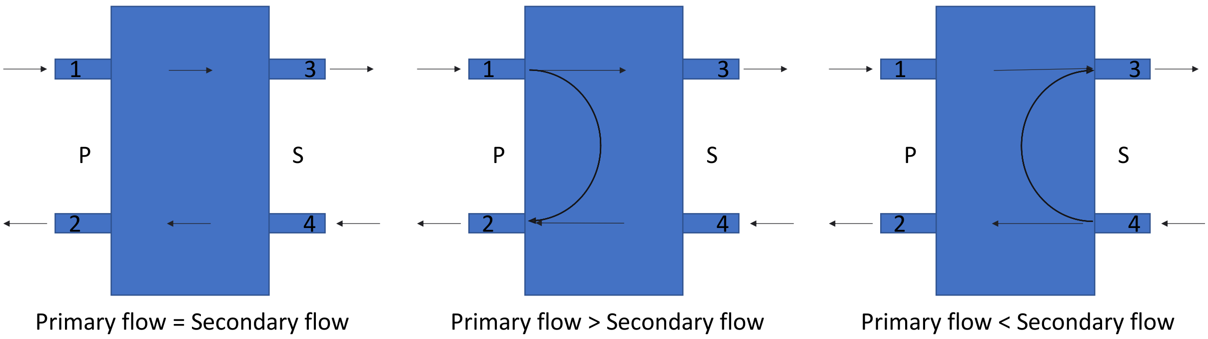


Figure 65. Substation heat transfer according to mass flow rate relations

3.3.2 Modelica Model implementation

The implementation of the hydraulic separator considers the 'top' and 'bottom' sections of the tank as perfectly mixed volumes with the possibility to exchange mass between them through a pipe that has the same volume as the 'body' section. Heat can also be transferred between top and bottom by means of a thermal capacitance that has the properties of the water as medium. Figure 66 shows the Substation Modelica model.

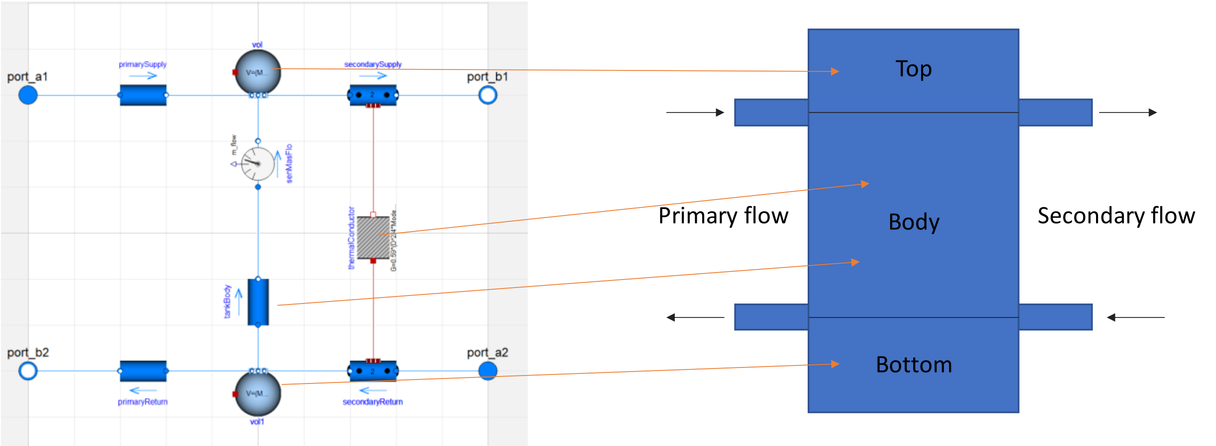


Figure 66. Substation Modelica Model

3.3.3 Schematic and Input/output variables

Figure 67 shows a schematic of the substation where the input/output variables can be seen.

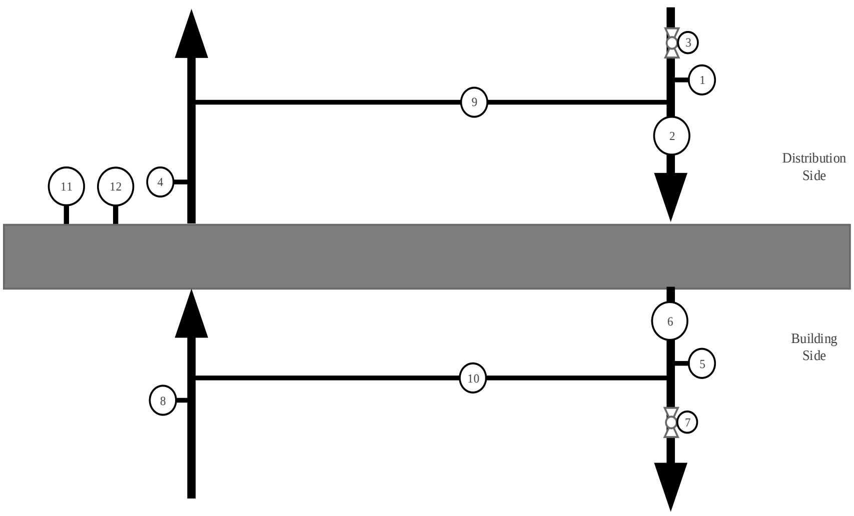


Figure 67. Substation input/output variables location

Table 16. Input/output variables for Substation model.

Component	Location	Signal	Type	sensor #
Substation	Supply Distribution Side	Temperature	Measurement	1
	Supply Distribution Side	Water mass flow rate	Measurement	2
	Supply Distribution Side	Valve position	Input	3
	Return Distribution Side	Temperature	Measurement	4
	Supply Building Side	Temperature	Measurement	5
	Supply Building Side	Water mass flow rate	Measurement	6
	Supply Building Side	Valve position	Input	7
	Return Building Side	Temperature	Measurement	8
	Distribution side	Heat Meter	Measurement	9
	Building Side	Heat Meter	Measurement	10
	Tank	Pressure	Measurement	11
	Tank	Temperature	Measurement	12

3.3.4 Parameters needed to run the model

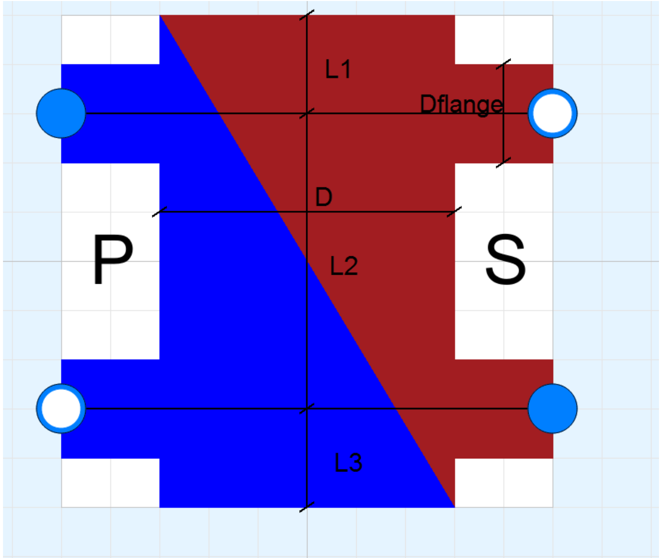


Figure 68. Modelica model icon

Table 17. Parameters needed to run model Substation.

Type	Name	Default	Description
Boolean	allowFlowReversal	true	allow flow reversal in component
MassFlowRate	m_flow_nominal		Nominal mass flow rate of either primary or secondary used for regularisation near zero flow [kg/s]
Diameter	D		Diameter of the tank [m]
Diameter	Dflange		Diameter of the flanges [m]
Length	L1		Height between the top and the lowest of the supply flanges [m]
Length	L2		Height between the lowest of the supply flanges and the highest of the return flanges [m]
Length	L3		Height between the highest of the return flanges and the bottom [m]

4 Whole building models

In this section, for each building, it is first briefly described their distribution system with screenshots taken from the design specifications and information supplied by partners VEO in deliverables D6.1 and D6.3. Next, the developed model is presented and described.

4.1 Aztarain

In Aztarain, two Type 1 AHU provide conditioned air to the building. One AHU, named 'Aislamiento' (isolation in Spanish), provides air for the zones with immunodrepessed patients. The other AHU, named 'Salas' (rooms in Spanish), provides air to eight Type 2 AHUs that deliver air to same number of zones. The following sections describe the air distribution system and the interconnected models (Modelica + EnergyPlus_fmu).

4.1.1 AHU 'Salas'

As mentioned before, AHU Salas distributes air to eight Type 2 air handling units that ultimately control indoor environmental conditions locally. Additionally, AHU Salas provides conditioned air to some areas in all floors of Aztarain.

4.1.1.1 Schematic

The air distribution schematic can be seen in Figure 69.

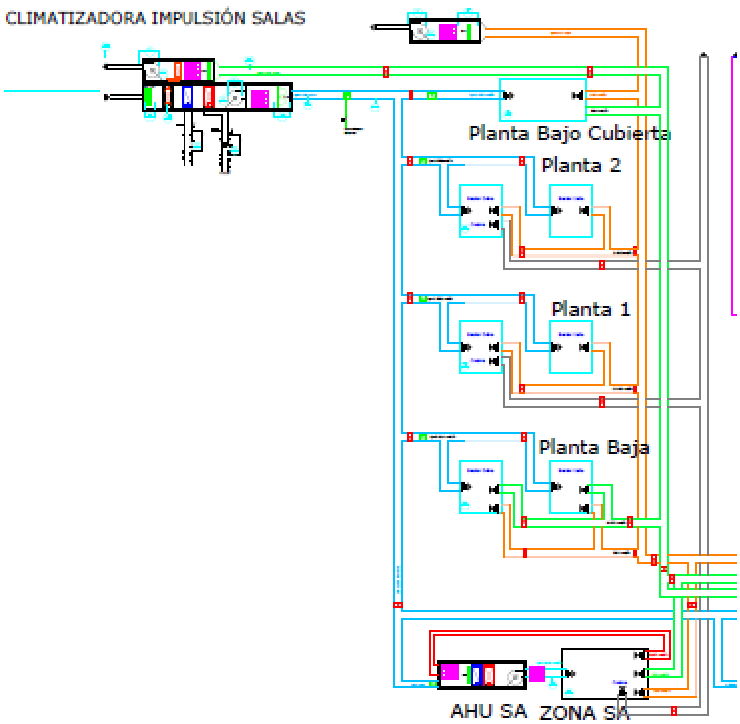


Figure 69. Air distribution Aztarain Salas

To note from the figure, that there are other seven zones supplied by Type 2 AHUs similar to the combination AHU_SA + ZONA_SA namely: _SB, _SC, _SE, _SF, _SH, _SJ, _SK.

4.1.1.2 Modelica Model

Aztarain Salas Modelica model interconnects the AHU Type 1 with the zones (Planta Bajo Cubierta (P3), Planta 2 (P2), Planta 1 (P1), Planta Baja (P0)) and the eight Type 2 AHUs with the respective zones in the EnergyPlus model, as shown in Figure 70.

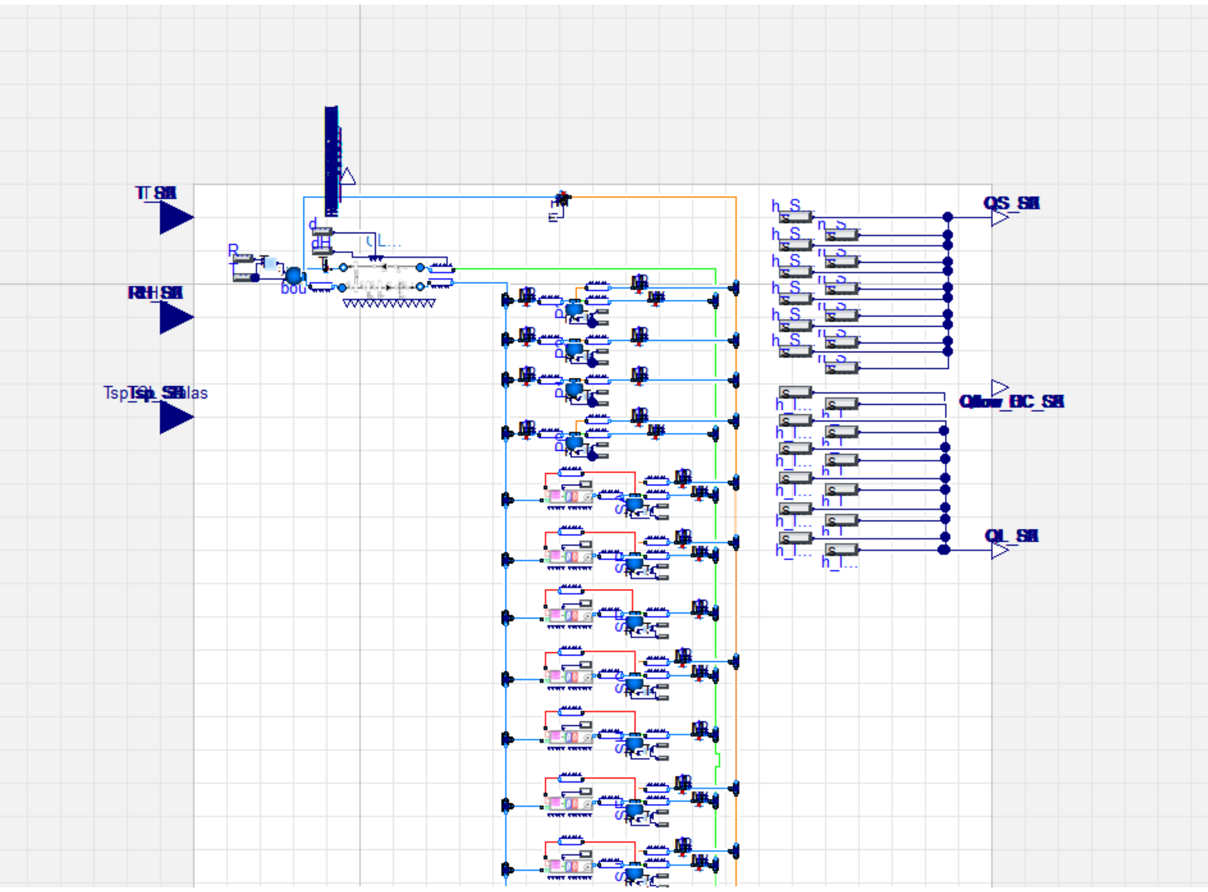


Figure 70. Aztarain Salas Modelica Model

4.1.1.3 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point.

Table 18. Input/output variables for AHU 'Salas'.

Type	Name	Units
input RealInput	T_o	[degC]
input RealInput	T_P3	[degC]
input RealInput	T_P2	[degC]
input RealInput	T_P1	[degC]
input RealInput	T_P0	[degC]
input RealInput	T_SA	[degC]
input RealInput	T_SB	[degC]
input RealInput	T_SE	[degC]
input RealInput	T_SC	[degC]
input RealInput	T_SH	[degC]
input RealInput	T_SF	[degC]
input RealInput	T_SJ	[degC]
input RealInput	T_SK	[degC]
input RealInput	RH_o	[%]
input RealInput	RH_P3	[%]

input Realinput	RH_P2	[%]
input Realinput	RH_P1	[%]
input Realinput	RH_P0	[%]
input Realinput	RH_SA	[%]
input Realinput	RH_SB	[%]
input Realinput	RH_SE	[%]
input Realinput	RH_SC	[%]
input Realinput	RH_SH	[%]
input Realinput	RH_SF	[%]
input Realinput	RH_SJ	[%]
input Realinput	RH_SK	[%]
input Realinput	Tsp_CL_Salas	[degC]
input Realinput	Tsp_SA	[degC]
input Realinput	Tsp_SB	[degC]
input Realinput	Tsp_SE	[degC]
input Realinput	Tsp_SC	[degC]
input Realinput	Tsp_SH	[degC]
input Realinput	Tsp_SF	[degC]
input Realinput	Tsp_SJ	[degC]
input Realinput	Tsp_SK	[degC]
output RealOutput	QS_P2	[W]
output RealOutput	QS_P1	[W]
output RealOutput	QS_P0	[W]
output RealOutput	QS_SA	[W]
output RealOutput	QS_SB	[W]
output RealOutput	QS_SE	[W]
output RealOutput	QS_SC	[W]
output RealOutput	QS_SH	[W]
output RealOutput	QS_SF	[W]
output RealOutput	QS_SJ	[W]
output RealOutput	QS_SK	[W]
output RealOutput	QL_P2	[W]
output RealOutput	QL_P1	[W]
output RealOutput	QL_P0	[W]
output RealOutput	QL_SA	[W]
output RealOutput	QL_SB	[W]
output RealOutput	QL_SE	[W]
output RealOutput	QL_SC	[W]
output RealOutput	QL_SH	[W]
output RealOutput	QL_SF	[W]
output RealOutput	QL_SJ	[W]
output RealOutput	QL_SK	[W]
output RealOutput	QS_P3	[W]
output RealOutput	QL_P3	[W]
output RealOutput	T_HR	[degC]
output RealOutput	T_CC	[degC]
output RealOutput	T_HC	[degC]
output RealOutput	Tr	[degC]
output RealOutput	T_supply	[degC]
output RealOutput	T_supply_SA	[degC]
output RealOutput	T_mix_SA	[degC]
output RealOutput	T_CC_SA	[degC]
output RealOutput	T_HC_SA	[degC]
output RealOutput	T_recirc_SA	[degC]
output RealOutput	T_supply_SB	[degC]
output RealOutput	T_mix_SB	[degC]
output RealOutput	T_CC_SB	[degC]
output RealOutput	T_HC_SB	[degC]
output RealOutput	T_recirc_SB	[degC]
output RealOutput	T_supply_SC	[degC]
output RealOutput	T_mix_SC	[degC]
output RealOutput	T_CC_SC	[degC]
output RealOutput	T_HC_SC	[degC]
output RealOutput	T_recirc_SC	[degC]
output RealOutput	RH_supply_SE	[%]
output RealOutput	RH_mix_SE	[%]
output RealOutput	RH_CC_SE	[%]
output RealOutput	RH_HC_SE	[%]
output RealOutput	RH_recirc_SE	[%]
output RealOutput	RH_supply_SF	[%]

output RealOutput	RH_mix_SF	[%]
output RealOutput	RH_CC_SF	[%]
output RealOutput	RH_HC_SF	[%]
output RealOutput	RH_recirc_SF	[%]
output RealOutput	RH_supply_SH	[%]
output RealOutput	RH_mix_SH	[%]
output RealOutput	RH_CC_SH	[%]
output RealOutput	RH_HC_SH	[%]
output RealOutput	RH_recirc_SH	[%]
output RealOutput	RH_supply_SJ	[%]
output RealOutput	RH_mix_SJ	[%]
output RealOutput	RH_CC_SJ	[%]
output RealOutput	RH_HC_SJ	[%]
output RealOutput	RH_recirc_SJ	[%]
output RealOutput	RH_supply_SK	[%]
output RealOutput	RH_mix_SK	[%]
output RealOutput	RH_CC_SK	[%]
output RealOutput	RH_HC_SK	[%]
output RealOutput	RH_recirc_SK	[%]
output RealOutput	Qflow_CC_CL	[W]
output RealOutput	Qflow_CC_SA	[W]
output RealOutput	Qflow_CC_SB	[W]
output RealOutput	Qflow_CC_SC	[W]
output RealOutput	Qflow_CC_SE	[W]
output RealOutput	Qflow_CC_SF	[W]
output RealOutput	Qflow_CC_SH	[W]
output RealOutput	Qflow_CC_SJ	[W]
output RealOutput	Qflow_CC_SK	[W]
output RealOutput	Qflow_HC_CL	[W]
output RealOutput	Qflow_HC_SA	[W]
output RealOutput	Qflow_HC_SB	[W]
output RealOutput	Qflow_HC_SC	[W]
output RealOutput	Qflow_HC_SE	[W]
output RealOutput	Qflow_HC_SF	[W]
output RealOutput	Qflow_HC_SH	[W]
output RealOutput	Qflow_HC_SJ	[W]
output RealOutput	Qflow_HC_SK	[W]

4.1.1.4 Parameters needed to run the model

Table 19. Parameters needed to run model AHU 'Salas'.

Type	Name	Default	Description
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)
Time	controlSampleTime	150	Sampling time of the Controller [s]

4.1.2 AHU 'Aislamiento'

AHU Aislamiento supplies air to two immunodepressed zones (pressure positive)

4.1.2.1 Schematic

Figure 71 shows the air distribution schematic for Aislamiento.

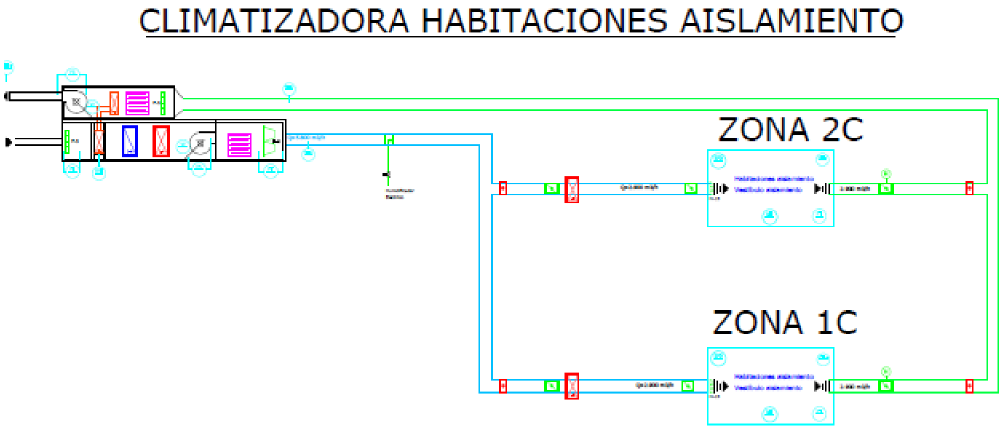


Figure 71. Air distribution Aztarain Aislamiento

4.1.2.2 Modelica Model

Figure 72 shows the Modelica model of the AHU serving two zones.

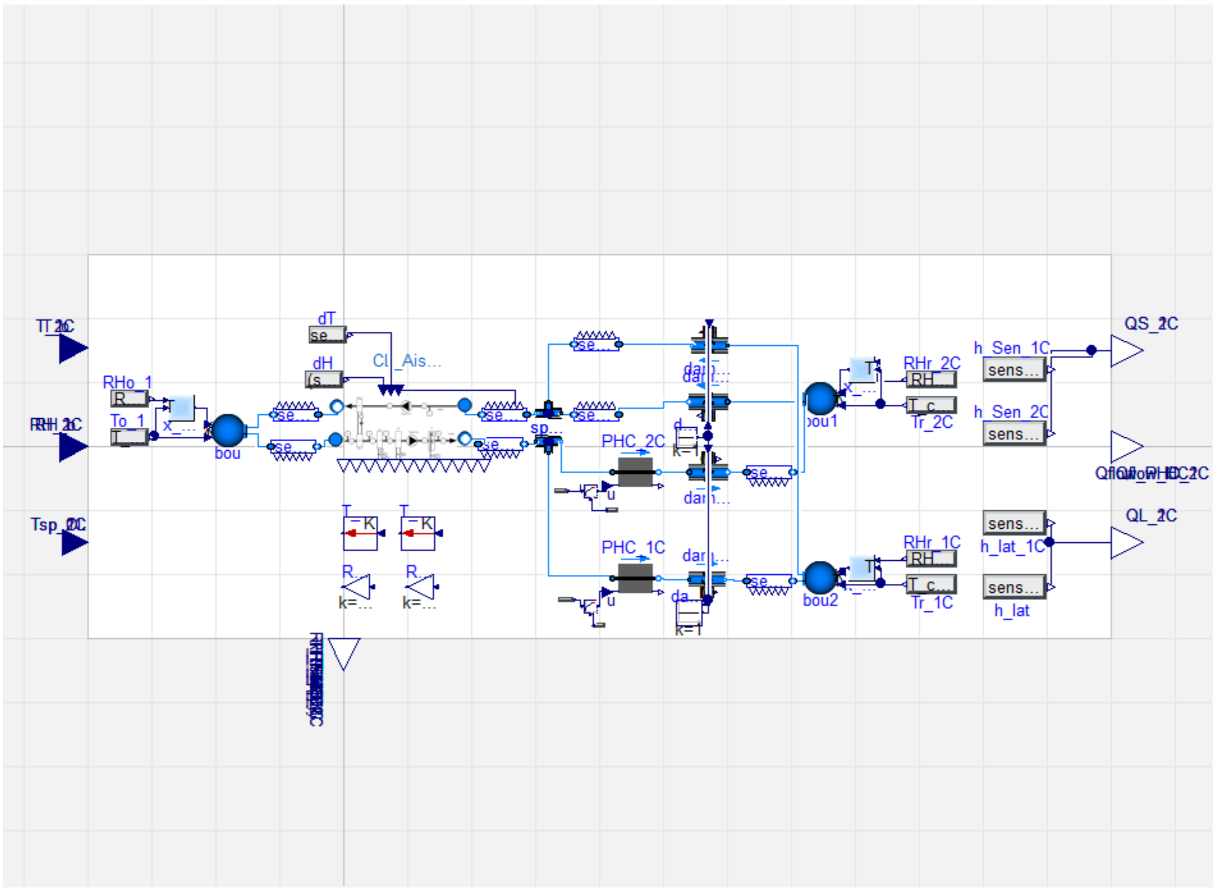


Figure 72. Aztarain Aislamiento Modelica Model

4.1.2.3 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point

Table 20. Input/output variables for AHU 'Aislamiento'.

Type	Name	Unit
input RealInput	RH_o	[%]
input RealInput	T_o	[degC]
output RealOutput	QS_2C	[W]
output RealOutput	QL_2C	[W]
input RealInput	RH_2C	[%]
input RealInput	T_2C	[degC]
output RealOutput	QS_1C	[W]
output RealOutput	QL_1C	[W]
input RealInput	RH_1C	[%]
input RealInput	T_1C	[degC]
input RealInput	Tsp_CL	[degC]
input RealInput	Tsp_1C	[degC]
input RealInput	Tsp_2C	[degC]
output RealOutput	T_HR	[degC]
output RealOutput	RH_HR	[%]
output RealOutput	Qflow_CC	[W]
output RealOutput	T_CC	[degC]
output RealOutput	RH_CC	[%]
output RealOutput	Qflow_HC	[W]
output RealOutput	T_HC	[degC]
output RealOutput	RH_HC	[%]
output RealOutput	Qflow_PHC_1C	[W]
output RealOutput	Qflow_PHC_2C	[W]
output RealOutput	T_PHC_1C	[degC]
output RealOutput	RH_PHC_1C	[%]
output RealOutput	T_PHC_2C	[degC]
output RealOutput	RH_PHC_2C	[%]
output RealOutput	Tr	[degC]
output RealOutput	RHr	[%]
output RealOutput	T_supply	[degC]
output RealOutput	RH_supply	[%]

4.1.2.4 Parameters needed to run the model

Table 21. Parameters needed to run model AHU 'Aislamiento'.

Type	Name	Default	Description
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0
MassFlowRate	m1_flow_nominal	2.01	Nominal mass flow rate supply and return air [kg/s]
MassFlowRate	m2_flow_nominal	4.38	Nominal mass flow rate of water through the cooling coil [kg/s]
MassFlowRate	m3_flow_nominal	0.97	Nominal mass flow rate through re-heating coils [kg/s]
Time	controlSampleTime	150	Sampling time of the Controller [s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)

4.1.3 Aztarain full model

The complete Aztarain model is the joining, in a single file of the two separate units supplying the respective zones

4.2 Gurtubay

In Gurtubay, three type 1 AHUs provide conditioned air to all zones in the building. Gurtubay is mostly composed of laboratories. There is one AHU, ‘Vestuarios’, that provides air to some areas of the basement floor. The other two AHUs, ‘SO’ and ‘NE’, provide air to the rest of the building. Both AHUs provide air to different areas in all floors. In Gurtubay, most zones’ environmental conditions are controlled by post-heating/cooling coils. All AHUs are controlled via a supply air temperature set-point, fixed via control panel and adjusted via a curve depending on outdoor conditions.

The following sections describe the air distribution system and the interconnected models (Modelica + EnergyPlus_fmu).

4.2.1 AHU ‘Vestuarios’

AHU ‘Vestuarios’ distribute air to some zones in the basement floor including. This is the only AHU in Gurtubay that distributes air in only one floor of the building. AHU Vestuarios provides air to 4 base thermal zones. Three zones controlled by post-heating coils and one lumped zone controlled directly by the AHU.

4.2.1.1 Schematic

Figure 73 shows the overall schematic of the air distribution for AHU Vestuarios.

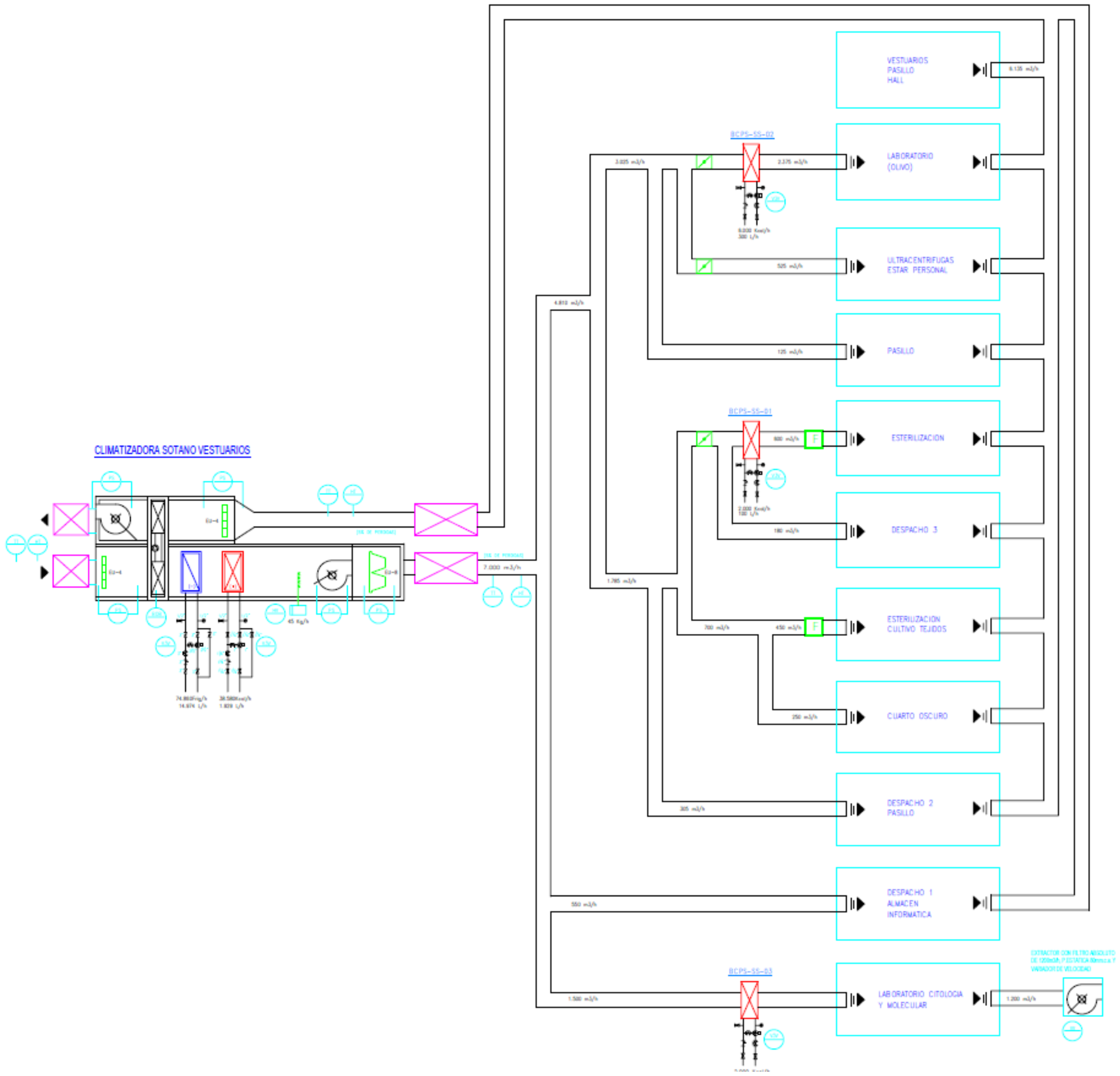


Figure 73. Gurtubay AHU Vestuarios Air Distribution

4.2.1.2 AHU Vestuarios air distribution zones

The table below provides characteristics of the zones supplied by Vestuarios.

Code	Type	Parameter	Value (in/out)	Units	Zone name	Zone type
	Air flow	Nominal air mass flow rate	0.22	kg/s	SS_esterilizacion	zonePHC
BC-PS-SS-01	Heating Coil	Nominal power	2.32	kW	SS_esterilizacion	zonePHC
	Air flow	Nominal air mass flow rate	0.78	kg/s	SS_laboratorio	zonePHC
BC-PS-SS-02	Heating Coil	Nominal power	6.97	kW	SS_laboratorio	zonePHC
	Air flow	Nominal air mass flow rate	0.65	kg/s	SS_citogenetica	zonePHC
BC-PS-SS-03	Heating Coil	Nominal power	3.49	kW	SS_citogenetica	zonePHC
	Air flow	Nominal air mass flow rate	0.226/1.22	kg/s	SS_pasillo	zone

4.2.1.3 Modelica Model

Figure 74 shows the Modelica model of AHU Vestuarios serving the 4 zones.

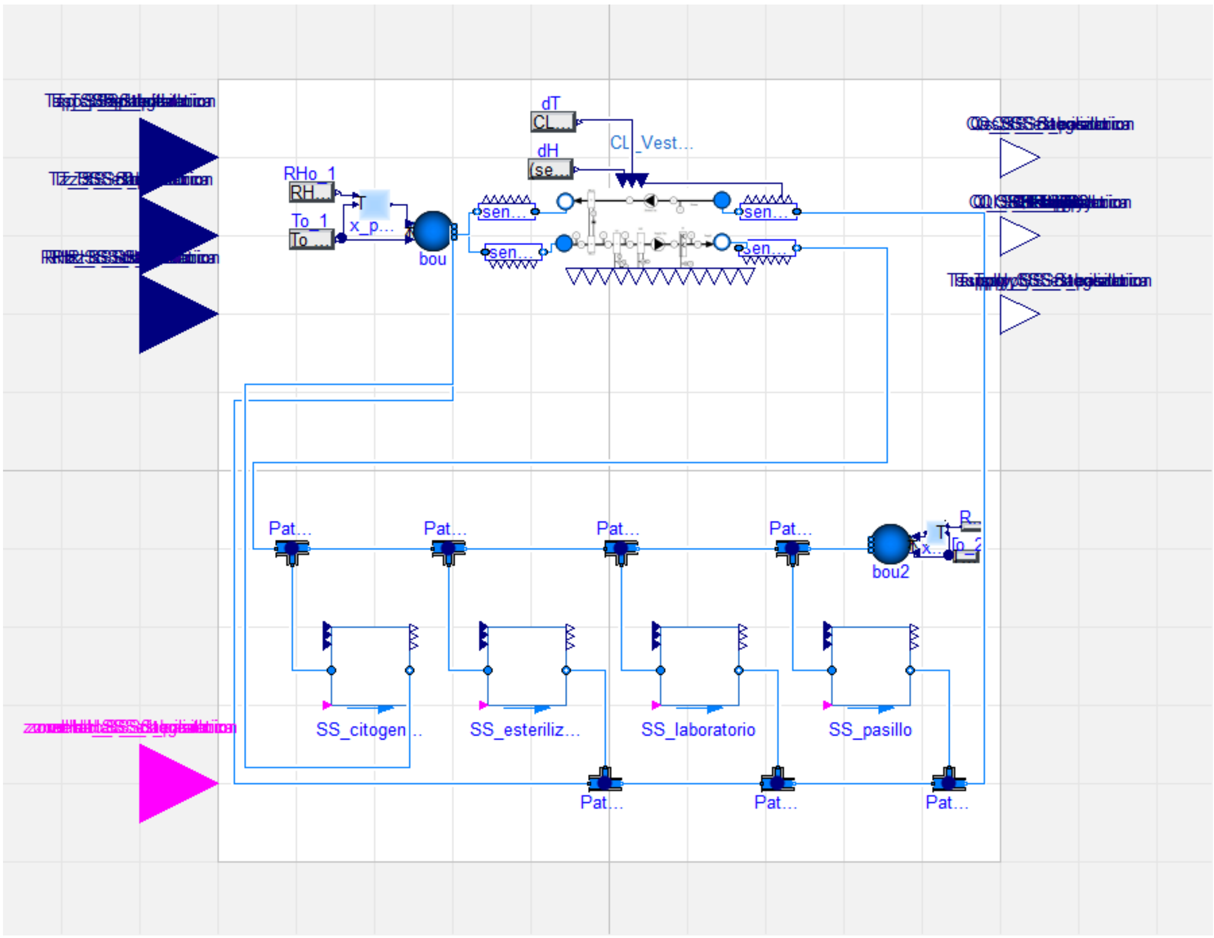


Figure 74. Gurtubay AHU Vestuarios Modelica Model.

4.2.1.4 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point.

Table 22. Input/output variables for AHU 'Vestuarios'.

Type	Name	Units
input RealInput	Tz_SS_citogenetica	[degC]
input RealInput	RHz_SS_citogenetica	[%]
input RealInput	Tsp_SS_citogenetica	[degC]
input BooleanInput	zoneHab_SS_citogenetica	[boolean]
output RealOutput	Qs_SS_citogenetica	[W]
output RealOutput	Ql_SS_citogenetica	[W]
output RealOutput	Tsupply_SS_citogenetica	[degC]
input RealInput	Tz_SS_laboratorio	[degC]
input RealInput	RHz_SS_laboratorio	[%]
input RealInput	Tsp_SS_laboratorio	[degC]
input BooleanInput	zoneHab_SS_laboratorio	[boolean]
output RealOutput	Qs_SS_laboratorio	[W]
output RealOutput	Ql_SS_laboratorio	[W]
output RealOutput	Tsupply_SS_laboratorio	[degC]
input RealInput	Tz_SS_esterilizacion	[degC]
input RealInput	RHz_SS_esterilizacion	[%]
input RealInput	Tsp_SS_esterilizacion	[degC]
input BooleanInput	zoneHab_SS_esterilizacion	[boolean]
output RealOutput	Qs_SS_esterilizacion	[W]
output RealOutput	Ql_SS_esterilizacion	[W]

output RealOutput	Tsupply_SS_esterilizacion	[degC]
input RealInput	Tz_SS_pasillo	[degC]
input RealInput	RHz_SS_pasillo	[%]
input RealInput	Tsp_SS_pasillo	[degC]
input BooleanInput	zoneHab_SS_pasillo	[boolean]
output RealOutput	Qs_SS_pasillo	[W]
output RealOutput	Ql_SS_pasillo	[W]
output RealOutput	Tsupply_SS_pasillo	[degC]
output RealOutput	Qflow_CC	[W]
output RealOutput	Qflow_HC	[W]
output RealOutput	RH_CC	[%]
output RealOutput	RH_HC	[%]
output RealOutput	RH_HR	[%]
output RealOutput	RH_r	[%]
output RealOutput	RH_supply	[%]
output RealOutput	T_CC	[degC]
output RealOutput	T_HC	[degC]
output RealOutput	T_HR	[degC]
output RealOutput	T_r	[degC]
output RealOutput	T_supply	[degC]
input RealInput	RHo	[%]
input RealInput	To	[degC]
input RealInput	Tsp_cold	[degC]
input RealInput	Tsp_hot	[degC]

4.2.1.5 Parameters needed to run the model

Table 23. Parameters needed to run model AHU 'Vestuarios'.

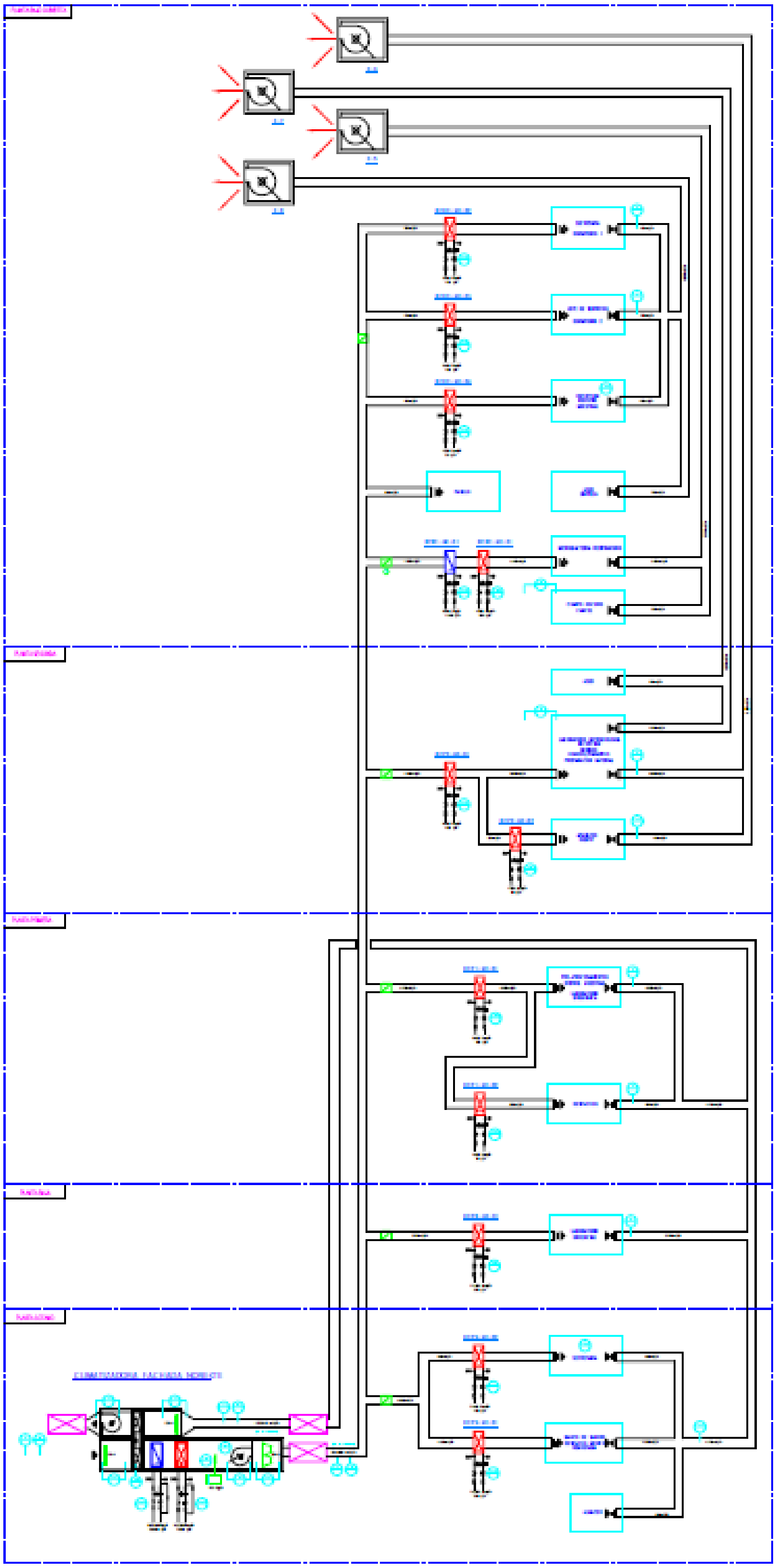
Type	Name	Default	Description
Time	controlSampleTime	150	Sampling time of the Controller [s]
MassFlowRate	m1_flow_nominal	1.87	Nominal air supply/return mass flow rate CL_vestuarios [kg/s]
MassFlowRate	m2_flow_nominal	4.2	Nominal water supply/return mass flow rate CL_vestuarios [kg/ s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)
Temp_C	Tmin	16	min supply temperature [degC]
Temp_C	Tmax	27	max supply temperature [degC]
Real	RHmax	0.70	Upper limits of RH
Real	RHmin	0.35	Lower limits of RH
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0

4.2.2 AHU 'NE'

AHU NE distributes air to some zones in all floors in Gurtubay buildings. AHU NE provides air to 11 base thermal zones. Air distribution in more complex in AHU NE where some some post-heating coils provide air to one or more zones which are also controlled by post-heating coil further down. Other zones are controlled by post heating and post cooling coils.

4.2.2.1 Schematic

Figure 75 shows the overall schematic of the air distribution for AHU NE.



EDIFICIO FACHADA NORESTE

Figure 75. Gurtubay AHU NE Air Distribution

4.2.2.2 AHU NE air distribution zones

The table below provides characteristics of the zones supplied by NE.

code	type	parameter	value(in/out)		units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	1.39	1.39	kg/s	SS_banco	zonePHC
BC-PS-NE-01	Heating Coil	Nominal power	11.62		kW	SS_banco	zonePHC
-	Air flow	Nominal air mass flow rate	0.20	0.20	kg/s	SS_secretaria	zonePHC
BC-PS-NE-02	Heating Coil	Nominal power	2.32		kW	SS_secretaria	zonePHC
-	Air flow	Nominal air mass flow rate	1.96	1.96	kg/s	P0_laboratorioNE	zonePHC
BC-PB-NE-01	Heating Coil	Nominal power	12.78		kW	P0_laboratorioNE	zonePHC
-	Air flow	Nominal air mass flow rate	1.60	1.38	kg/s	P1_laboratorioNE	zonePHC_splitSup
BC-P1-NE-01	Heating Coil	Nominal power	10.46		kW	P1_laboratorioNE	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.22	0.22	kg/s	P1_despachos2	zonePHC
BC-P1-NE-02	Heating Coil	Nominal power	1.16		kW	P1_despachos2	zonePHC
-	Air flow	Nominal air mass flow rate	1.42	1.43	kg/s	P2_heridas	zonePHC
-	Air flow	Nominal air mass flow rate	9.3		kW	P2_heridas	zonePHC
-	Air flow	Nominal air mass flow rate	0.66	0.85	kg/s	P3_microbacteria	zonePHC_PCC
BC-BC-NE-01	Heating Coil	Nominal power	4.65		kW	P3_microbacteria	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.66	0.85	kg/s	P3_microbacteria	zonePHC_PCC
BC-BF-NE-01	Cooling Coil	Nominal power	5.81		kW	P3_microbacteria	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.19	0.15	kg/s	P3_secretaria	zonePHC
BC-BC-NE-02	Heating Coil	Nominal power	3.49		kW	P3_secretaria	zonePHC
-	Air flow	Nominal air mass flow rate	0.25	0.25	kg/s	P3_jefe	zonePHC
BC-BC-NE-03	Heating Coil	Nominal power	2.32		kW	P3_jefe	zonePHC
-	Air flow	Nominal air mass flow rate	0.16	0.16	kg/s	P3_recepcion	zonePHC
BC-BC-NE-04	Heating Coil	Nominal power	1.16		kW	P3_recepcion	zonePHC
	Air flow	Nominal air mass flow rate	0.07	0.10	kg/s	P3_pasilloNE	zone

4.2.2.3 Modelica Model

Figure 76 shows the Modelica model of AHU NE serving the zones.

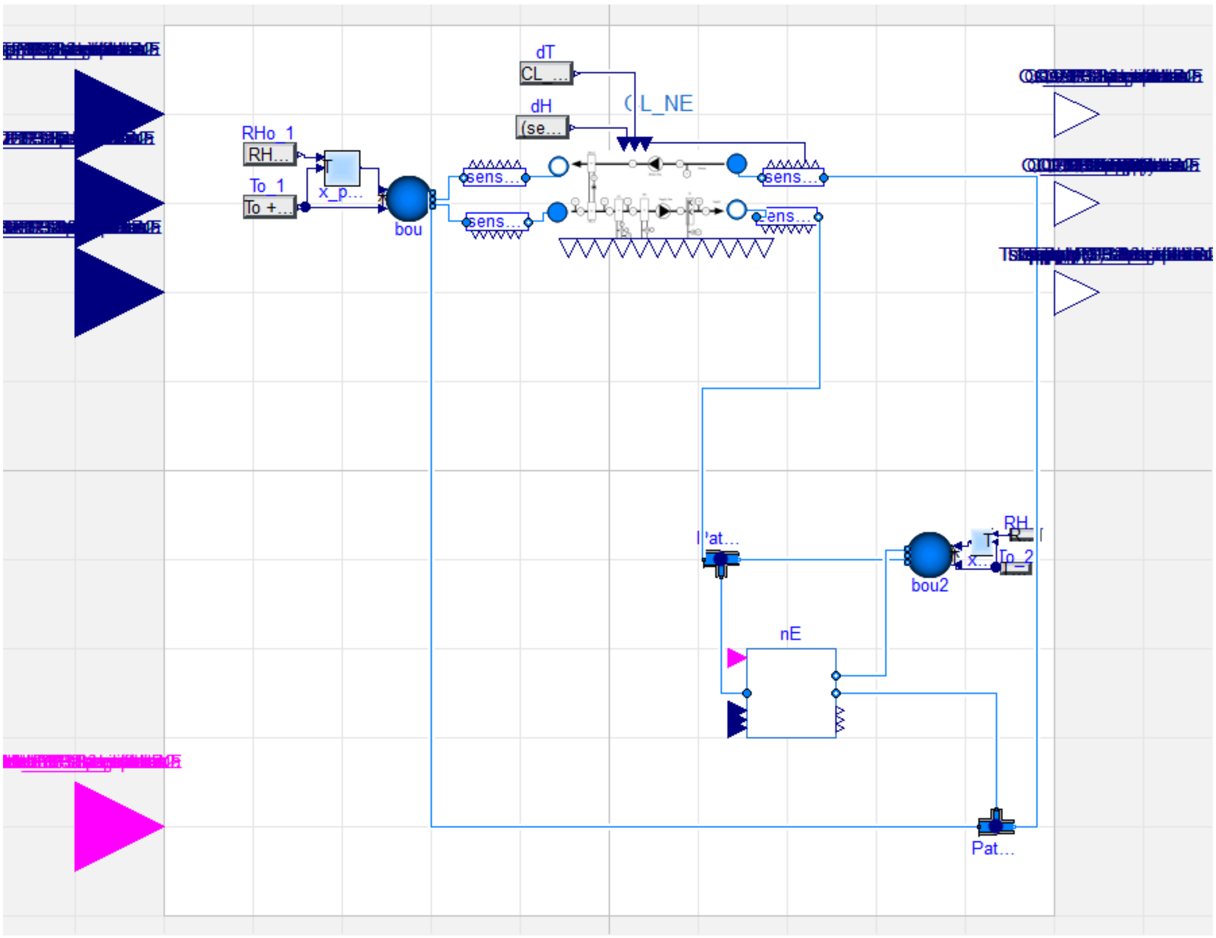


Figure 76. Gurtubay AHU NE Modelica Model.

Figure 77 shows the the Modelica model of the 11 zones served by the AHU NE.

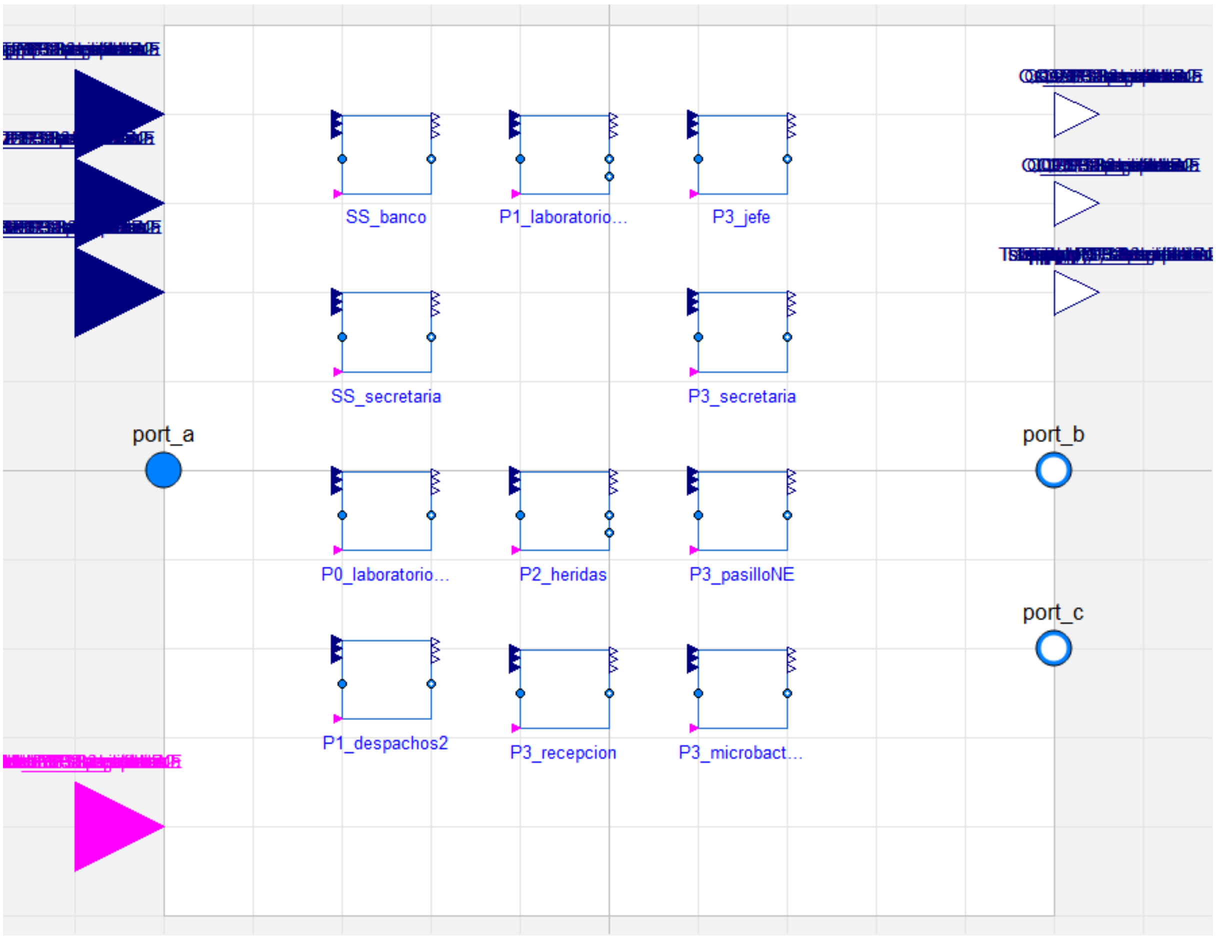


Figure 77. Gurtubay AHU NE zoning Modelica model.

4.2.2.4 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point.

Table 24. Input/output variables for AHU 'NE'.

Type	Name	Units
output RealOutput	Qflow_CC	[W]
output RealOutput	Qflow_HC	[W]
output RealOutput	RH_CC	[%]
output RealOutput	RH_HC	[%]
output RealOutput	RH_HR	[%]
output RealOutput	RH_r	[%]
output RealOutput	RH_supply	[%]
output RealOutput	T_CC	[degC]
output RealOutput	T_HC	[degC]
output RealOutput	T_HR	[degC]
output RealOutput	T_r	[degC]
output RealOutput	T_supply	[degC]
input RealInput	RHo	[%]
input RealInput	To	[degC]
input RealInput	Tsp_cold	[degC]
input RealInput	Tsp_hot	[degC]
input RealInput	Tz_SS_banco	[degC]
input RealInput	RHz_SS_banco	[%]

input RealInput	Tsp_SS_banco	[degC]
input BooleanInput	zoneHab_SS_banco	[boolean]
output RealOutput	Qs_SS_banco	[W]
output RealOutput	Ql_SS_banco	[W]
output RealOutput	Tsupply_SS_banco	[degC]
input RealInput	Tz_SS_secretaria	[degC]
input RealInput	RHz_SS_secretaria	[%]
input RealInput	Tsp_SS_secretaria	[degC]
input BooleanInput	zoneHab_SS_secretaria	[boolean]
output RealOutput	Qs_SS_secretaria	[W]
output RealOutput	Ql_SS_secretaria	[W]
output RealOutput	Tsupply_SS_secretaria	[degC]
input RealInput	Tz_P0_laboratorioNE	[degC]
input RealInput	RHz_P0_laboratorioNE	[%]
input RealInput	Tsp_P0_laboratorioNE	[degC]
input BooleanInput	zoneHab_P0_laboratorioNE	[boolean]
output RealOutput	Qs_P0_laboratorioNE	[W]
output RealOutput	Ql_P0_laboratorioNE	[W]
output RealOutput	Tsupply_P0_laboratorioNE	[degC]
input RealInput	Tz_P1_despachos2	[degC]
input RealInput	RHz_P1_despachos2	[%]
input RealInput	Tsp_P1_despachos2	[degC]
input BooleanInput	zoneHab_P1_despachos2	[boolean]
output RealOutput	Qs_P1_despachos2	[W]
output RealOutput	Ql_P1_despachos2	[W]
output RealOutput	Tsupply_P1_despachos2	[degC]
input RealInput	Tz_P1_laboratorioNE	[degC]
input RealInput	RHz_P1_laboratorioNE	[%]
input RealInput	Tsp_P1_laboratorioNE	[degC]
input BooleanInput	zoneHab_P1_laboratorioNE	[boolean]
output RealOutput	Qs_P1_laboratorioNE	[W]
output RealOutput	Ql_P1_laboratorioNE	[W]
output RealOutput	Tsupply_P1_laboratorioNE	[degC]
input RealInput	Tz_P2_heridas	[degC]
input RealInput	RHz_P2_heridas	[%]
input RealInput	Tsp_P2_heridas	[degC]
input BooleanInput	zoneHab_P2_heridas	[boolean]
output RealOutput	Qs_P2_heridas	[W]
output RealOutput	Ql_P2_heridas	[W]
output RealOutput	Tsupply_P2_heridas	[degC]
input RealInput	Tz_P3_microbacteria	[degC]
input RealInput	RHz_P3_microbacteria	[%]
input RealInput	Tsp_P3_microbacteria	[degC]
input BooleanInput	zoneHab_P3_microbacteria	[boolean]
output RealOutput	Qs_P3_microbacteria	[W]
output RealOutput	Ql_P3_microbacteria	[W]
output RealOutput	Tsupply_P3_microbacteria	[degC]
input RealInput	Tz_P3_jefe	[degC]
input RealInput	RHz_P3_jefe	[%]
input RealInput	Tsp_P3_jefe	[degC]
input BooleanInput	zoneHab_P3_jefe	[boolean]
output RealOutput	Qs_P3_jefe	[W]
output RealOutput	Ql_P3_jefe	[W]
output RealOutput	Tsupply_P3_jefe	[degC]
input RealInput	Tz_P3_secretaria	[degC]
input RealInput	RHz_P3_secretaria	[%]
input RealInput	Tsp_P3_secretaria	[degC]
input BooleanInput	zoneHab_P3_secretaria	[boolean]
output RealOutput	Qs_P3_secretaria	[W]
output RealOutput	Ql_P3_secretaria	[W]
output RealOutput	Tsupply_P3_secretaria	[degC]
input RealInput	Tz_P3_recepcion	[degC]
input RealInput	RHz_P3_recepcion	[%]
input RealInput	Tsp_P3_recepcion	[degC]
input BooleanInput	zoneHab_P3_recepcion	[boolean]
output RealOutput	Qs_P3_recepcion	[W]
output RealOutput	Ql_P3_recepcion	[W]
output RealOutput	Tsupply_P3_recepcion	[degC]
input RealInput	Tz_P3_pasilloNE	[degC]
input RealInput	RHz_P3_pasilloNE	[%]

input RealInput	Tsp_P3_pasilloNE	[degC]
input BooleanInput	zoneHab_P3_pasilloNE	[boolean]
output RealOutput	Qs_P3_pasilloNE	[W]
output RealOutput	Ql_P3_pasilloNE	[W]
output RealOutput	Tsupply_P3_pasilloNE	[degC]

4.2.2.5 Parameters needed to run the model

Table 25. Parameters needed to run model AHU 'NE'.

Type	Name	Default	Description
Time	controlSampleTime	150	Sampling time of the Controller [s]
MassFlowRate	m1_flow_nominal	8.2	Nominal air supply/return mass flow rate CL_vestuarios [kg/s]
MassFlowRate	m2_flow_nominal	16.11	Nominal water supply/return mass flow rate CL_vestuarios [kg/ s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)
Temp_C	Tmin	16	min supply temperature [degC]
Temp_C	Tmax	27	max supply temperature [degC]
Real	RHmax	0.70	Upper limits of RH
Real	RHmin	0.35	Lower limits of RH
Real	RH_multiplier	0.01	multiplier if RH is not in range [0..1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0

4.2.3 AHU 'SO'

AHU SO distributes air to some zones in all floors in Gurtubay buildings. AHU SO provides air to 23 base thermal zones. Air distribution is more complex than it is in AHU NE where some post-heating coils provide air to one or more zones which are also controlled by post-heating coil further down. Other zones are controlled by post heating and post cooling coils.

4.2.3.1 Schematic

Figure 78 shows the overall schematic of the air distribution for AHU SO.

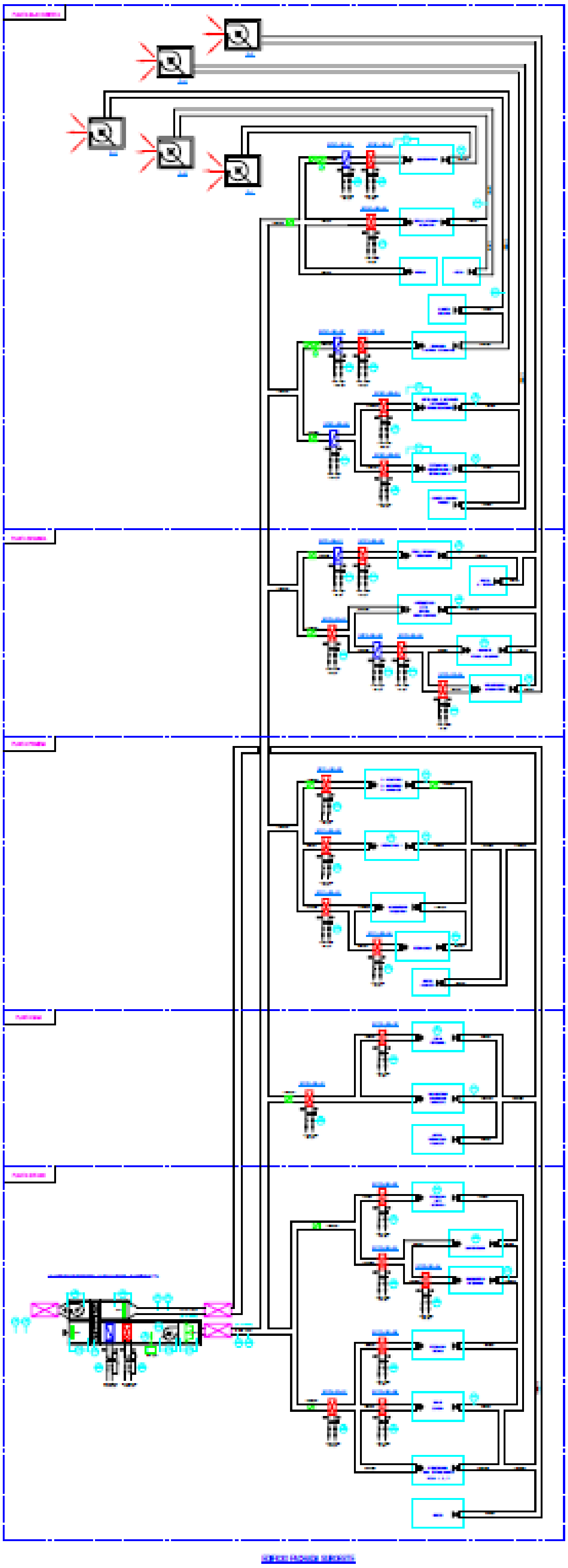


Figure 78. Gurtubay AHU SO Air Distribution

4.2.3.2 AHU SO air distribution zones

The table below provides characteristics of the zones supplied by SO.

code	type	parameter	value(in/out)		units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	0.34	0.34	kg/s	SS_diagnostico	zonePHC
BC-PS-SO-04	Heating Coil	Nominal power	2.32		kW	SS_diagnostico	zonePHC
-	Air flow	Nominal air mass flow rate	0.42	0.07	kg/s	SS_supervisora	zonePHC_splitSup
BC-PS-SO-03	Heating Coil	Nominal power	2.32		kW	SS_supervisora	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.14	0.14	kg/s	SS_jefe	zonePHC
BC-PS-SO-02	Heating Coil	Nominal power	2.32		kW	SS_jefe	zonePHC
-	Air flow	Nominal air mass flow rate	1.10	0.87	kg/s	SS_general	zonePHC_splitSup
BC-PS-SO-01	Heating Coil	Nominal power	9.30		kW	SS_general	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.12	0.12	kg/s	SS_salaEspera	zonePHC
BC-PS-SO-05	Heating Coil	Nominal power	1.16		kW	SS_salaEspera	zonePHC
-	Air flow	Nominal air mass flow rate	0.00	0.07	kg/s	SS_hall	zone
-	Air flow	Nominal air mass flow rate	0.00	0.17	kg/s	P0_despachos	zone
-	Air flow	Nominal air mass flow rate	1.94	2.09	kg/s	P0_laboratorioSO	zonePHC_splitSup
BC-P0-SO-01	Heating Coil	Nominal power	12.78		kW	P0_laboratorioSO	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.14	0.14	kg/s	P0_estar	zonePHC
BC-P0-SO-02	Heating Coil	Nominal power	1.16		kW	P0_estar	zonePHC
-	Air flow	Nominal air mass flow rate	0.44	0.44	kg/s	P1_prep	zonePHC
BC-P1-SO-02	Heating Coil	Nominal power	3.49		kW	P1_prep	zonePHC
-	Air flow	Nominal air mass flow rate	0.12	0.12	kg/s	P1_despachos1	zonePHC
BC-P1-SO-03	Heating Coil	Nominal power	1.16		kW	P1_despachos1	zonePHC
-	Air flow	Nominal air mass flow rate	0.12	0.12	kg/s	P1_despachos	zonePHC
BC-P1-SO-04	Heating Coil	Nominal power	1.16		kW	P1_despachos	zonePHC
-	Air flow	Nominal air mass flow rate	1.40	1.28	kg/s	P1_laboratorioSO	zonePHC_splitSup
BC-P1-SO-01	Heating Coil	Nominal power	10.46		kW	P1_laboratorioSO	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.53	0.53	kg/s	P2_serologia	zonePHC_PCC
BC-P2-SO-02	Heating Coil	Nominal power	3.49		kW	P2_serologia	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.53	0.53	kg/s	P2_serologia	zonePHC_PCC
BF-P2-SO-01	Cooling Coil	Nominal power	3.49		kW	P2_serologia	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	1.62	0.88	kg/s	P2_ETS	zonePHC_splitSup
BC-P2-SO-01	Heating Coil	Nominal power	10.46		kW	P2_ETS	zonePHC_splitSup
-	Air flow	Nominal air mass flow rate	0.61	0.34	kg/s	P2_hemos	zonePHC_PCC_splitSupp
BC-P2-SO-03	Heating Coil	Nominal power	2.32		kW	P2_hemos	zonePHC_PCC_splitSupp
-	Air flow	Nominal air mass flow rate	0.61	0.34	kg/s	P2_hemos	zonePHC_PCC_splitSupp
BF-P2-SO-02	Heating Coil	Nominal power	4.65		kW	P2_hemos	zonePHC_PCC_splitSupp
-	Air flow	Nominal air mass flow rate	0.27	0.31	kg/s	P2_laboratorio	zonePHC
BC-P2-SO-04	Heating Coil	Nominal power	1.16		kW	P2_laboratorio	zonePHC
-	Air flow	Nominal air mass flow rate	0.39	0.51	kg/s	P3_bioseguridad	zonePHC_PCC
BC-PBC-SO-01	Heating Coil	Nominal power	2.32		kW	P3_bioseguridad	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.39	0.51	kg/s	P3_bioseguridad	zonePHC_PCC
BF-PBC-SO-01	Coolin Coil	Nominal power	3.49		kW	P3_bioseguridad	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.75	0.97	kg/s	P3_virologia	zonePHC_PCC
BC-PBC-SO-02	Heating Coil	Nominal power	3.49		kW	P3_virologia	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.75	0.97	kg/s	P3_virologia	zonePHC_PCC
BF-PBC-SO-02	Coolin Coil	Nominal power	5.81		kW	P3_virologia	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.68	0.11	kg/s	P3_retrovirus	zonePHC_PCC
BC-PBC-SO-04	Heating Coil	Nominal power	4.65		kW	P3_retrovirus	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.68	0.11	kg/s	P3_retrovirus	zonePHC_PCC
BF-PBC-SO-03A	Coolin Coil	Nominal power	3.49		kW	P3_retrovirus	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.39	0.27	kg/s	P3_extraccion	zonePHC_PCC
BC-PBC-SO-05	Heating Coil	Nominal power	2.32		kW	P3_extraccion	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.39	0.27	kg/s	P3_extraccion	zonePHC_PCC
BF-PBC-SO-03B	Coolin Coil	Nominal power	3.49		kW	P3_extraccion	zonePHC_PCC
-	Air flow	Nominal air mass flow rate	0.07	0.07	kg/s	P3_pasilloSO	zone
-	Air flow	Nominal air mass flow rate	0.15	0.15	kg/s	P3_estar	zonePHC
BC-PBC-SO-03	Heating Coil	Nominal power	2.32		kW	P3_estar	zonePHC

4.2.3.3 Modelica Model

Figure 79 shows the Modelica model of AHU SO serving the zones.

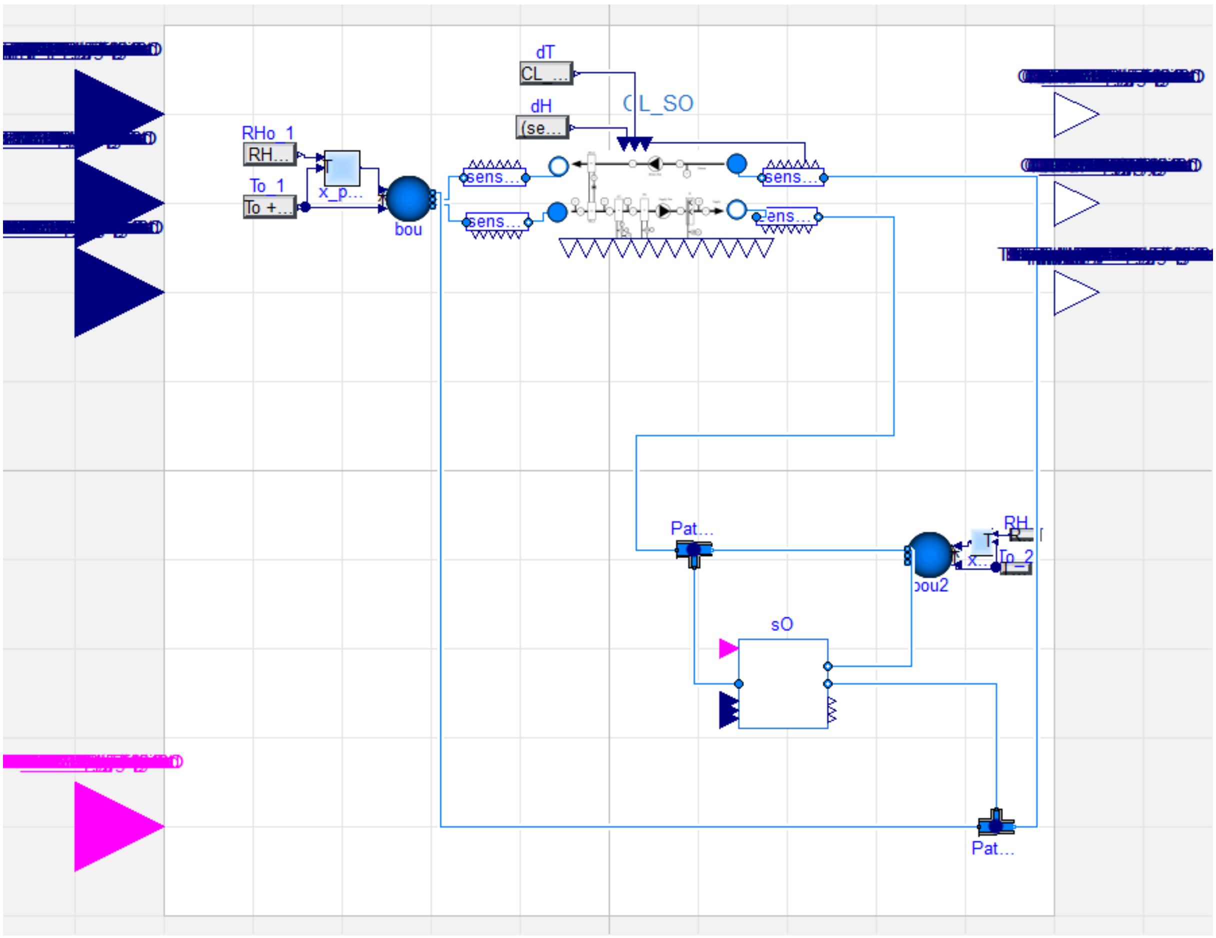


Figure 79. Gurtubay AHU SO Modelica Model.

Figure 80 shows the the Modelica model of the 23 zones served by the AHU SO.

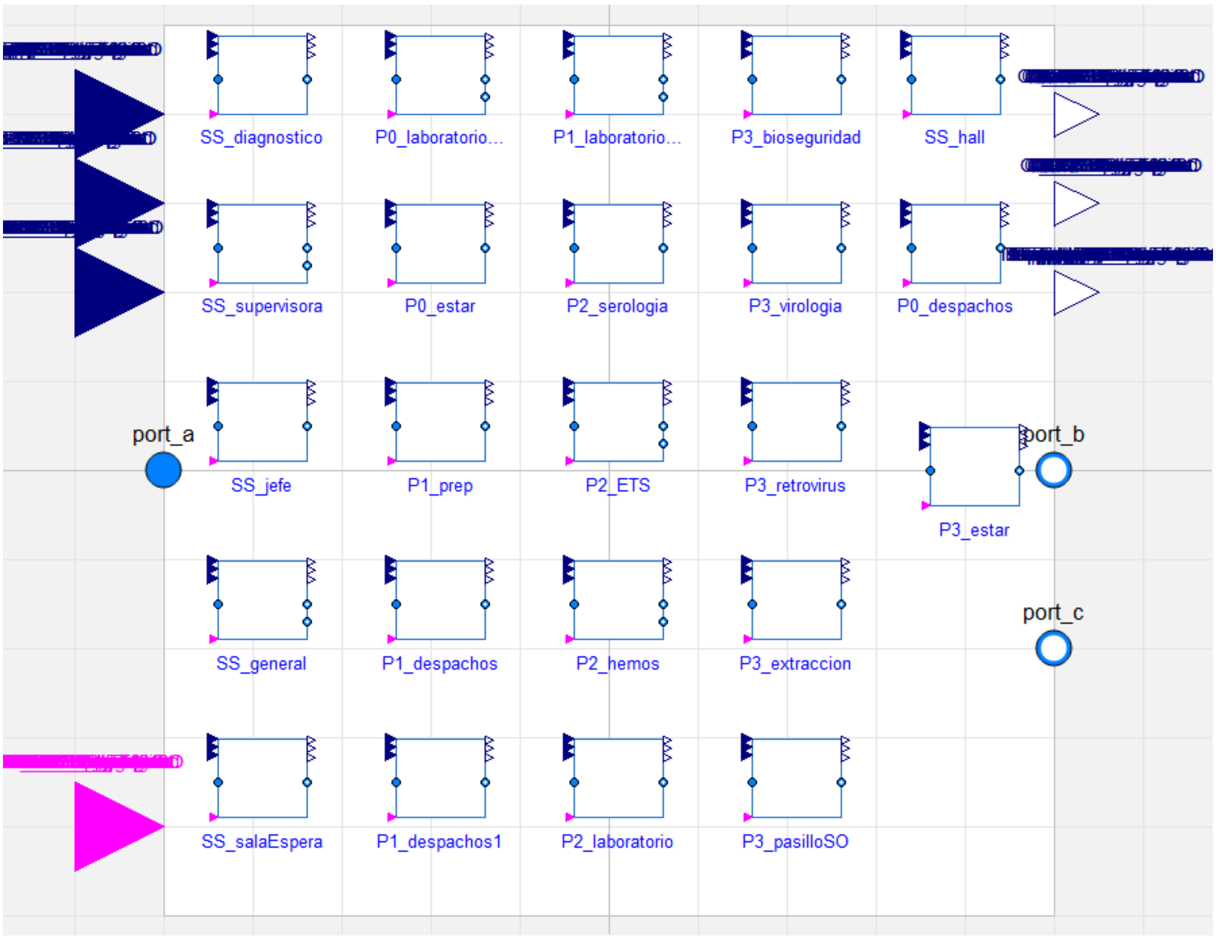


Figure 80. Gurtubay AHU SO zoning Modelica model.

4.2.3.4 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point.

Table 26. Input/output variables for AHU 'SO'.

Type	Name	Description
output RealOutput	Qflow_CC	[W]
output RealOutput	Qflow_HC	[W]
output RealOutput	RH_CC	[%]
output RealOutput	RH_HC	[%]
output RealOutput	RH_HR	[%]
output RealOutput	RH_r	[%]
output RealOutput	RH_supply	[%]
output RealOutput	T_CC	[degC]
output RealOutput	T_HC	[degC]
output RealOutput	T_HR	[degC]
output RealOutput	T_r	[degC]
output RealOutput	T_supply	[degC]
input RealInput	Tz_SS_diagnostico	[degC]
input RealInput	RHz_SS_diagnostico	[%]
input RealInput	Tsp_SS_diagnostico	[degC]
input BooleanInput	zoneHab_SS_diagnostico	[boolean]
output RealOutput	Qs_SS_diagnostico	[W]
output RealOutput	Ql_SS_diagnostico	[W]
output RealOutput	Tsupply_SS_diagnostico	[degC]
input RealInput	Tz_SS_supervisora	[degC]

input RealInput	RHz_SS_supervisora	[%]
input RealInput	Tsp_SS_supervisora	[degC]
input BooleanInput	zoneHab_SS_supervisora	[boolean]
output RealOutput	Qs_SS_supervisora	[W]
output RealOutput	Ql_SS_supervisora	[W]
output RealOutput	Tsupply_SS_supervisora	[degC]
input RealInput	Tz_SS_jefe	[degC]
input RealInput	RHz_SS_jefe	[%]
input RealInput	Tsp_SS_jefe	[degC]
input BooleanInput	zoneHab_SS_jefe	[boolean]
output RealOutput	Qs_SS_jefe	[W]
output RealOutput	Ql_SS_jefe	[W]
output RealOutput	Tsupply_SS_jefe	[degC]
input RealInput	Tz_SS_general	[degC]
input RealInput	RHz_SS_general	[%]
input RealInput	Tsp_SS_general	[degC]
input BooleanInput	zoneHab_SS_general	[boolean]
output RealOutput	Qs_SS_general	[W]
output RealOutput	Ql_SS_general	[W]
output RealOutput	Tsupply_SS_general	[degC]
input RealInput	Tz_SS_salaEspera	[degC]
input RealInput	RHz_SS_salaEspera	[%]
input RealInput	Tsp_SS_salaEspera	[degC]
input BooleanInput	zoneHab_SS_salaEspera	[boolean]
output RealOutput	Qs_SS_salaEspera	[W]
output RealOutput	Ql_SS_salaEspera	[W]
output RealOutput	Tsupply_SS_salaEspera	[degC]
input RealInput	Tz_P0_laboratorioSO	[degC]
input RealInput	RHz_P0_laboratorioSO	[%]
input RealInput	Tsp_P0_laboratorioSO	[degC]
input BooleanInput	zoneHab_P0_laboratorioSO	[boolean]
output RealOutput	Qs_P0_laboratorioSO	[W]
output RealOutput	Ql_P0_laboratorioSO	[W]
output RealOutput	Tsupply_P0_laboratorioSO	[degC]
input RealInput	Tz_P0_estar	[degC]
input RealInput	RHz_P0_estar	[%]
input RealInput	Tsp_P0_estar	[degC]
input BooleanInput	zoneHab_P0_estar	[boolean]
output RealOutput	Qs_P0_estar	[W]
output RealOutput	Ql_P0_estar	[W]
output RealOutput	Tsupply_P0_estar	[degC]
input RealInput	Tz_P1_prep	[degC]
input RealInput	RHz_P1_prep	[%]
input RealInput	Tsp_P1_prep	[degC]
input BooleanInput	zoneHab_P1_prep	[boolean]
output RealOutput	Qs_P1_prep	[W]
output RealOutput	Ql_P1_prep	[W]
output RealOutput	Tsupply_P1_prep	[degC]
input RealInput	Tz_P1_despachos1	[degC]
input RealInput	RHz_P1_despachos1	[%]
input RealInput	Tsp_P1_despachos1	[degC]
input BooleanInput	zoneHab_P1_despachos1	[boolean]
output RealOutput	Qs_P1_despachos1	[W]
output RealOutput	Ql_P1_despachos1	[W]
output RealOutput	Tsupply_P1_despachos1	[degC]
input RealInput	Tz_P1_despachos	[degC]
input RealInput	RHz_P1_despachos	[%]
input RealInput	Tsp_P1_despachos	[degC]
input BooleanInput	zoneHab_P1_despachos	[boolean]
output RealOutput	Qs_P1_despachos	[W]
output RealOutput	Ql_P1_despachos	[W]
output RealOutput	Tsupply_P1_despachos	[degC]
input RealInput	Tz_P1_laboratorioSO	[degC]
input RealInput	RHz_P1_laboratorioSO	[%]
input RealInput	Tsp_P1_laboratorioSO	[degC]
input BooleanInput	zoneHab_P1_laboratorioSO	[boolean]
output RealOutput	Qs_P1_laboratorioSO	[W]
output RealOutput	Ql_P1_laboratorioSO	[W]
output RealOutput	Tsupply_P1_laboratorioSO	[degC]
input RealInput	Tz_P2_serologia	[degC]

input RealInput	RHz_P2_serologia	[%]
input RealInput	Tsp_P2_serologia	[degC]
input BooleanInput	zoneHab_P2_serologia	[boolean]
output RealOutput	Qs_P2_serologia	[W]
output RealOutput	Ql_P2_serologia	[W]
output RealOutput	Tsupply_P2_serologia	[degC]
input RealInput	Tz_P2_ETS	[degC]
input RealInput	RHz_P2_ETS	[%]
input RealInput	Tsp_P2_ETS	[degC]
input BooleanInput	zoneHab_P2_ETS	[boolean]
output RealOutput	Qs_P2_ETS	[W]
output RealOutput	Ql_P2_ETS	[W]
output RealOutput	Tsupply_P2_ETS	[degC]
input RealInput	Tz_P2_hemos	[degC]
input RealInput	RHz_P2_hemos	[%]
input RealInput	Tsp_P2_hemos	[degC]
input BooleanInput	zoneHab_P2_hemos	[boolean]
output RealOutput	Qs_P2_hemos	[W]
output RealOutput	Ql_P2_hemos	[W]
output RealOutput	Tsupply_P2_hemos	[degC]
input RealInput	Tz_P2_laboratorio	[degC]
input RealInput	RHz_P2_laboratorio	[%]
input RealInput	Tsp_P2_laboratorio	[degC]
input BooleanInput	zoneHab_P2_laboratorio	[boolean]
output RealOutput	Qs_P2_laboratorio	[W]
output RealOutput	Ql_P2_laboratorio	[W]
output RealOutput	Tsupply_P2_laboratorio	[degC]
input RealInput	Tz_P3_bioseguridad	[degC]
input RealInput	RHz_P3_bioseguridad	[%]
input RealInput	Tsp_P3_bioseguridad	[degC]
input BooleanInput	zoneHab_P3_bioseguridad	[boolean]
output RealOutput	Qs_P3_bioseguridad	[W]
output RealOutput	Ql_P3_bioseguridad	[W]
output RealOutput	Tsupply_P3_bioseguridad	[degC]
input RealInput	Tz_P3_virologia	[degC]
input RealInput	RHz_P3_virologia	[%]
input RealInput	Tsp_P3_virologia	[degC]
input BooleanInput	zoneHab_P3_virologia	[boolean]
output RealOutput	Qs_P3_virologia	[W]
output RealOutput	Ql_P3_virologia	[W]
output RealOutput	Tsupply_P3_virologia	[degC]
input RealInput	Tz_P3_retrovirus	[degC]
input RealInput	RHz_P3_retrovirus	[%]
input RealInput	Tsp_P3_retrovirus	[degC]
input BooleanInput	zoneHab_P3_retrovirus	[boolean]
output RealOutput	Qs_P3_retrovirus	[W]
output RealOutput	Ql_P3_retrovirus	[W]
output RealOutput	Tsupply_P3_retrovirus	[degC]
input RealInput	Tz_P3_extraccion	[degC]
input RealInput	RHz_P3_extraccion	[%]
input RealInput	Tsp_P3_extraccion	[degC]
input BooleanInput	zoneHab_P3_extraccion	[boolean]
output RealOutput	Qs_P3_extraccion	[W]
output RealOutput	Ql_P3_extraccion	[W]
output RealOutput	Tsupply_P3_extraccion	[degC]
input RealInput	Tz_P3_pasilloSO	[degC]
input RealInput	RHz_P3_pasilloSO	[%]
input RealInput	Tsp_P3_pasilloSO	[degC]
input BooleanInput	zoneHab_P3_pasilloSO	[boolean]
output RealOutput	Qs_P3_pasilloSO	[W]
output RealOutput	Ql_P3_pasilloSO	[W]
output RealOutput	Tsupply_P3_pasilloSO	[degC]
input RealInput	Tz_P3_estar	[degC]
input RealInput	RHz_P3_estar	[%]
input RealInput	Tsp_P3_estar	[degC]
input BooleanInput	zoneHab_P3_estar	[boolean]
output RealOutput	Qs_P3_estar	[W]
output RealOutput	Ql_P3_estar	[W]
output RealOutput	Tsupply_P3_estar	[degC]
input RealInput	Tz_SS_hall	[degC]

input RealInput	RHz_SS_hall	[%]
input RealInput	Tsp_SS_hall	[degC]
input BooleanInput	zoneHab_SS_hall	[boolean]
output RealOutput	Qs_SS_hall	[W]
output RealOutput	Ql_SS_hall	[W]
output RealOutput	Tsupply_SS_hall	[degC]
input RealInput	Tz_P0_despachos	[degC]
input RealInput	RHz_P0_despachos	[%]
input RealInput	Tsp_P0_despachos	[degC]
input BooleanInput	zoneHab_P0_despachos	[boolean]
output RealOutput	Qs_P0_despachos	[W]
output RealOutput	Ql_P0_despachos	[W]
output RealOutput	Tsupply_P0_despachos	[degC]
input RealInput	RHo	[%]
input RealInput	To	[degC]
input RealInput	Tsp_cold	[degC]
input RealInput	Tsp_hot	[degC]

4.2.3.5 Parameters needed to run the model

Table 27. Parameters needed to run model AHU 'SO'.

Type	Name	Default	Description
Time	controlSampleTime	150	Sampling time of the Controller [s]
MassFlowRate	m1_flow_nominal	10.45	Nominal air supply/return mass flow rate CL_vestuarios [kg/s]
MassFlowRate	m2_flow_nominal	21.23	Nominal water supply/return mass flow rate CL_vestuarios [kg/ s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)
Temp_C	Tmin	16	min supply temperature [degC]
Temp_C	Tmax	27	max supply temperature [degC]
Real	RHmax	0.70	Upper limits of RH
Real	RHmin	0.35	Lower limits of RH
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0

4.2.4 Gurtubay full model

4.3 Areilza (Surgical Block)

In surgical block, only two floors of the phase III building (name given to the building by Basurto hospital) are modelled. This was decided since these areas will be used for running the more detailed and invasive experiments under the test plans defined in deliverable D6.3. The reason for choosing this building is the fact that it is currently not in operation (so we avoid disturbing the normal operation of the hospital) while it has all the components needed to validate the models. Each of the floors is supplied by one AHU that provides primary air to multiple post-heating coils/fan coils that control indoor environmental condition on each zone. The following sections describe the air distribution system and the interconnected models (Modelica + EnergyPlus_fmu).

4.3.1 AHU CL1 – Second Floor

AHU CL1 distributes air to the second floor of Areilza's phase III building. AHU CL1 distributes air to 33 distinct zones grouped in three air paths (patinillos). Zone local environmental conditions are maintained either via post-heating coils or via fancoils. CL1 provides primary air to the zones so that the supply air temperature is equal to the minimum air temperature after the post-heating coil of all enabled zones.

4.3.1.1 Schematic

Figure 81 shows the overall schematic of the air distribution for AHU CL1.

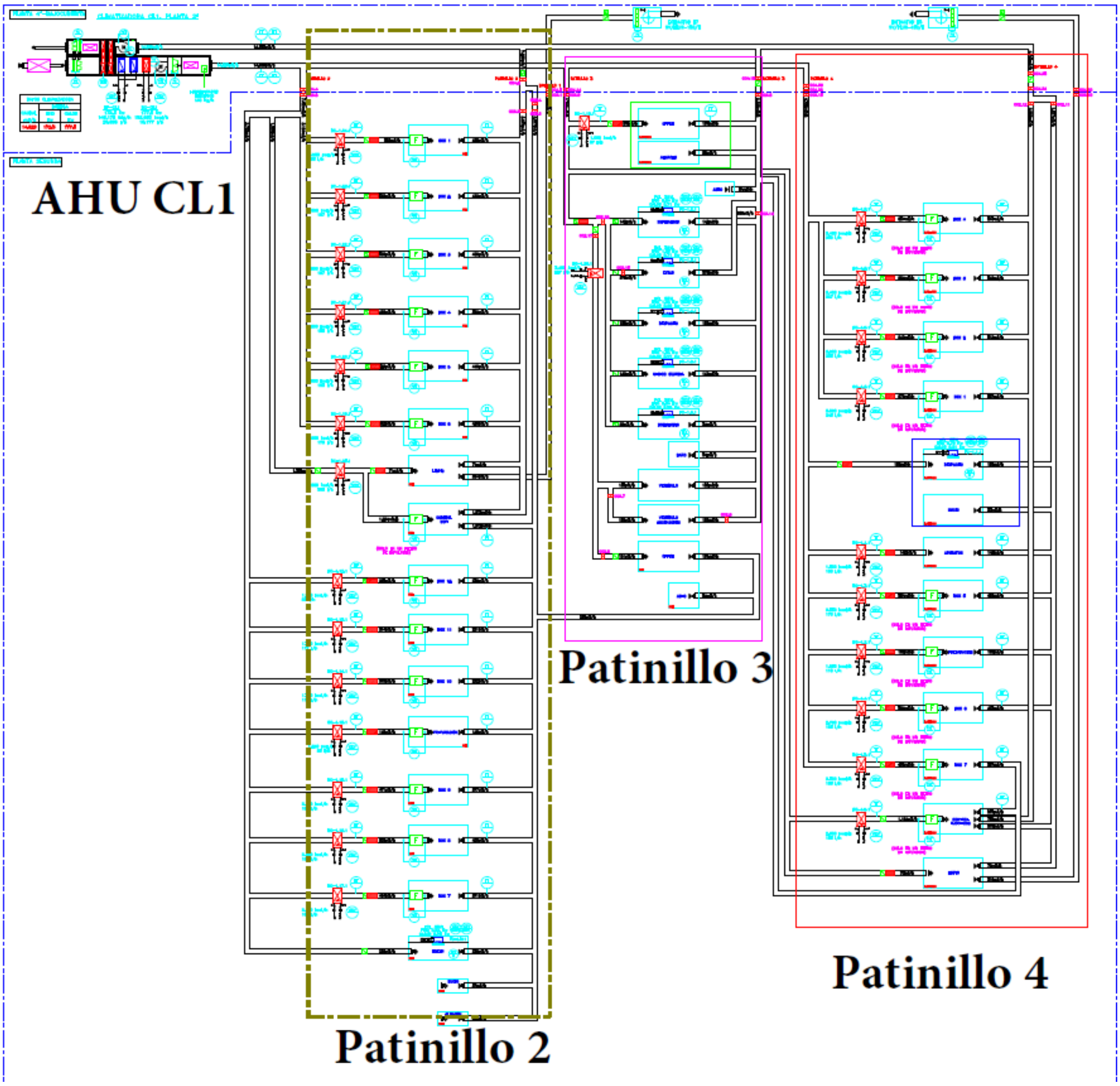


Figure 81. Areilza AHU CL1 Air Distribution

4.3.1.2 AHU CL1 air distribution zones

4.3.1.2.1 Patinillo 2

The table below provides characteristics of the zones in Patinillo 2.

Code	Type	Parameter	Value	Units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	0.10	kg/s	Box_12	zonePHC
BC-1.12.1	Heating Coil	Nominal power	1.45	kW	Box_12	zonePHC
-	Air flow	Nominal air mass flow rate	0.11	kg/s	Box_11	zonePHC
BC-1.13.1	Heating Coil	Nominal power	2.03	kW	Box_11	zonePHC
-	Air flow	Nominal air mass flow rate	0.11	kg/s	Box_10	zonePHC
BC-1.14.1	Heating Coil	Nominal power	2.03	kW	Box_10	zonePHC
-	Air flow	Nominal air mass flow rate	0.16	kg/s	Box_9	zonePHC
BC-1.15.1	Heating Coil	Nominal power	2.73	kW	Box_9	zonePHC
-	Air flow	Nominal air mass flow rate	0.17	kg/s	Box_8	zonePHC
BC-1.16.1	Heating Coil	Nominal power	2.73	kW	Box_8	zonePHC
-	Air flow	Nominal air mass flow rate	0.16	kg/s	Box_7	zonePHC

BC-1.17.1	Heating Coil	Nominal power	2.85	kW	Box_7	zonePHC
-	Air flow	Nominal air mass flow rate	0.05	kg/s	preparacion	zonePHC
BC-1.18.1	Heating Coil	Nominal power	1.45	kW	preparacion	zonePHC
-	Air flow	Nominal air mass flow rate	0.18	kg/s	Box_6	zonePHC
BC-1.19.1	Heating Coil	Nominal power	3.02	kW	Box_6	zonePHC
-	Air flow	Nominal air mass flow rate	0.18	kg/s	Box_5	zonePHC
BC-1.20.1	Heating Coil	Nominal power	3.37	kW	Box_5	zonePHC
-	Air flow	Nominal air mass flow rate	0.17	kg/s	Box_4	zonePHC
BC-1.21.1	Heating Coil	Nominal power	2.67	kW	Box_4	zonePHC
-	Air flow	Nominal air mass flow rate	0.17	kg/s	Box_3	zonePHC
BC-1.22.1	Heating Coil	Nominal power	3.25	kW	Box_3	zonePHC
-	Air flow	Nominal air mass flow rate	0.18	kg/s	Box_2	zonePHC
BC-1.23.1	Heating Coil	Nominal power	3.43	kW	Box_2	zonePHC
-	Air flow	Nominal air mass flow rate	0.20	kg/s	Box_1	zonePHC
BC-1.24.1	Heating Coil	Nominal power	4.07	kW	Box_1	zonePHC
-	Air flow	Nominal air mass flow rate	0.45	kg/s	control	zonePHCe
BC-1.25.1	Heating Coil	Nominal power	6.86	kW	control	zonePHCe
-	Air flow	Nominal air mass flow rate	0.028	kg/s	estar	zoneFancoil
FC-1.7.1	Fan Coil	Nominal power	6.0	kW	estar	zoneFancoil

4.3.1.2.2 Patinillo 3

The table below provides characteristics of the zones in Patinillo 3.

Code	Type	Parameter	Value	Units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	0.23	kg/s	office	zonePHC
BC-1.10.1	Heating Coil	Nominal power	4.24	kW	office	zonePHC
-	Air flow	Nominal air mass flow rate	0.22	kg/s	vestibulos	zonePHC
BC-1.26.1	Heating Coil	Nominal power	4.07	kW	vestibulos	zonePHC
-	Air flow	Nominal air mass flow rate	0.2	kg/s	estar	zoneFancoil
FC-1.2.1	Fan Coil	Nominal power	6.0	kW	estar	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	supervisor	zoneFancoil
FC-1.3.1	Fan Coil	Nominal power	6.0	kW	supervisor	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho	zoneFancoil
FC-1.4.1	Fan Coil	Nominal power	6.0	kW	despacho	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	medicoGuardia	zoneFancoil
FC-1.5.1	Fan Coil	Nominal power	6.0	kW	medicoGuardia	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	dormitorio	zoneFancoil
FC-1.6.1	Fan Coil	Nominal power	6.0	kW	dormitorio	zoneFancoil

4.3.1.2.3 Patinillo 4

The table below provides characteristics of the zones in Patinillo 4.

Code	Type	Parameter	Value	Units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	0.05	kg/s	aparatos	zonePHC
BC-1.1.1	Heating Coil	Nominal power	1.74	kW	aparatos	zonePHC
-	Air flow	Nominal air mass flow rate	0.07	kg/s	preparacion	zonePHC
BC-1.2.1	Heating Coil	Nominal power	1.92	kW	preparacion	zonePHC
-	Air flow	Nominal air mass flow rate	0.20	kg/s	Box_5	zonePHC
BC-1.3.1	Heating Coil	Nominal power	2.96	kW	Box_5	zonePHC
-	Air flow	Nominal air mass flow rate	0.17	kg/s	Box_6	zonePHC
BC-1.4.1	Heating Coil	Nominal power	3.20	kW	Box_6	zonePHC
-	Air flow	Nominal air mass flow rate	0.17	kg/s	Box_7	zonePHC
BC-1.5.1	Heating Coil	Nominal power	2.67	kW	Box_7	zonePHC
-	Air flow	Nominal air mass flow rate	0.23	kg/s	Box_1	zonePHC
BC-1.6.1	Heating Coil	Nominal power	4.24	kW	Box_1	zonePHC
-	Air flow	Nominal air mass flow rate	0.22	kg/s	Box_2	zonePHC
BC-1.7.1	Heating Coil	Nominal power	4.07	kW	Box_2	zonePHC
-	Air flow	Nominal air mass flow rate	0.23	kg/s	Box_3	zonePHC
BC-1.8.1	Heating Coil	Nominal power	3.95	kW	Box_3	zonePHC
-	Air flow	Nominal air mass flow rate	0.22	kg/s	Box_4	zonePHC
BC-1.9.1	Heating Coil	Nominal power	4.01	kW	Box_4	zonePHC
-	Air flow	Nominal air mass flow rate	0.43	kg/s	control	zonePHC
BC-1.11.1	Heating Coil	Nominal power	6.74	kW	control	zonePHC
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho	zoneFancoil
FC-1.1.1	Fan Coil	Nominal power	6.0	kW	despacho	zoneFancoil

4.3.1.3 Modelica Model

Figure 82 shows the Modelica model of AHU CL_1 serving the three ‘patinillo’ areas.

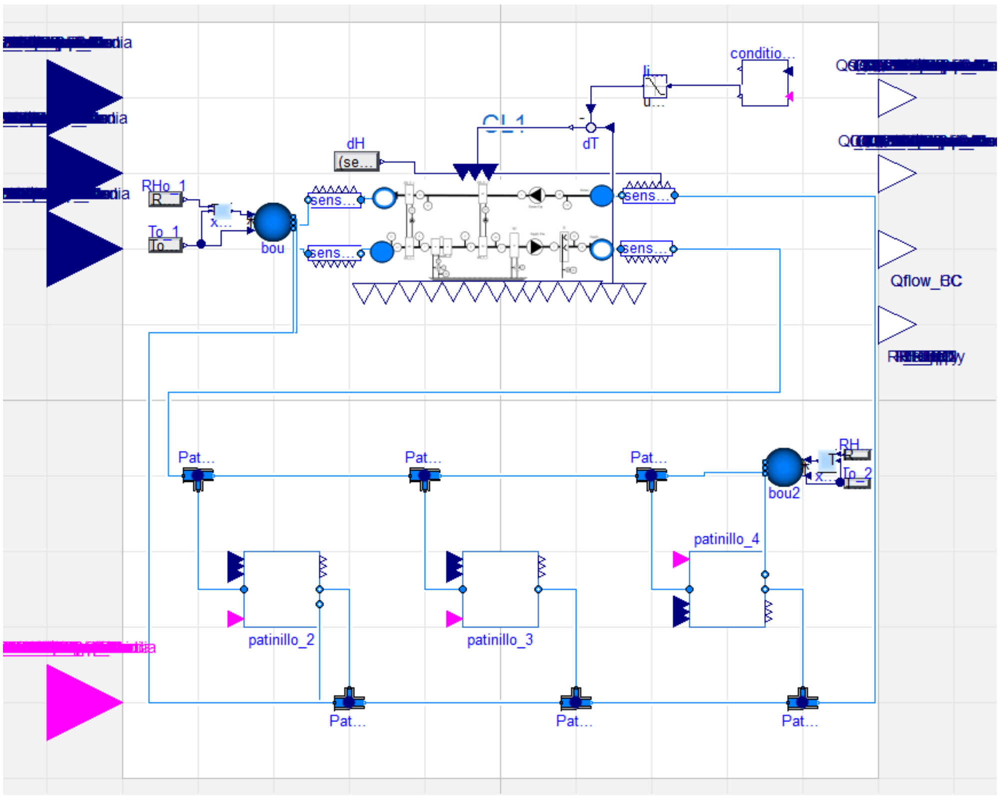


Figure 82. Areilza AHU CL_1 Modelica Model.

4.3.1.3.1 Patinillo 2

Figure 83 shows the the Modelica model of the 15 zones served by the AHU CL_1 in patinillo 2.

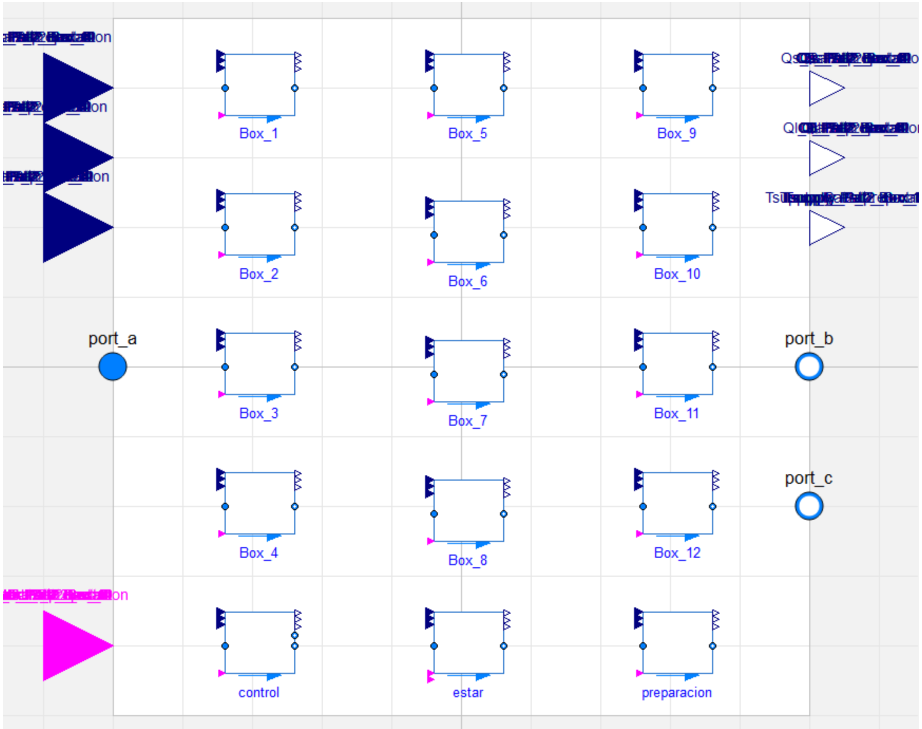


Figure 83. Areilza Patinillo 2 Modelica Model.

4.3.1.3.2 Patinillo 3

Figure 84 shows the the Modelica model of the 7 zones served by the AHU CL_1 in patinillo 3.

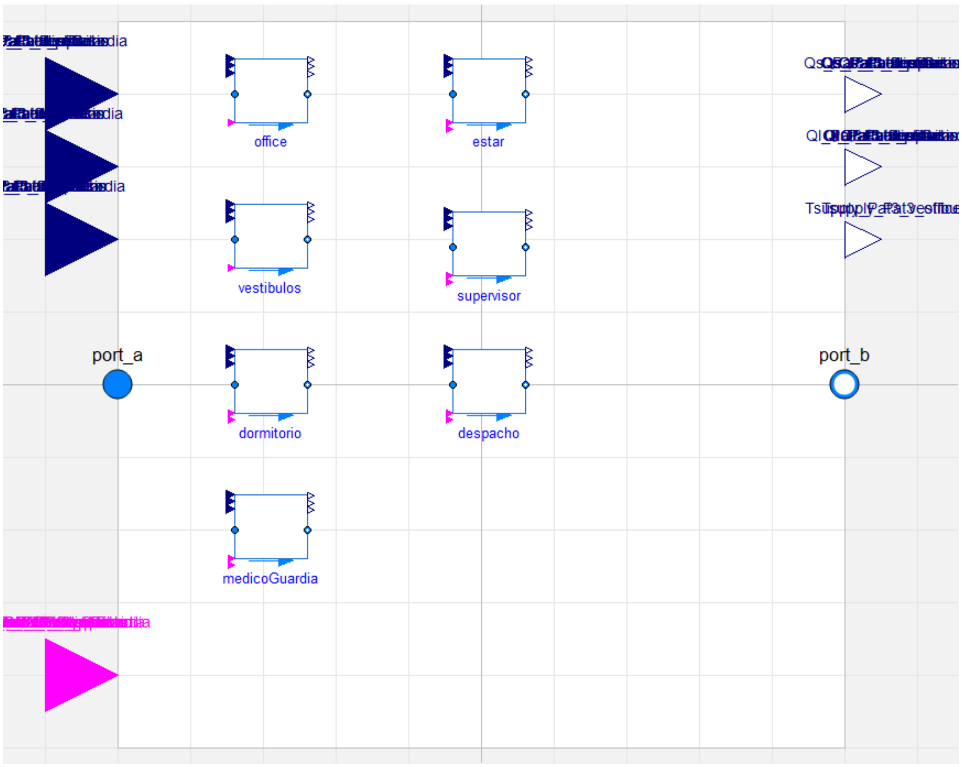


Figure 84. Areilza Patinillo 3 Modelica Model.

4.3.1.3.3 Patinillo 4

Figure 85 shows the the Modelica model of the 11 zones served by the AHU CL_1 in patinillo 4.

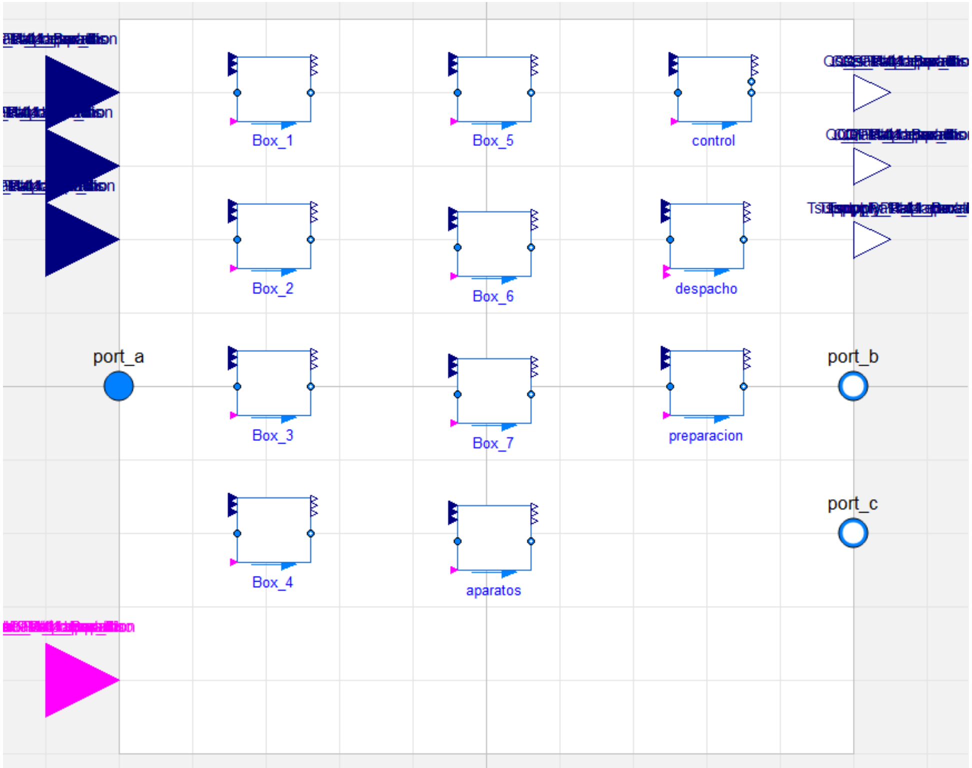


Figure 85. Areilza Patinillo 4 Modelica Model.

4.3.1.4 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point

Table 28. Input/output variables for AHU CL1 – Second Floor.

Type	Name	Units
input RealInput	To	[degC]
input RealInput	RHo	[%]
input RealInput	Tsp_Pat3_office	[degC]
input RealInput	Tz_Pat3_office	[degC]
input RealInput	RH_Pat3_office	[%]
input RealInput	Tsp_Pat3_vestibulos	[degC]
input RealInput	Tz_Pat3_vestibulos	[degC]
input RealInput	RH_Pat3_vestibulos	[%]
input RealInput	Tsp_Pat3_dormitorio	[degC]
input RealInput	Tz_Pat3_dormitorio	[degC]
input RealInput	RH_Pat3_dormitorio	[%]
input RealInput	Tsp_Pat3_medicoGuardia	[degC]
input RealInput	Tz_Pat3_medicoGuardia	[degC]
input RealInput	RH_Pat3_medicoGuardia	[%]
input RealInput	Tsp_Pat3_estar	[degC]
input RealInput	Tz_Pat3_estar	[degC]
input RealInput	RH_Pat3_estar	[%]
input RealInput	Tsp_Pat3_supervisor	[degC]

input RealInput	Tz_Pat3_supervisor	[degC]
input RealInput	RH_Pat3_supervisor	[%]
input RealInput	Tsp_Pat3_despacho	[degC]
input RealInput	Tz_Pat3_despacho	[degC]
input RealInput	RH_Pat3_despacho	[%]
input BooleanInput	zoneHab_Pat3_office	[boolean]
input BooleanInput	zoneHab_Pat3_vestibulos	[boolean]
input BooleanInput	zoneHab_Pat3_dormitorio	[boolean]
input BooleanInput	fancoilHab_Pat3_dormitorio	[boolean]
input BooleanInput	zoneHab_Pat3_medicoGuardia	[boolean]
input BooleanInput	fancoilHab_Pat3_medicoGuardia	[boolean]
input BooleanInput	zoneHab_Pat3_estar	[boolean]
input BooleanInput	fancoilHab_Pat3_estar	[boolean]
input BooleanInput	zoneHab_Pat3_supervisor	[boolean]
input BooleanInput	fancoilHab_Pat3_supervisor	[boolean]
input BooleanInput	zoneHab_Pat3_despacho	[boolean]
input BooleanInput	fancoilHab_Pat3_despacho	[W]
output RealOutput	Qs_Pat3_office	[W]
output RealOutput	Ql_Pat3_office	[W]
output RealOutput	Qs_Pat3_vestibulos	[W]
output RealOutput	Ql_Pat3_vestibulos	[W]
output RealOutput	Qs_Pat3_dormitorio	[W]
output RealOutput	Ql_Pat3_dormitorio	[W]
output RealOutput	Qs_Pat3_medicoGuardia	[W]
output RealOutput	Ql_Pat3_medicoGuardia	[W]
output RealOutput	Qs_Pat3_estar	[W]
output RealOutput	Ql_Pat3_estar	[W]
output RealOutput	Qs_Pat3_supervisor	[W]
output RealOutput	Ql_Pat3_supervisor	[W]
output RealOutput	Qs_Pat3_despacho	[W]
output RealOutput	Ql_Pat3_despacho	[W]
output RealOutput	Qs_Pat2_Box_1	[W]
output RealOutput	Ql_Pat2_Box_1	[W]
output RealOutput	Qs_Pat2_Box_2	[W]
output RealOutput	Ql_Pat2_Box_2	[W]
output RealOutput	Qs_Pat2_Box_3	[W]
output RealOutput	Ql_Pat2_Box_3	[W]
output RealOutput	Qs_Pat2_Box_4	[W]
output RealOutput	Ql_Pat2_Box_4	[W]
output RealOutput	Qs_Pat2_Box_5	[W]
output RealOutput	Ql_Pat2_Box_5	[W]
output RealOutput	Qs_Pat2_Box_6	[W]
output RealOutput	Ql_Pat2_Box_6	[W]
output RealOutput	Qs_Pat2_Box_7	[W]
output RealOutput	Ql_Pat2_Box_7	[W]
output RealOutput	Qs_Pat2_Box_8	[W]
output RealOutput	Ql_Pat2_Box_8	[W]
output RealOutput	Qs_Pat2_Box_9	[W]
output RealOutput	Ql_Pat2_Box_9	[W]
output RealOutput	Qs_Pat2_Box_10	[W]
output RealOutput	Ql_Pat2_Box_10	[W]
output RealOutput	Qs_Pat2_Box_11	[W]
output RealOutput	Ql_Pat2_Box_11	[W]
output RealOutput	Qs_Pat2_Box_12	[W]
output RealOutput	Ql_Pat2_Box_12	[W]
output RealOutput	Qs_Pat2_control	[W]
output RealOutput	Ql_Pat2_control	[W]
output RealOutput	Qs_Pat2_estar	[W]
output RealOutput	Ql_Pat2_estar	[W]
output RealOutput	Qs_Pat2_preparacion	[W]
output RealOutput	Ql_Pat2_preparacion	[W]
input RealInput	Tsp_Pat4_Box_1	[degC]
input RealInput	Tz_Pat4_Box_1	[degC]
input RealInput	RH_Pat4_Box_1	[%]
input RealInput	Tsp_Pat4_Box_2	[degC]
input RealInput	Tz_Pat4_Box_2	[degC]
input RealInput	RH_Pat4_Box_2	[%]
input RealInput	Tsp_Pat4_Box_3	[degC]
input RealInput	Tz_Pat4_Box_3	[degC]
input RealInput	RH_Pat4_Box_3	[%]

input RealInput	Tsp_Pat4_Box_4	[degC]
input RealInput	Tz_Pat4_Box_4	[degC]
input RealInput	RH_Pat4_Box_4	[%]
input RealInput	Tsp_Pat4_Box_5	[degC]
input RealInput	Tz_Pat4_Box_5	[degC]
input RealInput	RH_Pat4_Box_5	[%]
input RealInput	Tsp_Pat4_Box_6	[degC]
input RealInput	Tz_Pat4_Box_6	[degC]
input RealInput	RH_Pat4_Box_6	[%]
input RealInput	Tsp_Pat4_Box_7	[degC]
input RealInput	Tz_Pat4_Box_7	[degC]
input RealInput	RH_Pat4_Box_7	[%]
input RealInput	Tsp_Pat4_aparatos	[degC]
input RealInput	Tz_Pat4_aparatos	[degC]
input RealInput	RH_Pat4_aparatos	[%]
input RealInput	Tsp_Pat4_control	[degC]
input RealInput	Tz_Pat4_control	[degC]
input RealInput	RH_Pat4_control	[%]
input RealInput	Tsp_Pat4_despacho	[degC]
input RealInput	Tz_Pat4_despacho	[degC]
input RealInput	RH_Pat4_despacho	[%]
input RealInput	Tsp_Pat4_preparacion	[degC]
input RealInput	Tz_Pat4_preparacion	[degC]
input RealInput	RH_Pat4_preparacion	[%]
input BooleanInput	zoneHab_Pat4_Box_1	[boolean]
input BooleanInput	zoneHab_Pat4_Box_2	[boolean]
input BooleanInput	zoneHab_Pat4_Box_3	[boolean]
input BooleanInput	zoneHab_Pat4_Box_4	[boolean]
input BooleanInput	zoneHab_Pat4_Box_5	[boolean]
input BooleanInput	zoneHab_Pat4_Box_6	[boolean]
input BooleanInput	zoneHab_Pat4_Box_7	[boolean]
input BooleanInput	zoneHab_Pat4_aparatos	[boolean]
input BooleanInput	zoneHab_Pat4_control	[boolean]
input BooleanInput	zoneHab_Pat4_despacho	[boolean]
input BooleanInput	fancoilHab_Pat4_despacho	[boolean]
input BooleanInput	zoneHab_Pat4_preparacion	[boolean]
output RealOutput	Qs_Pat4_Box_1	[W]
output RealOutput	Ql_Pat4_Box_1	[W]
output RealOutput	Qs_Pat4_Box_2	[W]
output RealOutput	Ql_Pat4_Box_2	[W]
output RealOutput	Qs_Pat4_Box_3	[W]
output RealOutput	Ql_Pat4_Box_3	[W]
output RealOutput	Qs_Pat4_Box_4	[W]
output RealOutput	Ql_Pat4_Box_4	[W]
output RealOutput	Qs_Pat4_Box_5	[W]
output RealOutput	Ql_Pat4_Box_5	[W]
output RealOutput	Qs_Pat4_Box_6	[W]
output RealOutput	Ql_Pat4_Box_6	[W]
output RealOutput	Qs_Pat4_Box_7	[W]
output RealOutput	Ql_Pat4_Box_7	[W]
output RealOutput	Qs_Pat4_aparatos	[W]
output RealOutput	Ql_Pat4_aparatos	[W]
output RealOutput	Qs_Pat4_control	[W]
output RealOutput	Ql_Pat4_control	[W]
output RealOutput	Qs_Pat4_despacho	[W]
output RealOutput	Ql_Pat4_despacho	[W]
output RealOutput	Qs_Pat4_preparacion	[W]
output RealOutput	Ql_Pat4_preparacion	[W]
input RealInput	Tsp_Pat2_Box_1	[degC]
input RealInput	Tz_Pat2_Box_1	[degC]
input RealInput	RH_Pat2_Box_1	[%]
input RealInput	Tsp_Pat2_Box_2	[degC]
input RealInput	Tz_Pat2_Box_2	[degC]
input RealInput	RH_Pat2_Box_2	[%]
input RealInput	Tsp_Pat2_Box_3	[degC]
input RealInput	Tz_Pat2_Box_3	[degC]
input RealInput	RH_Pat2_Box_3	[%]
input RealInput	Tsp_Pat2_Box_4	[degC]
input RealInput	Tz_Pat2_Box_4	[degC]
input RealInput	RH_Pat2_Box_4	[%]

input RealInput	Tsp_Pat2_Box_5	[degC]
input RealInput	Tz_Pat2_Box_5	[degC]
input RealInput	RH_Pat2_Box_5	[%]
input RealInput	Tsp_Pat2_Box_6	[degC]
input RealInput	Tz_Pat2_Box_6	[degC]
input RealInput	RH_Pat2_Box_6	[%]
input RealInput	Tsp_Pat2_Box_7	[degC]
input RealInput	Tz_Pat2_Box_7	[degC]
input RealInput	RH_Pat2_Box_7	[%]
input RealInput	Tsp_Pat2_Box_8	[degC]
input RealInput	Tz_Pat2_Box_8	[degC]
input RealInput	RH_Pat2_Box_8	[%]
input RealInput	Tsp_Pat2_Box_9	[degC]
input RealInput	Tz_Pat2_Box_9	[degC]
input RealInput	RH_Pat2_Box_9	[%]
input RealInput	Tsp_Pat2_Box_10	[degC]
input RealInput	Tz_Pat2_Box_10	[degC]
input RealInput	RH_Pat2_Box_10	[%]
input RealInput	Tsp_Pat2_Box_11	[degC]
input RealInput	Tz_Pat2_Box_11	[degC]
input RealInput	RH_Pat2_Box_11	[%]
input RealInput	Tsp_Pat2_Box_12	[degC]
input RealInput	Tz_Pat2_Box_12	[degC]
input RealInput	RH_Pat2_Box_12	[%]
input RealInput	Tsp_Pat2_control	[degC]
input RealInput	Tz_Pat2_control	[degC]
input RealInput	RH_Pat2_control	[%]
input RealInput	Tsp_Pat2_estar	[degC]
input RealInput	Tz_Pat2_estar	[degC]
input RealInput	RH_Pat2_estar	[%]
input RealInput	Tsp_Pat2_preparacion	[degC]
input RealInput	Tz_Pat2_preparacion	[degC]
input RealInput	RH_Pat2_preparacion	[%]
input BooleanInput	zoneHab_Pat2_Box_1	[boolean]
input BooleanInput	zoneHab_Pat2_Box_2	[boolean]
input BooleanInput	zoneHab_Pat2_Box_3	[boolean]
input BooleanInput	zoneHab_Pat2_Box_4	[boolean]
input BooleanInput	zoneHab_Pat2_Box_5	[boolean]
input BooleanInput	zoneHab_Pat2_Box_6	[boolean]
input BooleanInput	zoneHab_Pat2_Box_7	[boolean]
input BooleanInput	zoneHab_Pat2_Box_8	[boolean]
input BooleanInput	zoneHab_Pat2_Box_9	[boolean]
input BooleanInput	zoneHab_Pat2_Box_10	[boolean]
input BooleanInput	zoneHab_Pat2_Box_11	[boolean]
input BooleanInput	zoneHab_Pat2_Box_12	[boolean]
input BooleanInput	zoneHab_Pat2_control	[boolean]
input BooleanInput	zoneHab_Pat2_estar	[boolean]
input BooleanInput	fancoilHab_Pat2_estar	[boolean]
input BooleanInput	zoneHab_Pat2_preparacion	[boolean]
output RealOutput	T_HR1	[degC]
output RealOutput	RH_HR2	[%]
output RealOutput	T_CC	[degC]
output RealOutput	RH_CC	[%]
output RealOutput	T_HC	[degC]
output RealOutput	RH_HC	[%]
output RealOutput	Tr	[degC]
output RealOutput	RHr	[%]
output RealOutput	T_supply	[degC]
output RealOutput	RH_supply	[%]
output RealOutput	Qflow_CC	[W]
output RealOutput	Qflow_HC	[W]
output RealOutput	T_HR2	[degC]
output RealOutput	RH_HR1	[%]

4.3.1.5 Parameters needed to run the model

Table 29. Parameters needed to run model AHU CL1 – Second Floor.

Type	Name	Default	Description
MassFlowRate	m1_flow_nominal	5.04598	Nominal air supply/return mass flow rate CL1 [kg/s]

MassFlowRate	m2_flow_nominal	8.2	Nominal cool water supply/return mass flow rate CL1 [kg/s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)
Time	controlSampleTime	150	Sampling time of the Controller [s]
Temp_C	Tmin	15	min supply temperature [degC]
Temp_C	Tmax	35	max supply temperature [degC]
Real	RHmax	0.65	Upper limits of RH
Real	RHmin	0.4	Lower limits of RH
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0

4.3.2 AHU CL3 – Fourth Floor

AHU CL3 distributes air to the fourth floor of Areilza's phase III building. AHU CL4 distributes air to 17 distinct zones. All zones' environmental conditions are controlled via local fancoils except for a meeting room that is controlled via VAV boxes. CL3 provides primary air to all zones so that the return set-point temperature is met.

4.3.2.1 Schematic

Figure 86 shows the overall schematic of the air distribution for AHU CL3.

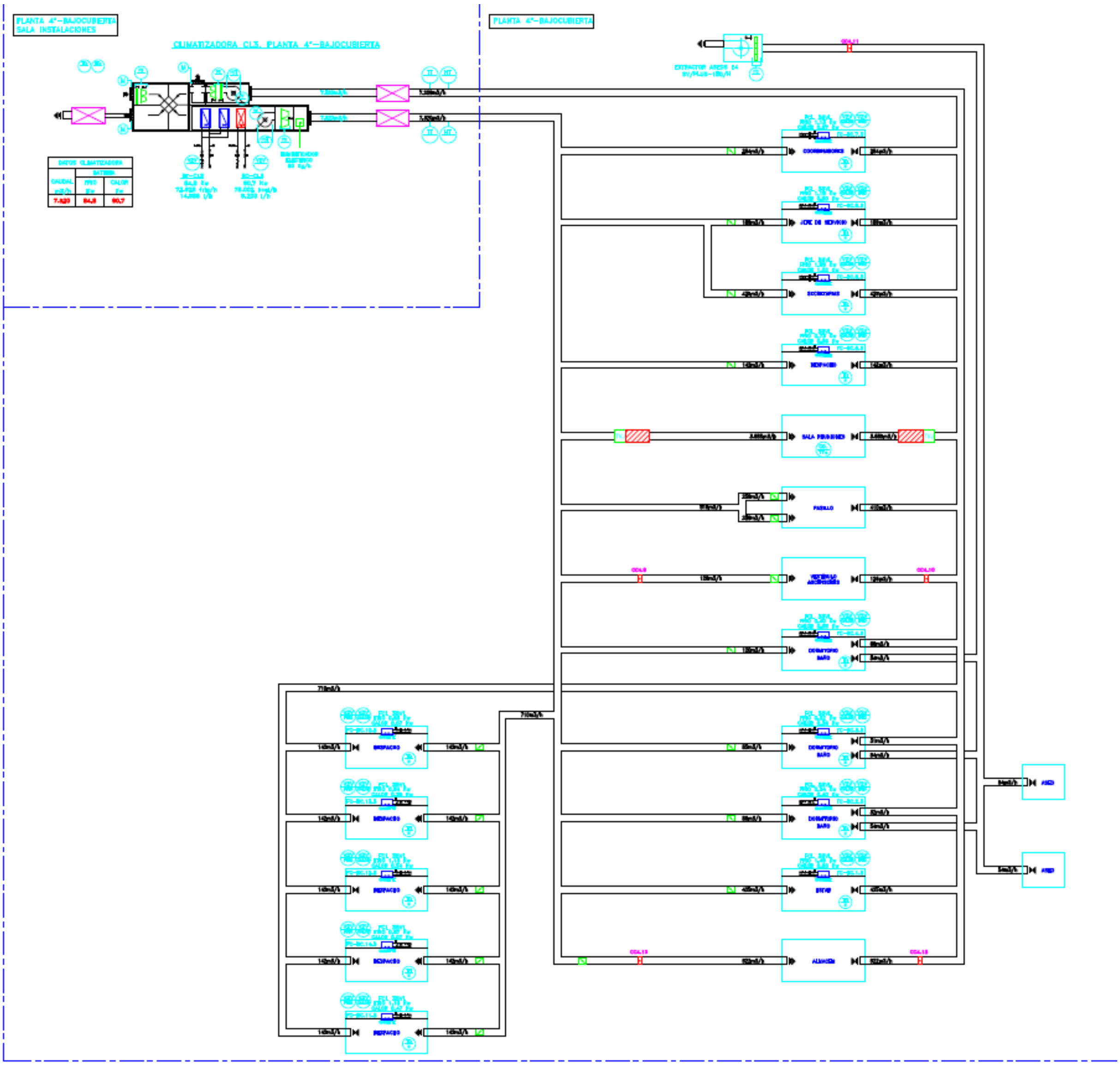


Figure 86. Areilza AHU CL3 Air Distribution.

4.3.2.2 CL3 air distribution zones

The table below provides characteristics of the zones supplied by CL3

Code	Type	Parameter	Value	Units	Zone name	Zone type
-	Air flow	Nominal air mass flow rate	0.2	kg/s	estar	zoneFancoil
FC-BC.2.1.3	Fan Coil	Nominal power	6.0	kW	estar	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	dormitorio1	zoneFancoile
FC-BC.2.2.3	Fan Coil	Nominal power	6.0	kW	dormitorio1	zoneFancoile
-	Air flow	Nominal air mass flow rate	0.2	kg/s	dormitorio2	zoneFancoil
FC-BC.2.3.3	Fan Coil	Nominal power	6.0	kW	dormitorio2	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	dormitorio3	zoneFancoile
FC-BC.2.4.3	Fan Coil	Nominal power	6.0	kW	dormitorio3	zoneFancoile
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho1	zoneFancoil
FC-BC.2.6.3	Fan Coil	Nominal power	6.0	kW	despacho1	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	coordinadores	zoneFancoil
FC-BC.2.7.3	Fan Coil	Nominal power	6.0	kW	coordinadores	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	secretarias	zoneFancoil
FC-BC.2.8.3	Fan Coil	Nominal power	6.0	kW	secretarias	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	jefe	zoneFancoil
FC-BC.2.9.3	Fan Coil	Nominal power	6.0	kW	jefe	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho2	zoneFancoil
FC-BC.2.10.3	Fan Coil	Nominal power	6.0	kW	despacho2	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho6	zoneFancoil

FC-BC.2.11.3	Fan Coil	Nominal power	6.0	kW	despacho6	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho4	zoneFancoil
FC-BC.2.12.3	Fan Coil	Nominal power	6.0	kW	despacho4	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho3	zoneFancoil
FC-BC.2.13.3	Fan Coil	Nominal power	6.0	kW	despacho3	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.2	kg/s	despacho5	zoneFancoil
FC-BC.2.14.3	Fan Coil	Nominal power	6.0	kW	despacho5	zoneFancoil
-	Air flow	Nominal air mass flow rate	0.18	kg/s	pasillo	zone
-	-	Nominal air mass flow rate	1.25	kg/s	salaReuniones	zone
-	Air flow	Nominal air mass flow rate	0.04	kg/s	vestibulo	zone
-	-	Nominal air mass flow rate	0.18	kg/s	almacen	zone

4.3.2.3 Modelica Model

Figure 87 shows the Modelica model of AHU CL_3 serving the zones in 'planta bajo cubierta'.

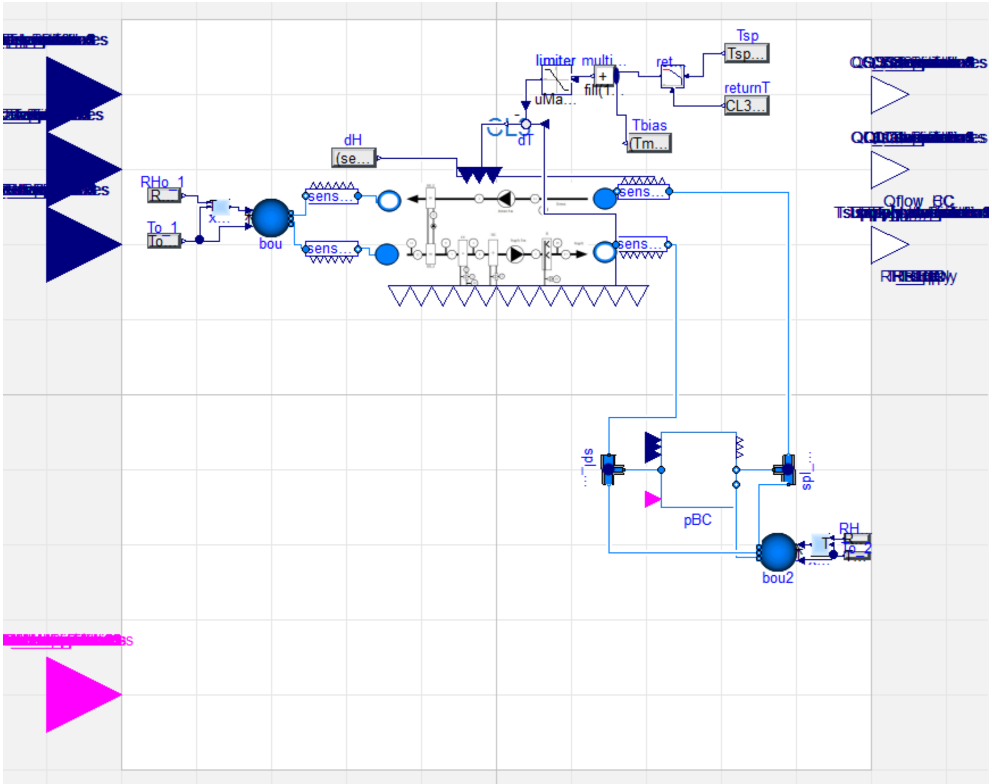


Figure 87. Areilza AHU CL_3 Modelica Model.

Figure 88 shows the the Modelica model of the 17 zones served by the AHU CL_3.

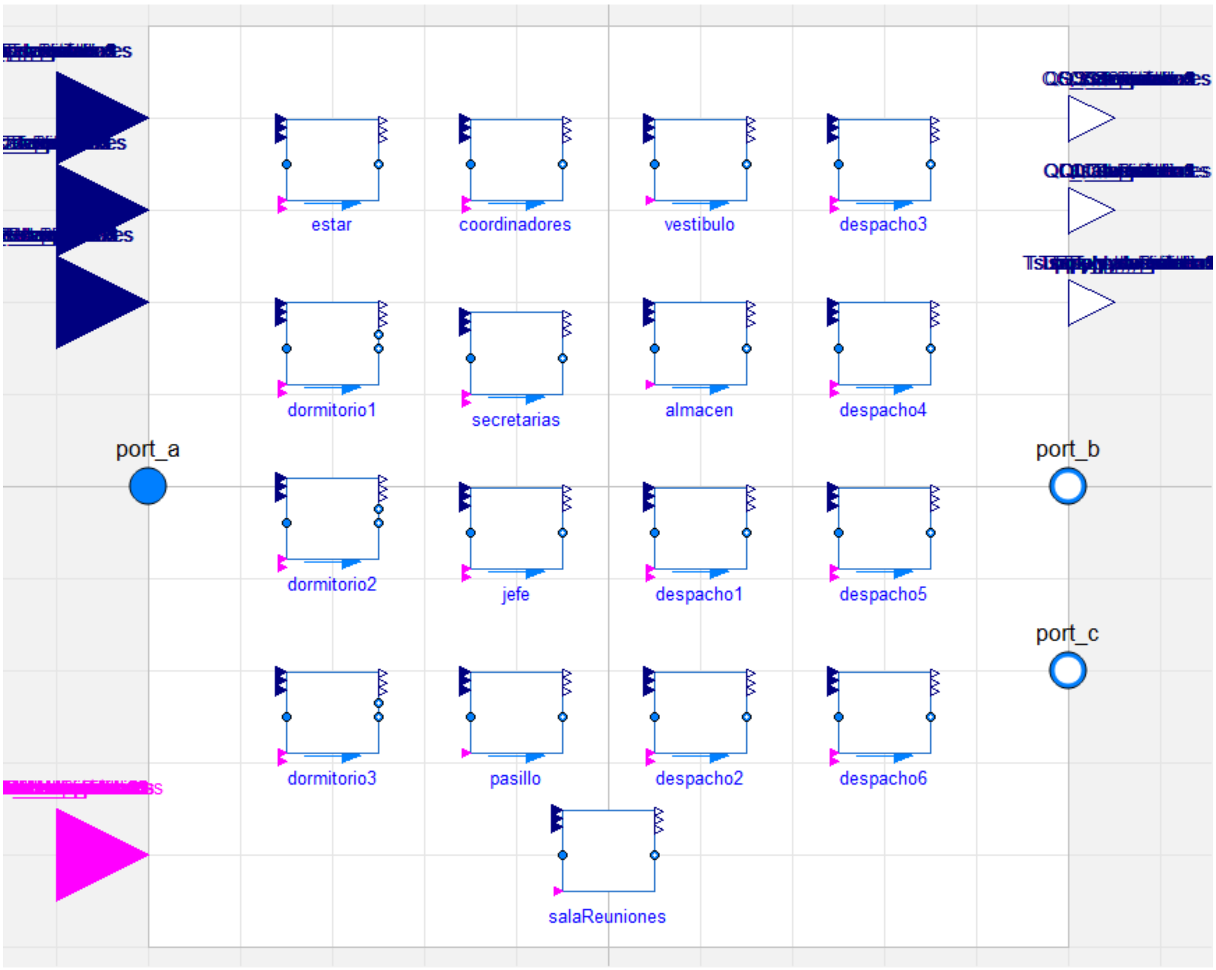


Figure 88. Areilza Fourth Floor zoning Modelica model

4.3.2.4 Input/output variables

Nomenclature for the table: [variable] + _ + [zone name/component Name]

T: Temperature; RH: Relative Humidity; o: outside; Qs: sensible heat flow; Ql: latent heat flow; HC: Heating Coil, CC; Cooling Coil; HR: Heat Recovery; H: Humidifier; r: Return; recirc: recirculation air; Qflow: heat flow rate; sp: set-point.

Table 30. Input/output variables for AHU CL3 – Fourth Floor.

Type	Name	Units
input RealInput	Tz_estar	[degC]
input RealInput	RHz_estar	[%]
input RealInput	Tsp_estar	[degC]
input RealInput	Tz_dormitorio1	[degC]
input RealInput	RHz_dormitorio1	[%]
input RealInput	Tsp_dormitorio1	[degC]
input RealInput	Tz_dormitorio2	[degC]
input RealInput	RHz_dormitorio2	[%]
input RealInput	Tsp_dormitorio2	[degC]
input RealInput	Tz_dormitorio3	[degC]
input RealInput	RHz_dormitorio3	[%]
input RealInput	Tsp_dormitorio3	[degC]
input RealInput	Tz_coordinadores	[degC]
input RealInput	RHz_coordinadores	[%]
input RealInput	Tsp_coordinadores	[degC]
input RealInput	Tz_secretarias	[degC]
input RealInput	RHz_secretarias	[%]
input RealInput	Tsp_secretarias	[degC]
input RealInput	Tz_jefe	[degC]

input RealInput	RHz_jefe	[%]
input RealInput	Tsp_jefe	[degC]
input RealInput	Tz_pasillo	[degC]
input RealInput	RHz_pasillo	[%]
input RealInput	Tsp_pasillo	[degC]
input RealInput	Tz_vestibulo	[degC]
input RealInput	RHz_vestibulo	[%]
input RealInput	Tsp_vestibulo	[degC]
input RealInput	Tz_almacen	[degC]
input RealInput	RHz_almacen	[%]
input RealInput	Tsp_almacen	[degC]
input RealInput	Tz_despacho1	[degC]
input RealInput	RHz_despacho1	[%]
input RealInput	Tsp_despacho1	[degC]
input RealInput	Tz_despacho2	[degC]
input RealInput	RHz_despacho2	[%]
input RealInput	Tsp_despacho2	[degC]
input RealInput	Tz_despacho3	[degC]
input RealInput	RHz_despacho3	[%]
input RealInput	Tsp_despacho3	[degC]
input RealInput	Tz_despacho4	[degC]
input RealInput	RHz_despacho4	[%]
input RealInput	Tsp_despacho4	[degC]
input RealInput	Tz_despacho5	[degC]
input RealInput	RHz_despacho5	[%]
input RealInput	Tsp_despacho5	[degC]
input RealInput	Tz_despacho6	[degC]
input RealInput	RHz_despacho6	[%]
input RealInput	Tsp_despacho6	[degC]
input RealInput	Tz_salaReuniones	[degC]
input RealInput	RHz_salaReuniones	[%]
input RealInput	Tsp_salaReuniones	[degC]
input BooleanInput	fanCoilHab_estar	[boolean]
input BooleanInput	zoneHab_estar	[boolean]
output RealOutput	QS_estar	[W]
output RealOutput	QL_estar	[W]
output RealOutput	Tsupply_estar	[degC]
input BooleanInput	fanCoilHab_dormitorio1	[boolean]
input BooleanInput	zoneHab_dormitorio1	[boolean]
output RealOutput	QS_dormitorio1	[W]
output RealOutput	QL_dormitorio1	[W]
output RealOutput	Tsupply_dormitorio1	[degC]
input BooleanInput	fanCoilHab_dormitorio2	[boolean]
input BooleanInput	zoneHab_dormitorio2	[boolean]
output RealOutput	QS_dormitorio2	[W]
output RealOutput	QL_dormitorio2	[W]
output RealOutput	Tsupply_dormitorio2	[degC]
input BooleanInput	fanCoilHab_dormitorio3	[boolean]
input BooleanInput	zoneHab_dormitorio3	[boolean]
output RealOutput	QS_dormitorio3	[W]
output RealOutput	QL_dormitorio3	[W]
output RealOutput	Tsupply_dormitorio3	[degC]
input BooleanInput	fanCoilHab_coordinadores	[boolean]
input BooleanInput	zoneHab_coordinadores	[boolean]
output RealOutput	QS_coordinadores	[W]
output RealOutput	QL_coordinadores	[W]
output RealOutput	Tsupply_coordinadores	[degC]
input BooleanInput	fanCoilHab_secretarias	[boolean]
input BooleanInput	zoneHab_secretarias	[boolean]
output RealOutput	QS_secretarias	[W]
output RealOutput	QL_secretarias	[W]
output RealOutput	Tsupply_secretarias	[degC]
input BooleanInput	fanCoilHab_jefe	[boolean]
input BooleanInput	zoneHab_jefe	[boolean]
output RealOutput	QS_jefe	[W]
output RealOutput	QL_jefe	[W]
output RealOutput	Tsupply_jefe	[degC]
input BooleanInput	zoneHab_pasillo	[boolean]
output RealOutput	QS_pasillo	[boolean]
output RealOutput	QL_pasillo	[W]

output RealOutput	Tsupply_pasillo	[W]
input BooleanInput	zoneHab_vestibulo	[boolean]
output RealOutput	QS_vestibulo	[W]
output RealOutput	QL_vestibulo	[W]
output RealOutput	Tsupply_vestibulo	[degC]
input BooleanInput	zoneHab_almacen	[boolean]
output RealOutput	QS_almacen	[W]
output RealOutput	QL_almacen	[W]
output RealOutput	Tsupply_almacen	[degC]
input BooleanInput	fanCoilHab_despacho1	[boolean]
input BooleanInput	zoneHab_despacho1	[boolean]
output RealOutput	QS_despacho1	[W]
output RealOutput	QL_despacho1	[W]
output RealOutput	Tsupply_despacho1	[degC]
input BooleanInput	fanCoilHab_despacho2	[boolean]
input BooleanInput	zoneHab_despacho2	[boolean]
output RealOutput	QS_despacho2	[W]
output RealOutput	QL_despacho2	[W]
output RealOutput	Tsupply_despacho2	[degC]
input BooleanInput	fanCoilHab_despacho3	[boolean]
input BooleanInput	zoneHab_despacho3	[boolean]
output RealOutput	QS_despacho3	[W]
output RealOutput	QL_despacho3	[W]
output RealOutput	Tsupply_despacho3	[degC]
input BooleanInput	fanCoilHab_despacho4	[boolean]
input BooleanInput	zoneHab_despacho4	[boolean]
output RealOutput	QS_despacho4	[W]
output RealOutput	QL_despacho4	[W]
output RealOutput	Tsupply_despacho4	[degC]
input BooleanInput	fanCoilHab_despacho5	[boolean]
input BooleanInput	zoneHab_despacho5	[boolean]
output RealOutput	QS_despacho5	[W]
output RealOutput	QL_despacho5	[W]
output RealOutput	Tsupply_despacho5	[degC]
input BooleanInput	fanCoilHab_despacho6	[boolean]
input BooleanInput	zoneHab_despacho6	[boolean]
output RealOutput	QS_despacho6	[W]
output RealOutput	QL_despacho6	[W]
output RealOutput	Tsupply_despacho6	[degC]
input BooleanInput	zoneHab_salaReuniones	[boolean]
output RealOutput	QS_salaReuniones	[W]
output RealOutput	QL_salaReuniones	[W]
output RealOutput	Tsupply_salaReuniones	[degC]
input RealInput	Tsp_CL3	[degC]
input RealInput	To	[degC]
input RealInput	RHo	[%]
output RealOutput	T_HR	[degC]
output RealOutput	T_CC	[degC]
output RealOutput	RH_CC	[%]
output RealOutput	T_HC	[degC]
output RealOutput	RH_HC	[%]
output RealOutput	Tr	[degC]
output RealOutput	RHr	[%]
output RealOutput	T_supply	[degC]
output RealOutput	RH_supply	[%]
output RealOutput	Qflow_CC	[W]
output RealOutput	Qflow_HC	[W]
output RealOutput	RH_HR	[%]

4.3.2.5 Parameters needed to run the model

Table 31. Parameters needed to run model AHU CL3 – Fourth Floor.

Type	Name	Default	Description
MassFlowRate	m1_flow_nominal	2.558889	Nominal air supply/return mass flow rate CL3 [kg/s]
MassFlowRate	m2_flow_nominal	4.0	Nominal water supply/return mass flow rate CL3 [kg/s]
Boolean	allowFlowReversal	true	= true to allow flow reversal, false restricts to design direction (port_a -> port_b)
Boolean	allowFlowReversal2	true	= true to allow flow reversal in medium 2, false restricts to design direction (port_a -> port_b)

Time	controlSampleTime	150	Sampling time of the Controller [s]
Temp_C	Tmin	15	min supply temperature [degC]
Temp_C	Tmax	35	max supply temperature [degC]
Real	RHmax	0.65	Upper limits of RH
Real	RHmin	0.4	Lower limits of RH
Real	RH_multiplier	0.01	multiplier if RH is not in range [0...1]
Real	T_conversion	273.15	conversion if T is given in ºC, if given in K change to 0

5 Conclusions

This report presented the results from activity 2.4 “Detailed models of the demand side”. Two buildings were modelled in full (Aztarain and Gurtubay) while another one was partially modelled according to decisions made during INDIGO partner’s meetings.

Models comprise two parts. A ‘Building’ part which is modelled in DesignBuilder, exported to .idf format and the compressed as an FMU, this model includes the weather file. A ‘HVAC’ part which comprises all the mechanical systems and air distribution Modelled in Modelica language, the FMU from the Building part is imported into the Modelica model and the whole simulated. The idea is that this whole building energy model is then exported as another FMU to be used as a test-bed for Model-Predictive Control developments in WP3.

All the export/import and FMU transformation processes have been tested with successful results.

Model validation is pending data acquisition and result will be presented in D6.5.

6 References

P.C. Tabares- Velasco et al. . (2012). Verification and Validation of EnergyPlus Conduction Finite Difference and Phase Change Material Models for Opaque Wall Assemblies. NATIONAL RENEWABLE ENERGY LABORATORY.

6946:2007(E), I. (2007). Components and elements for housebuilding and thermal transmittance Method of calculation.

ASHRAE FUNDAMENTALS. (2009). Typical Metabolic Heat Generation. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

D.T. Reindl et al. (1990). Diffuse fraction correlations. *Solar Energy, Volume: 45*(n. 1), 1 -7.

EN 410. (2011). Glass in building - Determination of luminous and solar characteristics of glazing.

G.N. Walton et al. (1983). Thermal Analysis Research Program Reference Manual. National Bureau of Standards (now NIST).

H.T. Ceylan et al. (1980). Long-time Solutions to Heat Conduction Transients. ASME Journal of Heat Transfer.

ISO 10456:2007(E). (2007). Building materials and products-Hygrothermal properties-Tabulated design values and procedures for determining declared and design thermal values.

J.E. Seem et al. (1987). Modeling of Heat Transfer in Buildings. Madison, WI: Ph.D. Thesis, University of Wisconsin, Madison, WI.

K. Ouyang et al. (1991). A Procedure for Calculating Thermal Response Factors of Multi-layered Walls–State Space Method. Building and Environment.

LAB. BERKELEY. (2017). *FMU Export of EnergyPlus*. Retrieved April 27, 2017, from http://simulationresearch.lbl.gov/fmu/EnergyPlus/export/index.html

Lawrence Berkeley National Laboratory (LBNL). (n.d.). *https://windows.lbl.gov/software/therm/therm.html*.

R. Perez et al. (1990). Modeling Daylight Availability and Irradiance Components from Direct and Global Irradiance.

U.S. Department of Energy, Engineering Reference. (2016). *EnergyPlus™ Version 8.6 Documentation; Engineering Reference*. Retrieved April 27, 2017, from http://bigladdersoftware.com/epx/docs/

U.S. Department of Energy, Input Output Reference. (2016). *EnergyPlus™ Version 8.6 Documentation; Input Output Reference*. Retrieved April 27, 2017, from http://bigladdersoftware.com/epx/docs/

UNI 10355:1994. (1994).

UNI/TS 11300-1. (2014). Determinazione del fabbisogno di energia. ENTE ITALIANO DI NORMAZIONE.

Walton, G.N. et al., 1983. *Thermal Analysis Research Program Reference Manual,* s.l.: National Bureau of Standards (now NIST).