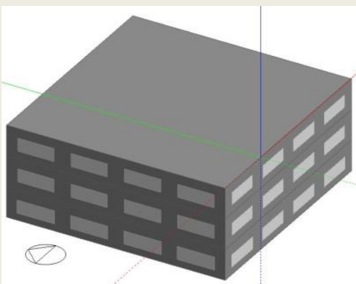
Demonstration of modeling of radiant cooling system in design builder

CONTENTS

- Introduction to Design Builder
- Building Energy Simulation
- Modeling procedure
  - Making a model
  - DOAS modeling
  - Chilled slab/ceiling modeling
- Results and comparisons
- Conclusion

Introduction

- Design Builder is a Graphical User Interface (GUI) for simulation tool "EnergyPlus"



Graphical User Interface

Simulation engine
- Energy Plus

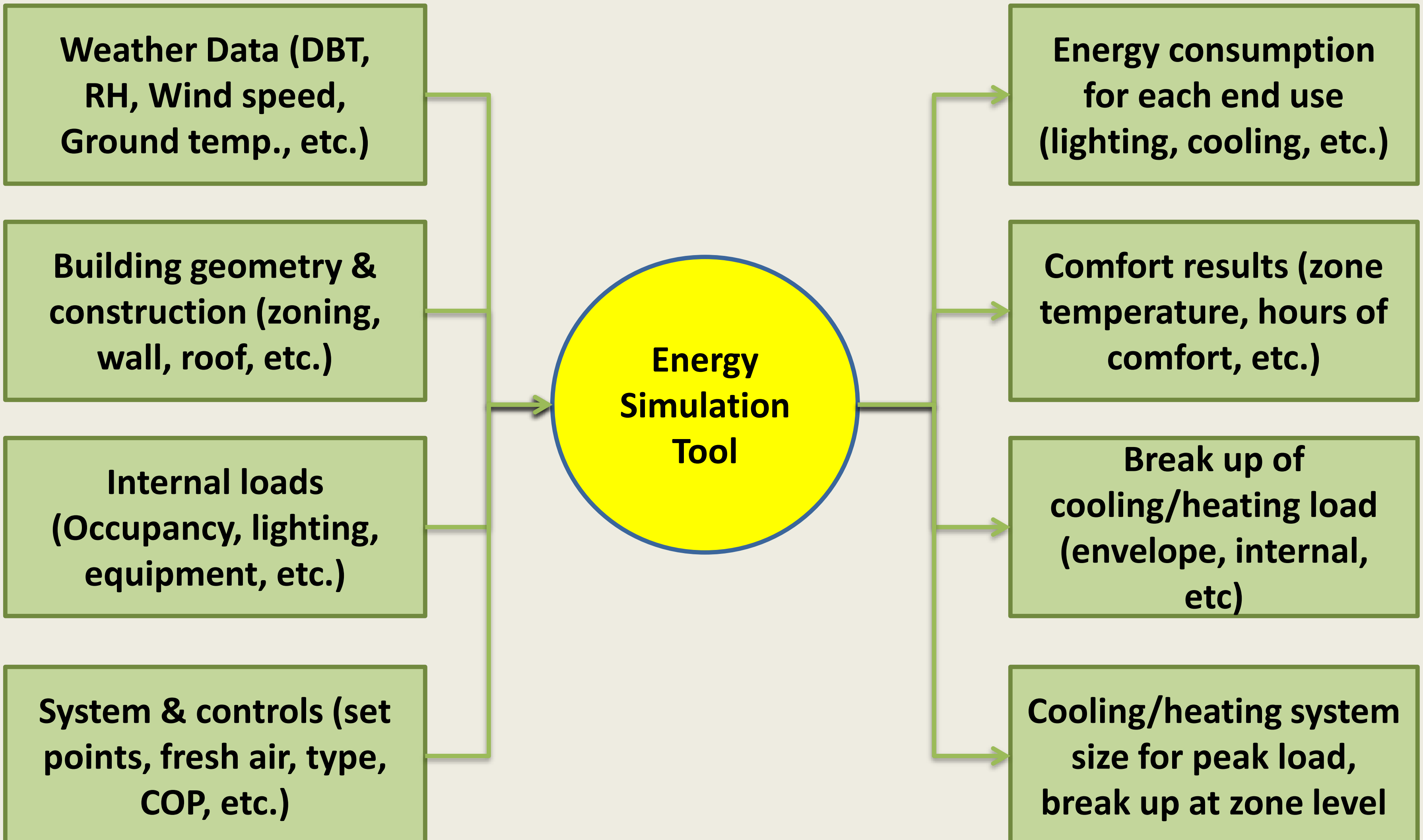
DesignBuilder

- Design Builder is available in different versions
- Latest one is 4.6 (Energy Plus – 8.3)

History of Design Builder

- EnergyPlus
  - Developed by US Department of Energy
  - Version 1.0 Launched April 2001; twice yearly updates
  - It is a modular, structured software tool based on the most popular features and capabilities of BLAST and DOE-2.1E.
  - It is primarily a simulation engine; input and output are simple text files.
- Design Builder
  - Developed by “DesignBuilder Software Ltd” based in London, UK
  - Version 1 of the product was launched in 2005; GUI to the EnergyPlus simulation engine
  - Version 2 (May 2009) adding CFD calculations linked to EnergyPlus
  - Version 3 (August 2011), advanced GUI to EnergyPlus HVAC systems & daylight evaluation tool using Radiance
  - Version 4 (May 2014), renewable, optimization, etc.

Inputs and outputs of a building simulation tool



Building Energy Simulation Procedure – 2 Steps

Step 1: Making Building Simulation Model

- Building envelope (walls, floors, ceilings, windows, glass etc.)
- Loads (Occupancy, Lighting and equipment etc.)
- Schedules

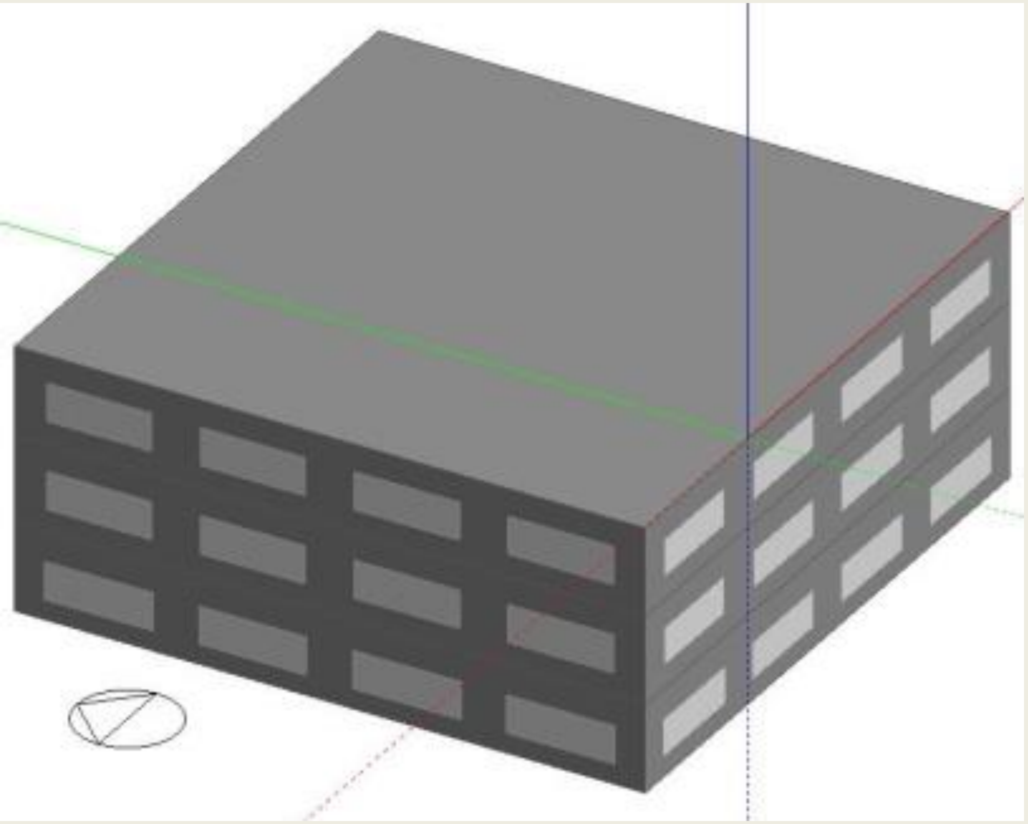
Step 2: HVAC modeling

- Air loops
- Chilled water loops
- Controls

Step 1: Building a simulation model

- Area = 625 m^2 (25 x 25 m)
- Floor to floor – 3.5 m
- Office building
- Day time operation
- 3 storey building
  - Ground floor
  - Intermediate
  - Top floor

(3 zones)



Step 1: Building a simulation model

Building envelope:

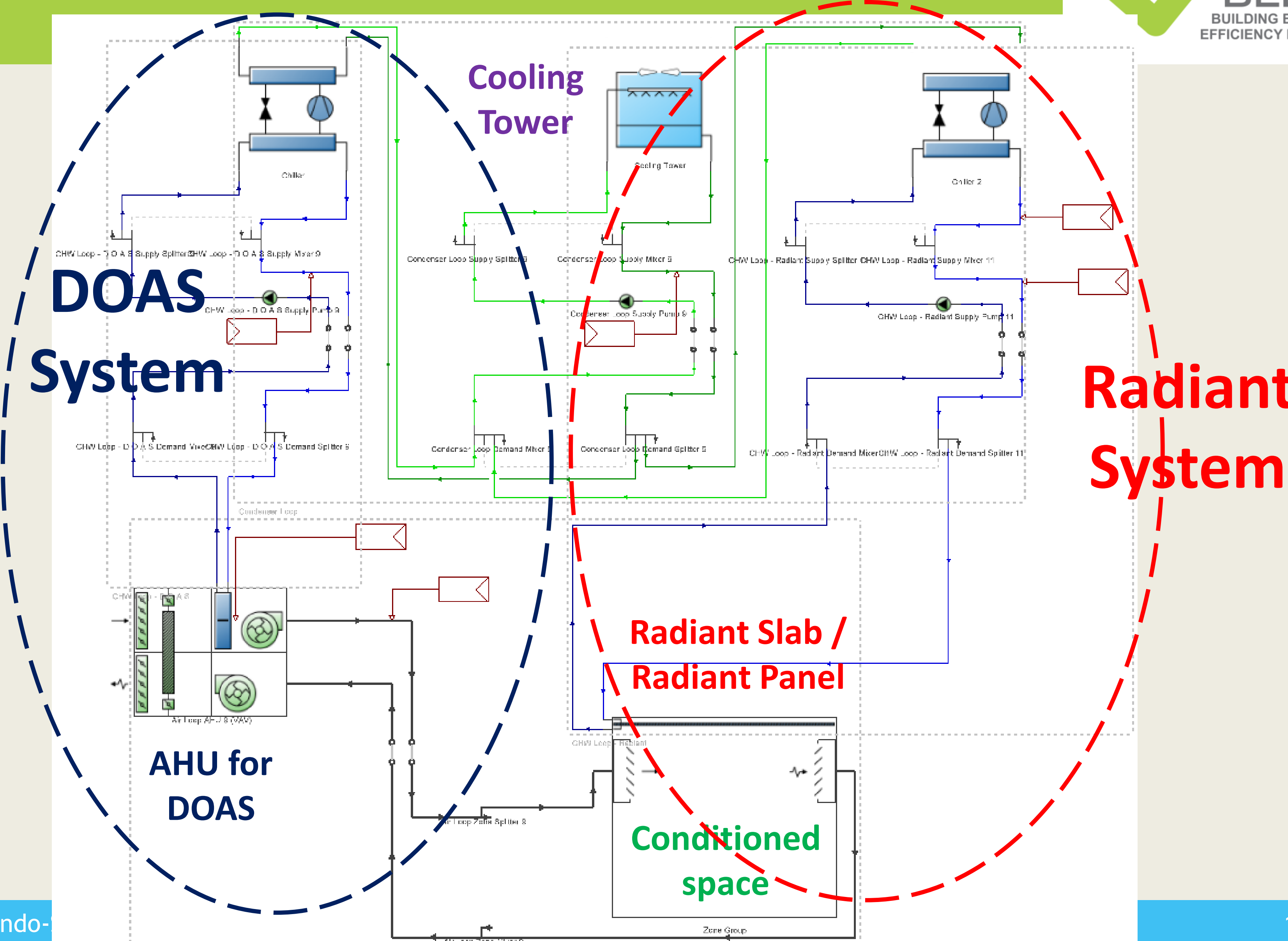
- Wall: 230 mm brick (U value – 0.438 W/m^2)
- Roof: RCC 150 mm + XPS Insulation (U value – 0.409 W/m^2)
- Internal floor: RCC 150 mm (U value – 2.47 W/m^2)
- Ground floor: RCC 150 + XPS insulation (U value – 0.409 W/m^2)
- Glazing: Double glazing
  - Window to Wall ratio = 30 %
  - SHGC = 0.27
  - VLT = 0.49
  - U Value = 1.5 W/m^2

Internal loads: (8 am to 6 pm; Monday to Friday)

- Occupancy = 9.29 m^2 / person
- Equipment = 10 W / m^2
- Lighting = 7 W / m^2
- Ventilation rate = 5.2 liter / sec / person

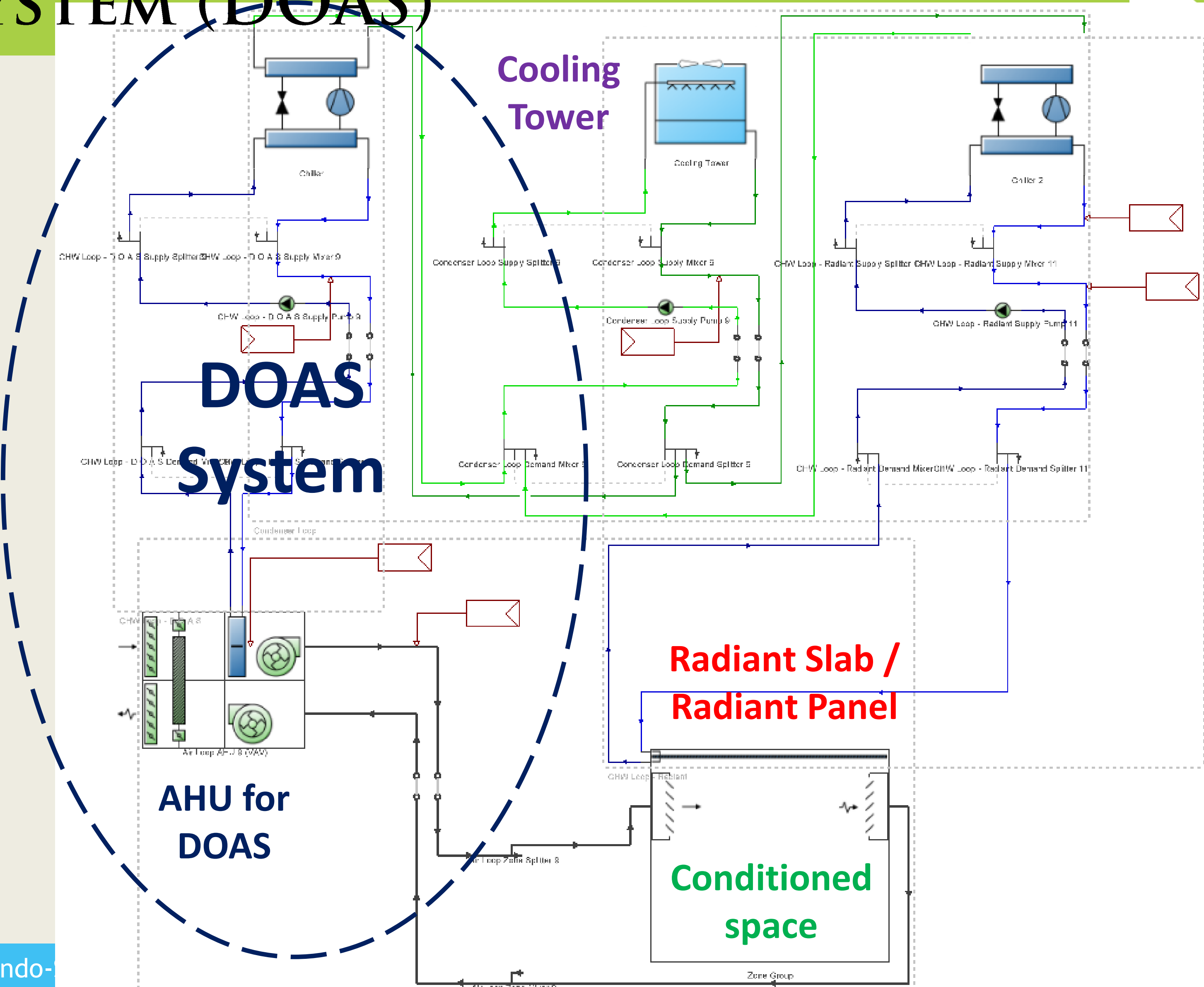
DEFINING SLAB COOLING IN DESIGN BUILDER

Objective – Modeling radiant slab cooling system

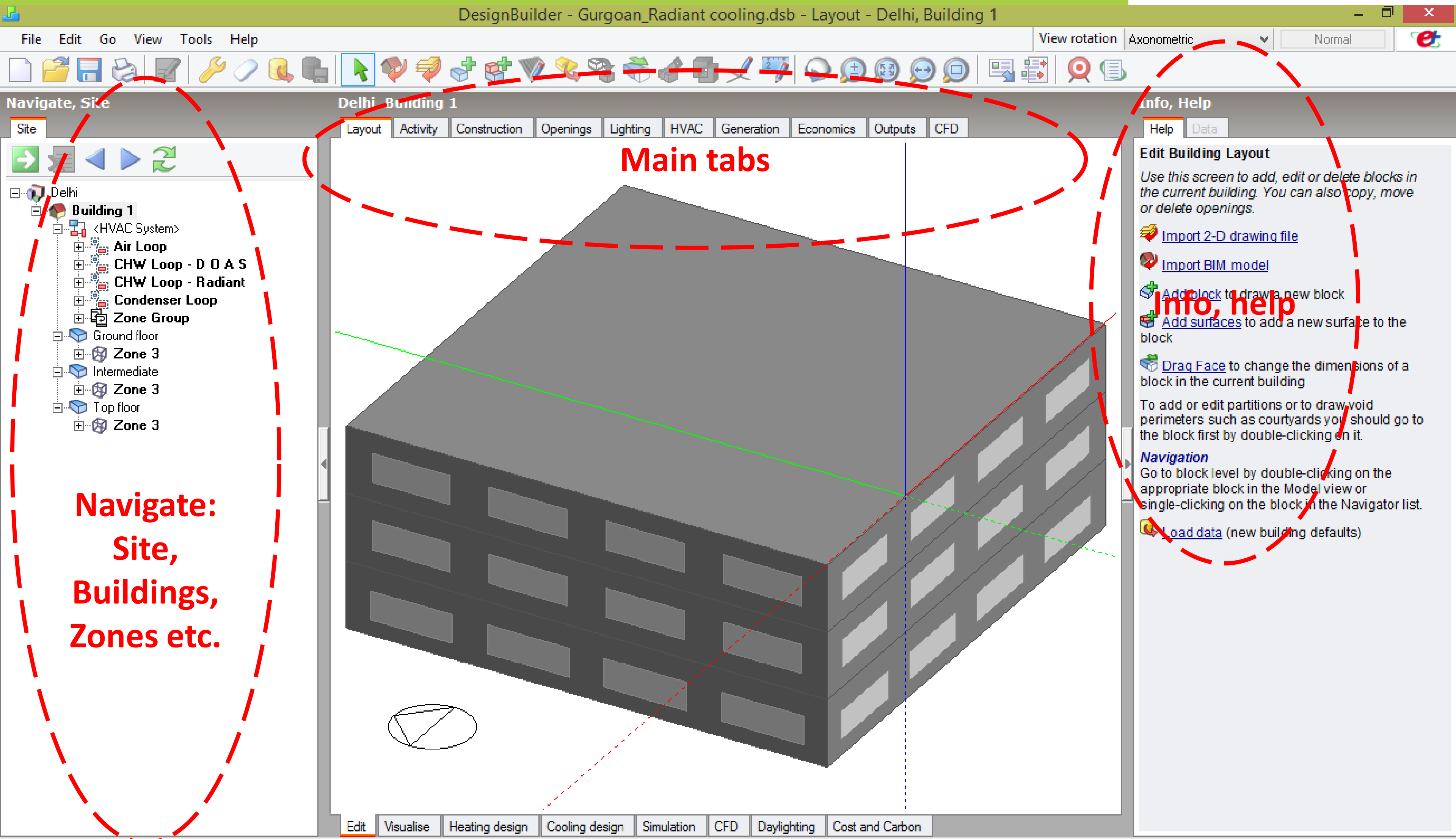


Step 2: Slab cooling modeling – Dedicated Outdoor Air System (DOAS)

BEEP
BUILDING ENERGY EFFICIENCY PROJECT



Step 2: Design Builder – Way to build a model

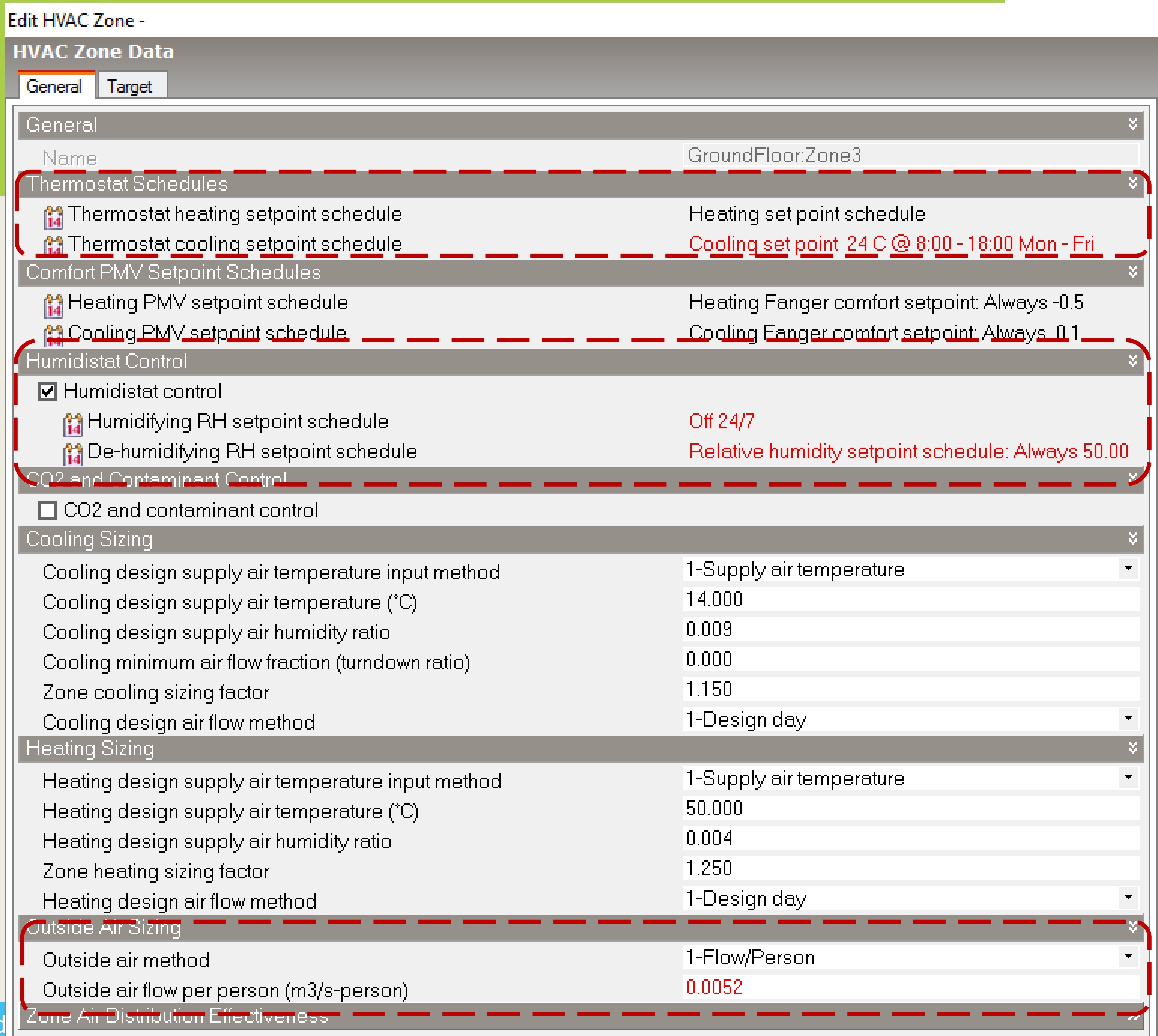


Step 2: Slab cooling modeling – D O A S

- Go to help/info tab
  - Add zone group using (3 zones)
- Go to navigate tab, zone level
  - Define set points: 24^0C (operative); RH – 50%
  - Define fresh air rate (5.2 l/s-person)
  - Target all 3 zones
    - Ground floor
    - Intermediate
    - Top floor

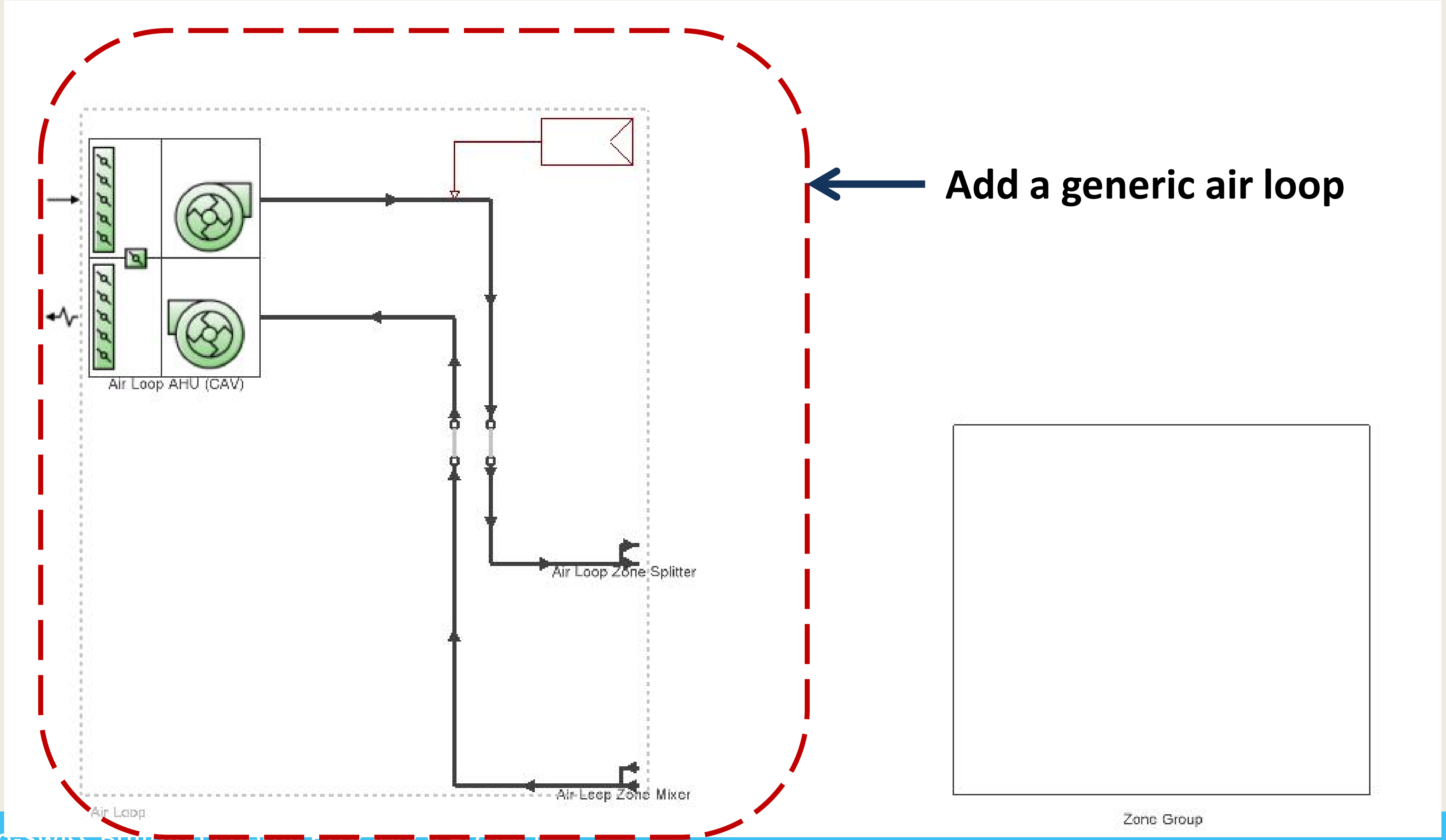
- Ground floor
- Intermediate
- Top floor

Zone Group


Edit HVAC Zone -
HVAC Zone Data
General
Target
General
Name
GroundFloor:Zone3
Thermostat Schedules
Thermostat heating setpoint schedule
Heating set point schedule
Thermostat cooling setpoint schedule
Cooling set point 24 C @ 8:00 - 18:00 Mon - Fri
Comfort PMV Setpoint Schedules
Heating PMV setpoint schedule
Heating Fanger comfort setpoint: Always -0.5
Cooling PMV setpoint schedule
Cooling Fanger comfort setpoint: Always 0.1
Humidistat Control
Humidistat control
Humidifying RH setpoint schedule
Off 24/7
De-humidifying RH setpoint schedule
Relative humidity setpoint schedule: Always 50.00
CO2 and Contaminant Control
CO2 and contaminant control
Cooling Sizing
Cooling design supply air temperature input method
1-Supply air temperature
Cooling design supply air temperature (°C)
14.000
Cooling design supply air humidity ratio
0.009
Cooling minimum air flow fraction (turndown ratio)
0.000
Zone cooling sizing factor
1.150
Cooling design air flow method
1-Design day
Heating Sizing
Heating design supply air temperature input method
1-Supply air temperature
Heating design supply air temperature (°C)
50.000
Heating design supply air humidity ratio
0.004
Zone heating sizing factor
1.250
Heating design air flow method
1-Design day
Outside Air Sizing
Outside air method
1-Flow/Person
Outside air flow per person (m3/s-person)
0.0052
Zone Air Distribution Effectiveness

STEP 2: SLAB COOLING MODELING – D O A S

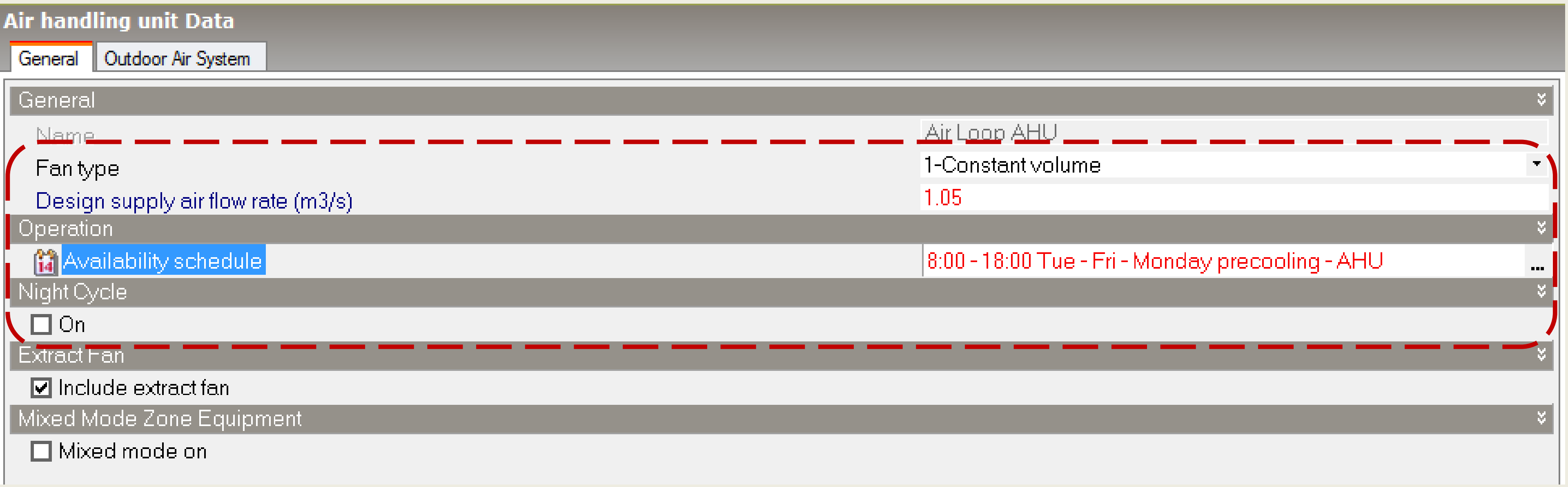
- Go to help/info tab
  - Add generic air loop



Step 2: Slab cooling modeling - DOAS

Go to navigate tab

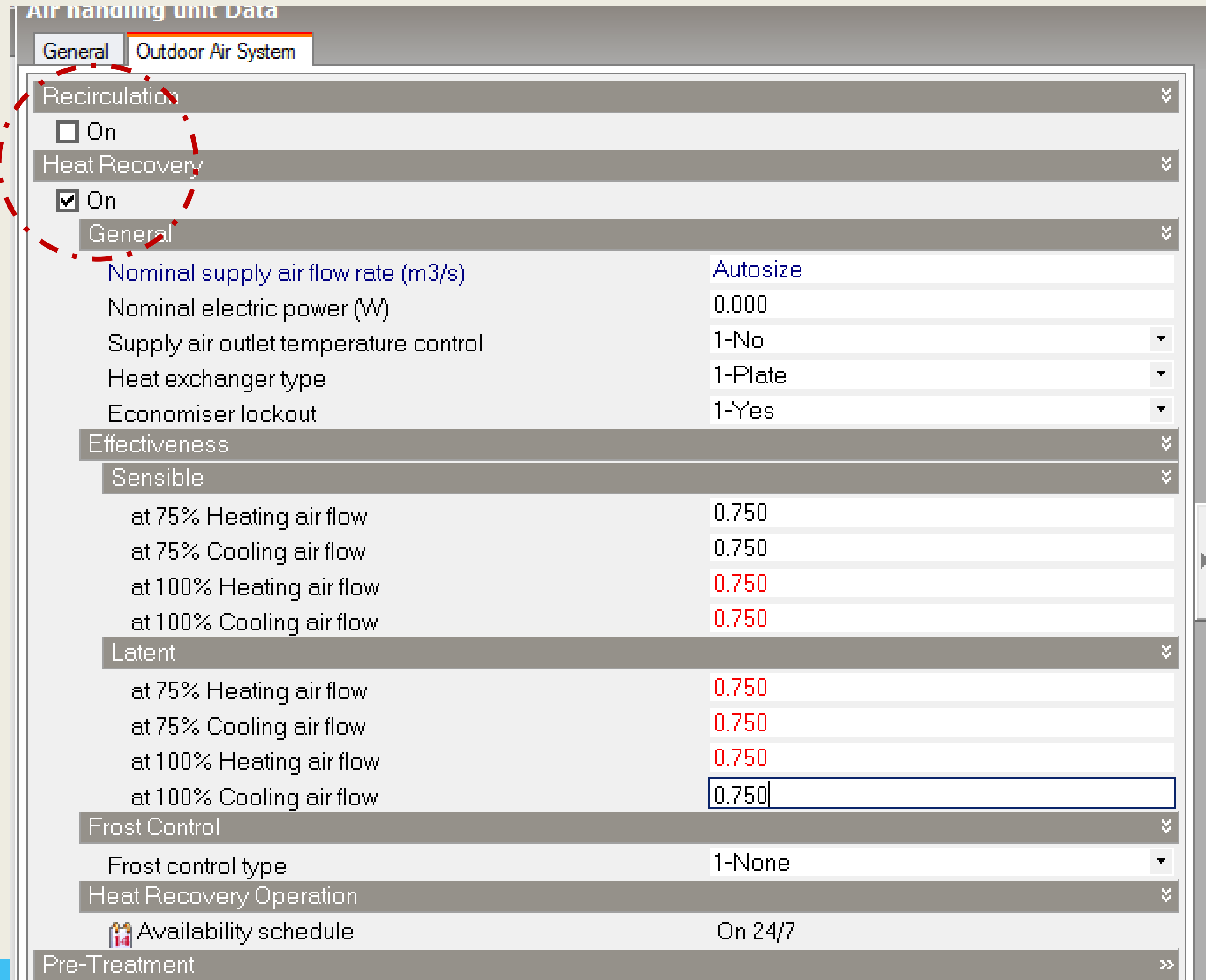
- Select AHU
- Go to edit at info tab
- Define supply air flow rate as 1.05 m^3/sec (fresh air only)
- Add Schedule



Step 2: Slab cooling modeling – D O A S

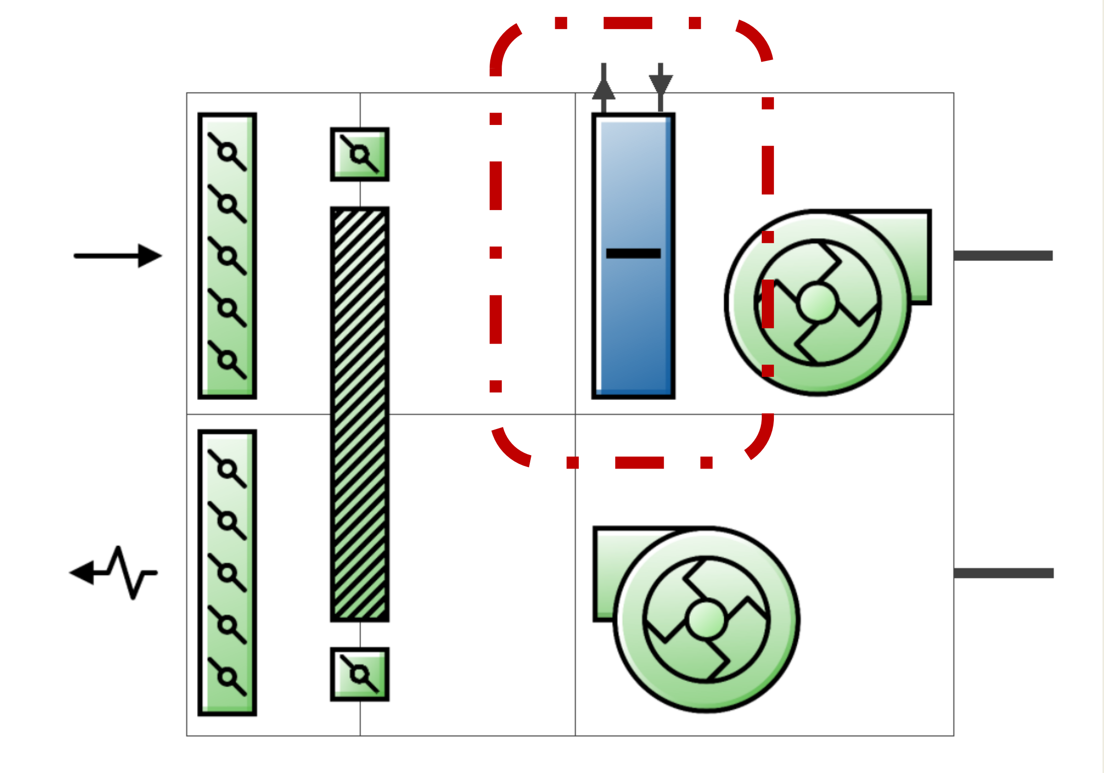
- AHU data: Outdoor air system
  - No recirculation
  - Heat recovery

  (75% Sensible & Latent)



Step 2: Slab cooling modeling – DOAS

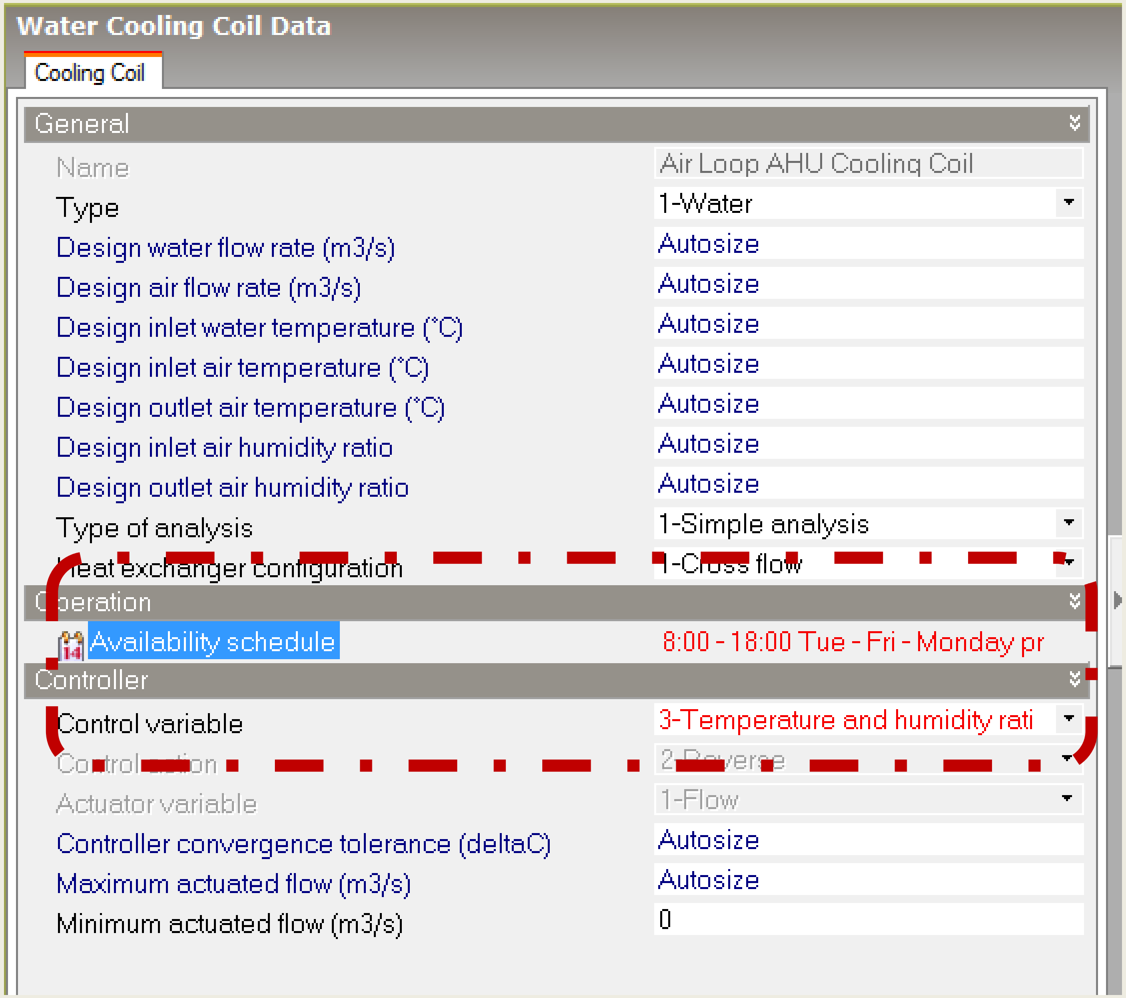
- In AHU Unit
  - Add cooling coil



Step 2: Slab cooling modeling – D O A S

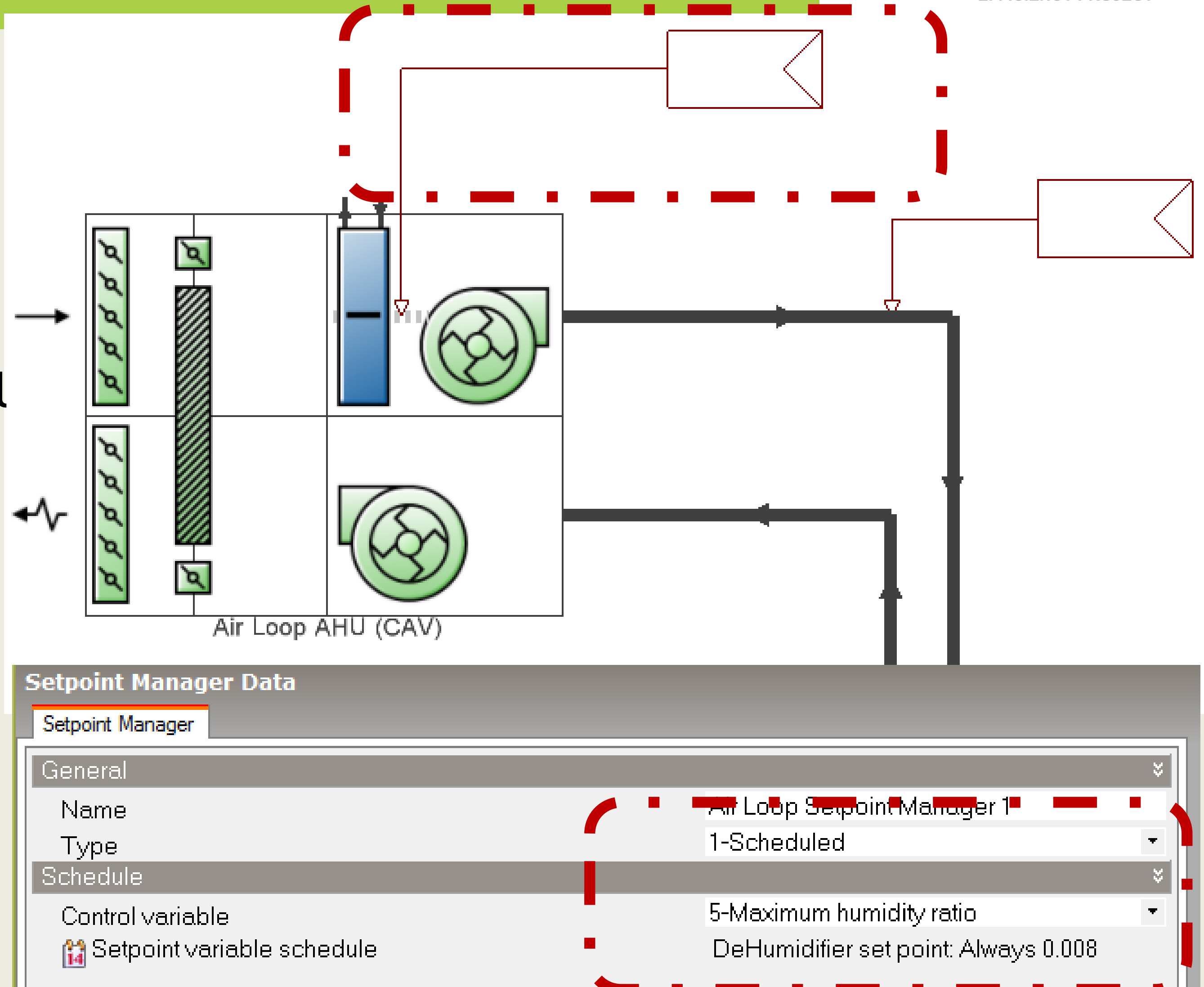
- Go to Water cooling coil data
  - Add scheduling
  - Select control type:

    3-temperature and humidity control



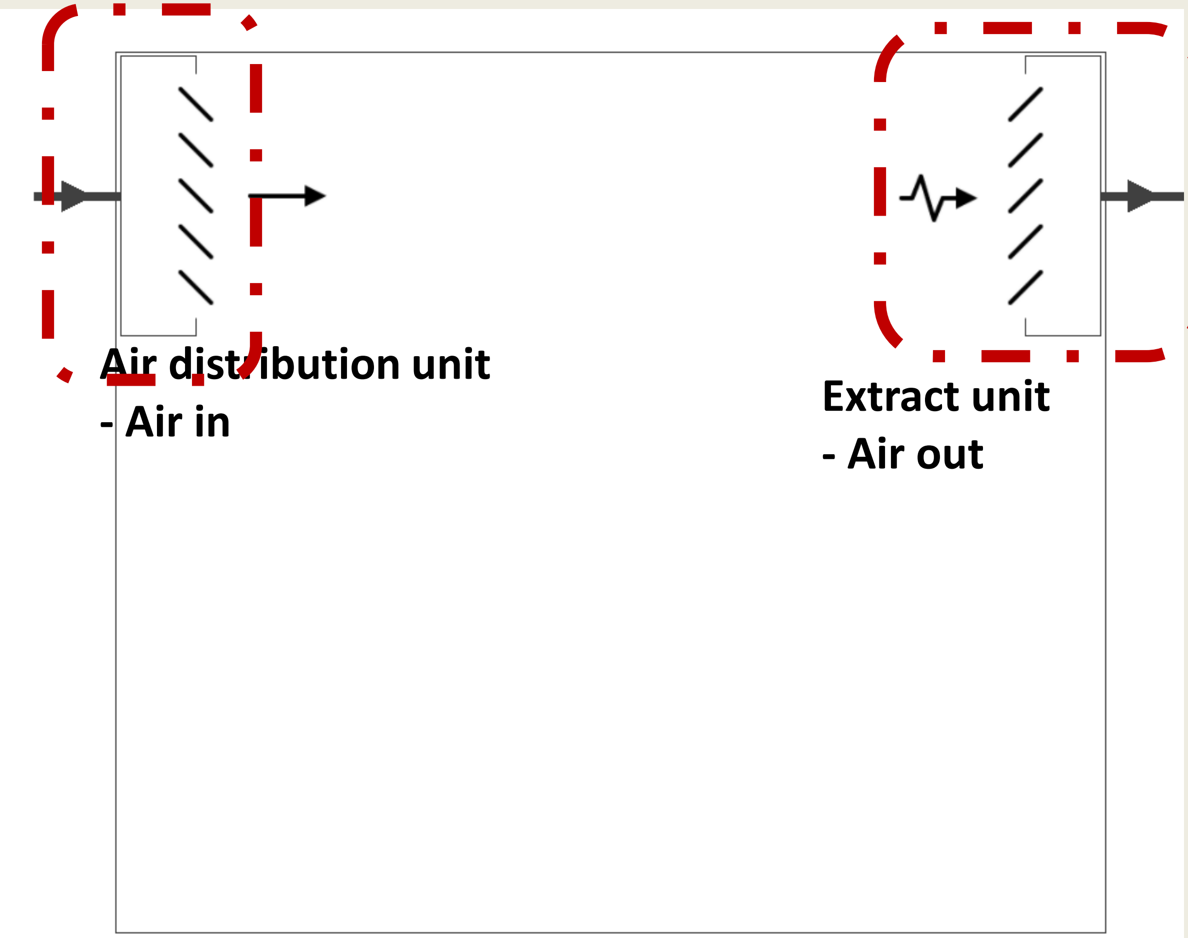
Step 2: Slab cooling modeling – DOAS

- Navigate tab
  - Go to air loop supply side
  - Add set point manager for humidity control

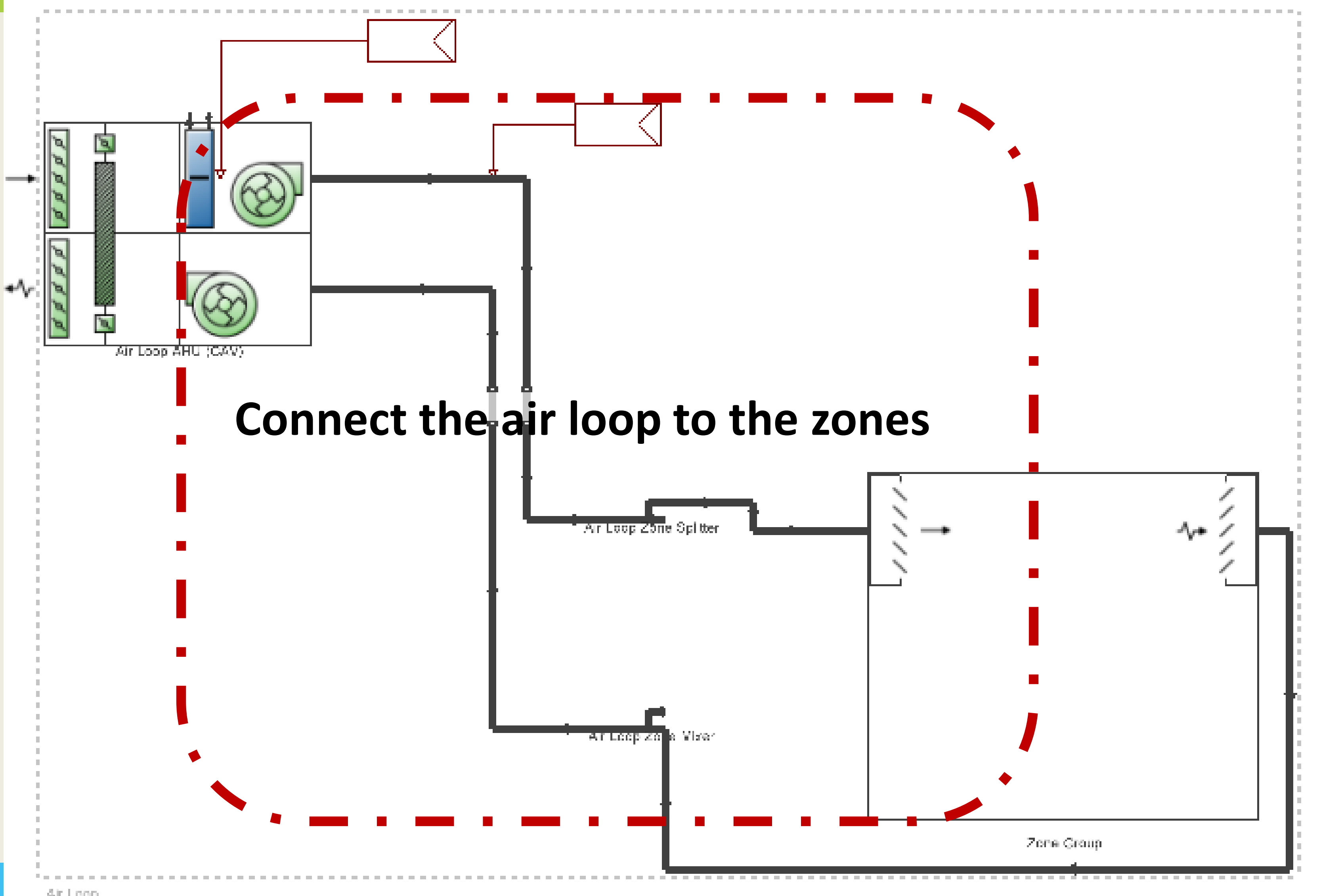


STEP 2: SLAB COOLING MODELING – D O A S

- Go to zone level
  - Add air distribution unit to the zones
  - Add extract unit to the zones

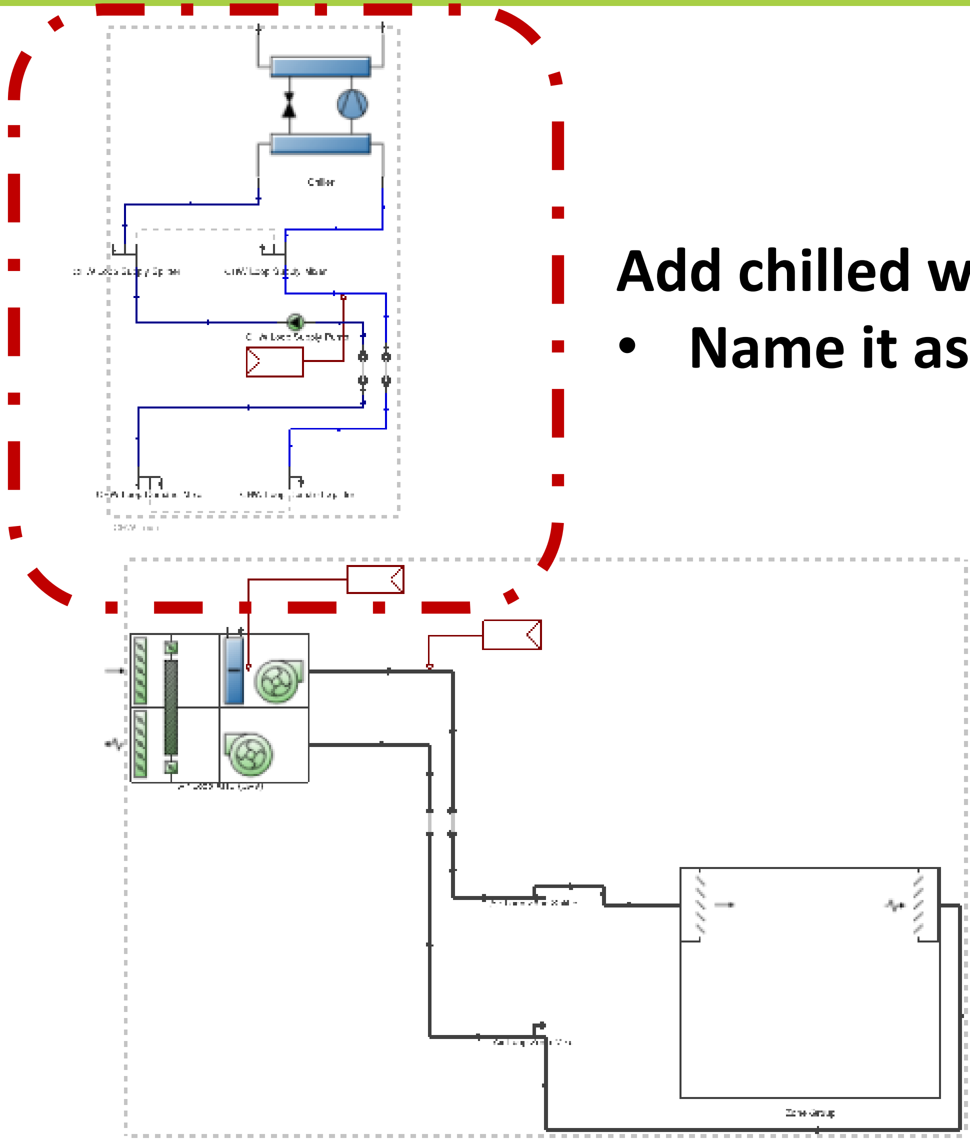


STEP 2: SLAB COOLING MODELING – D O A S



Connect the air loop to the zones

Step 2: Slab cooling modeling – D O A S

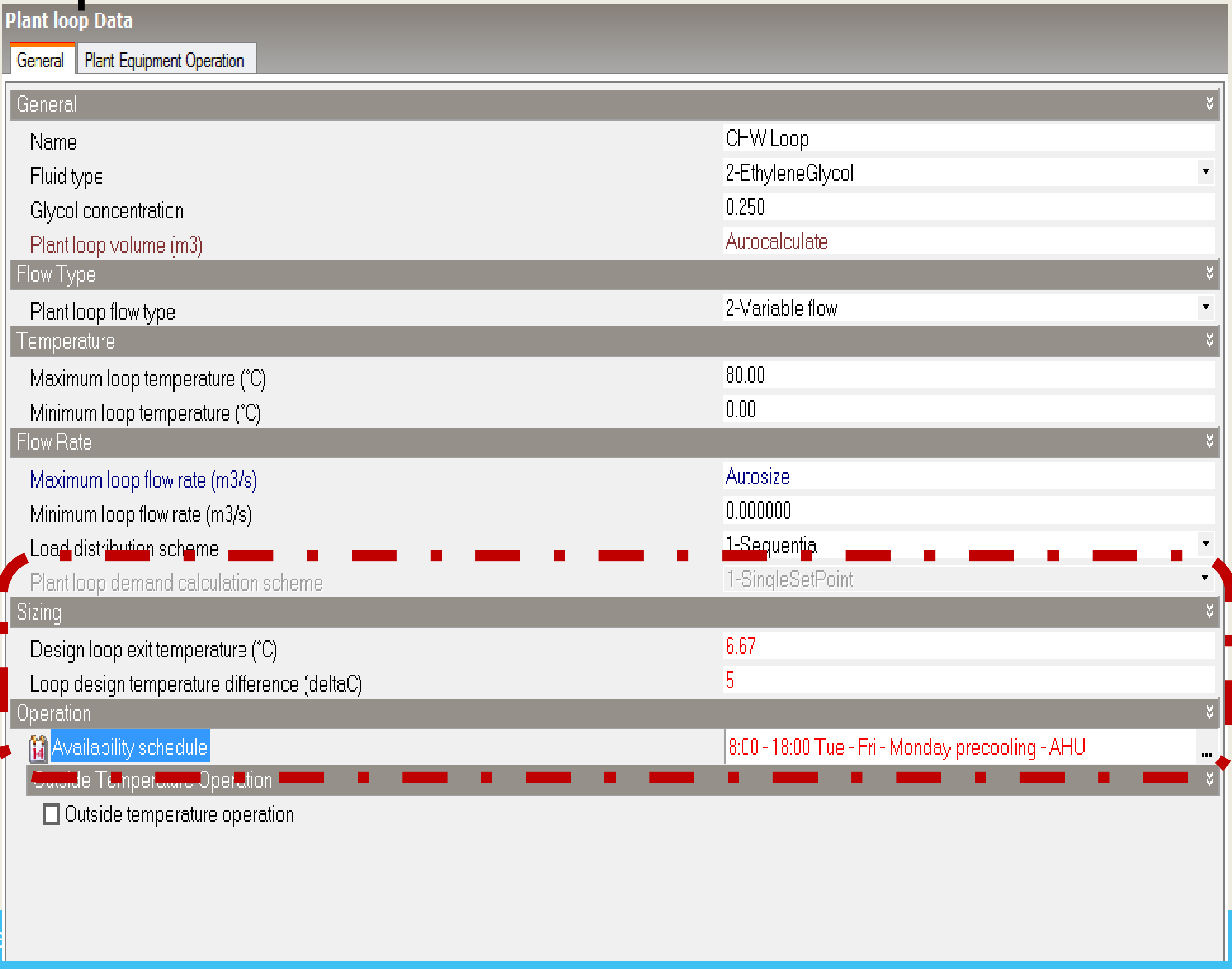


Add chilled water plant loop

- **Name it as CHW loop – D O A S**

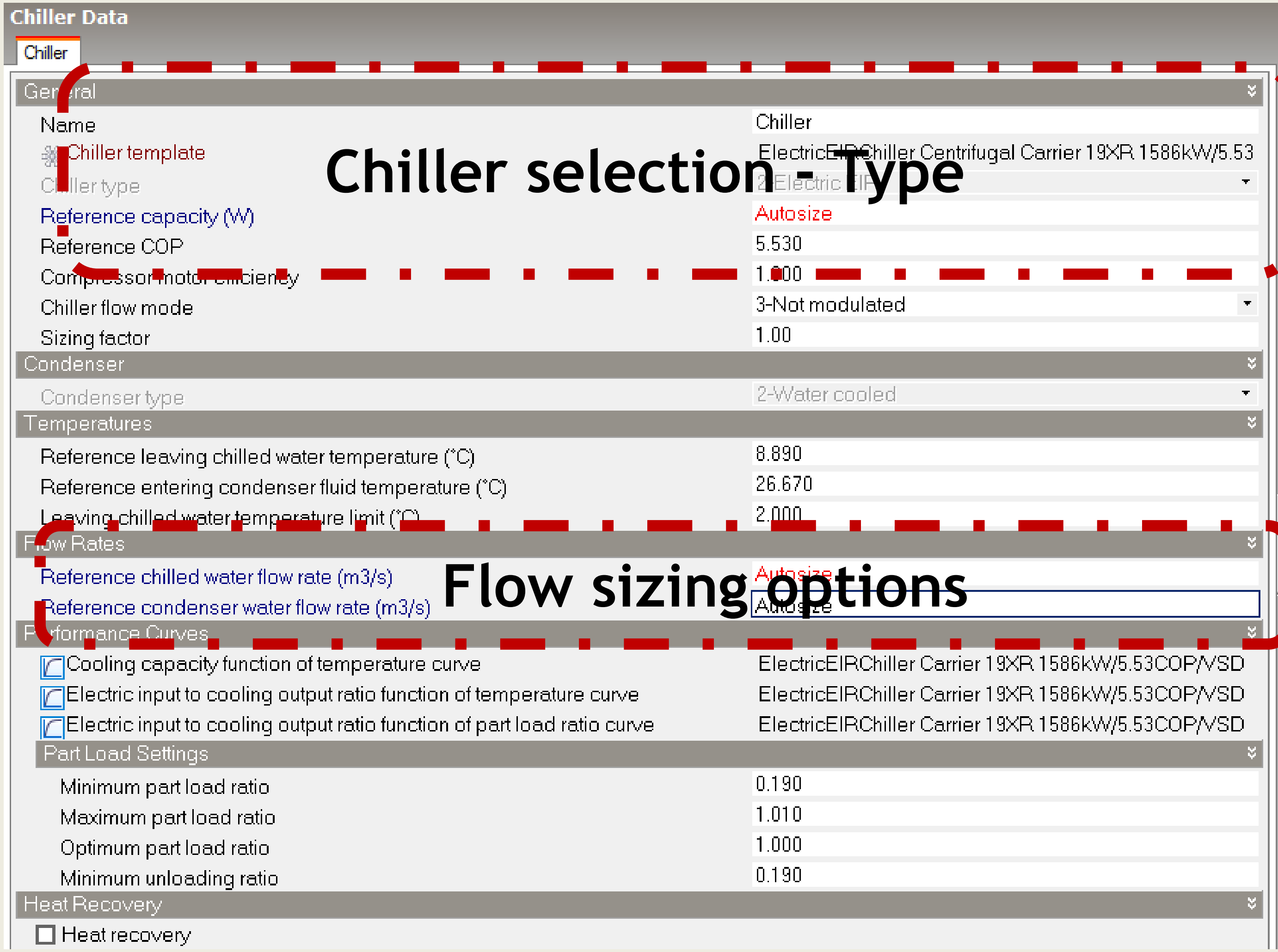
Step 2: Slab cooling modeling – D O A S

- Chilled water loop – D O A S
  - Define chilled water loop schedule
  - Specify values under sizing header



STEP 2: SLAB COOLING MODELING – D O A S

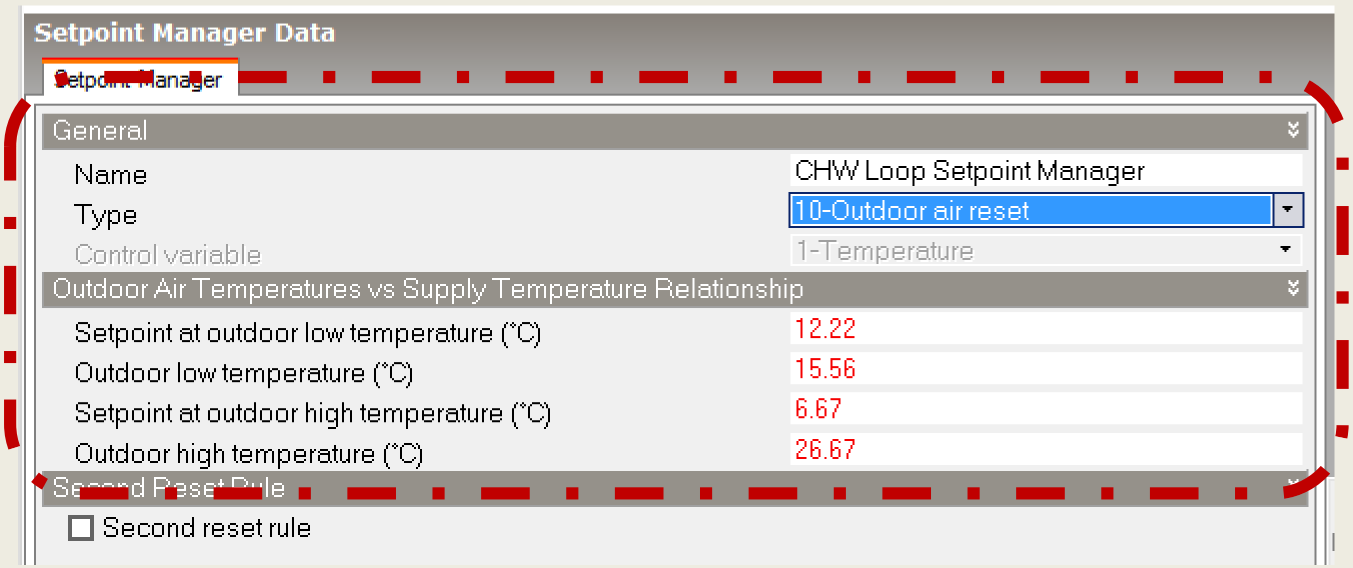
– Chiller selection - VSD
– Auto-size capacity
– Auto-size flow rates



Step 2: Slab cooling modeling – D O A S

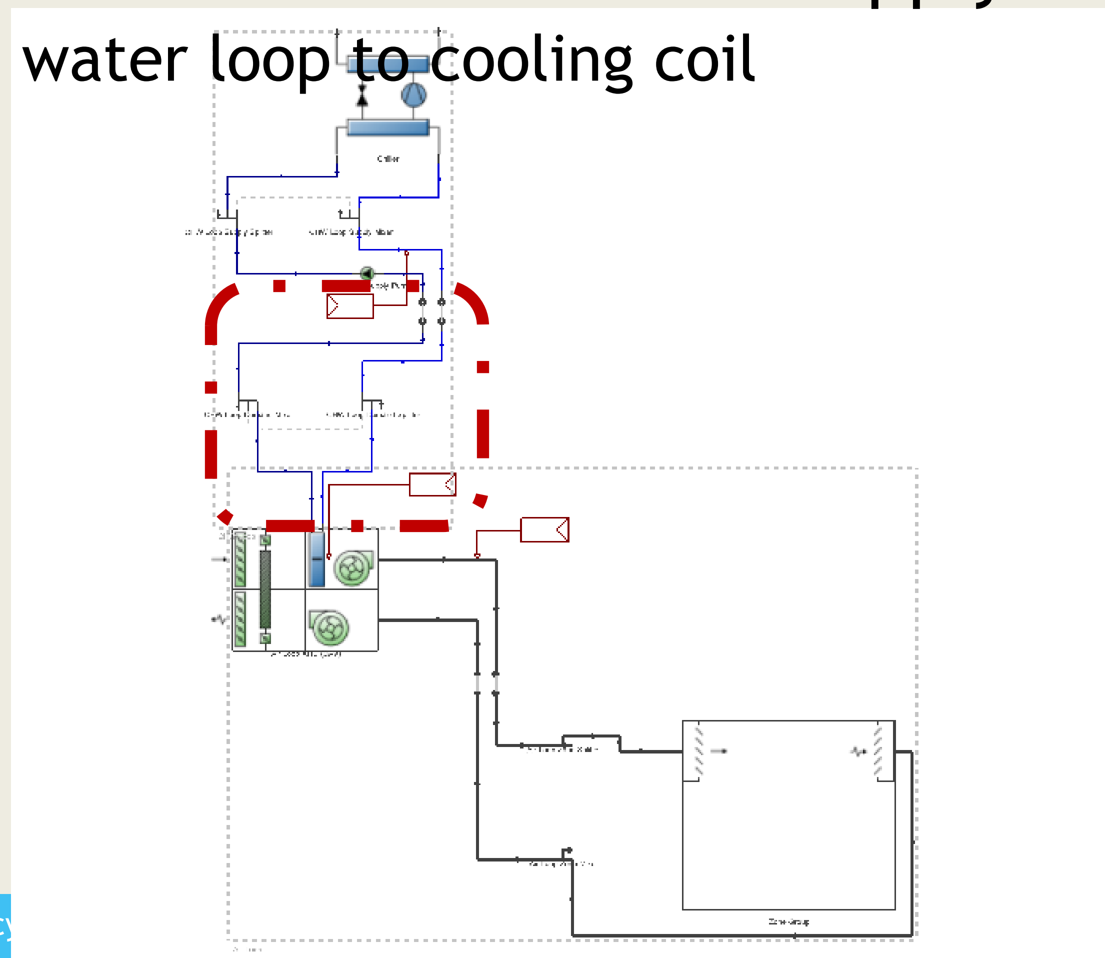
Chilled water loop – D O A S

- Control: Outdoor air set point



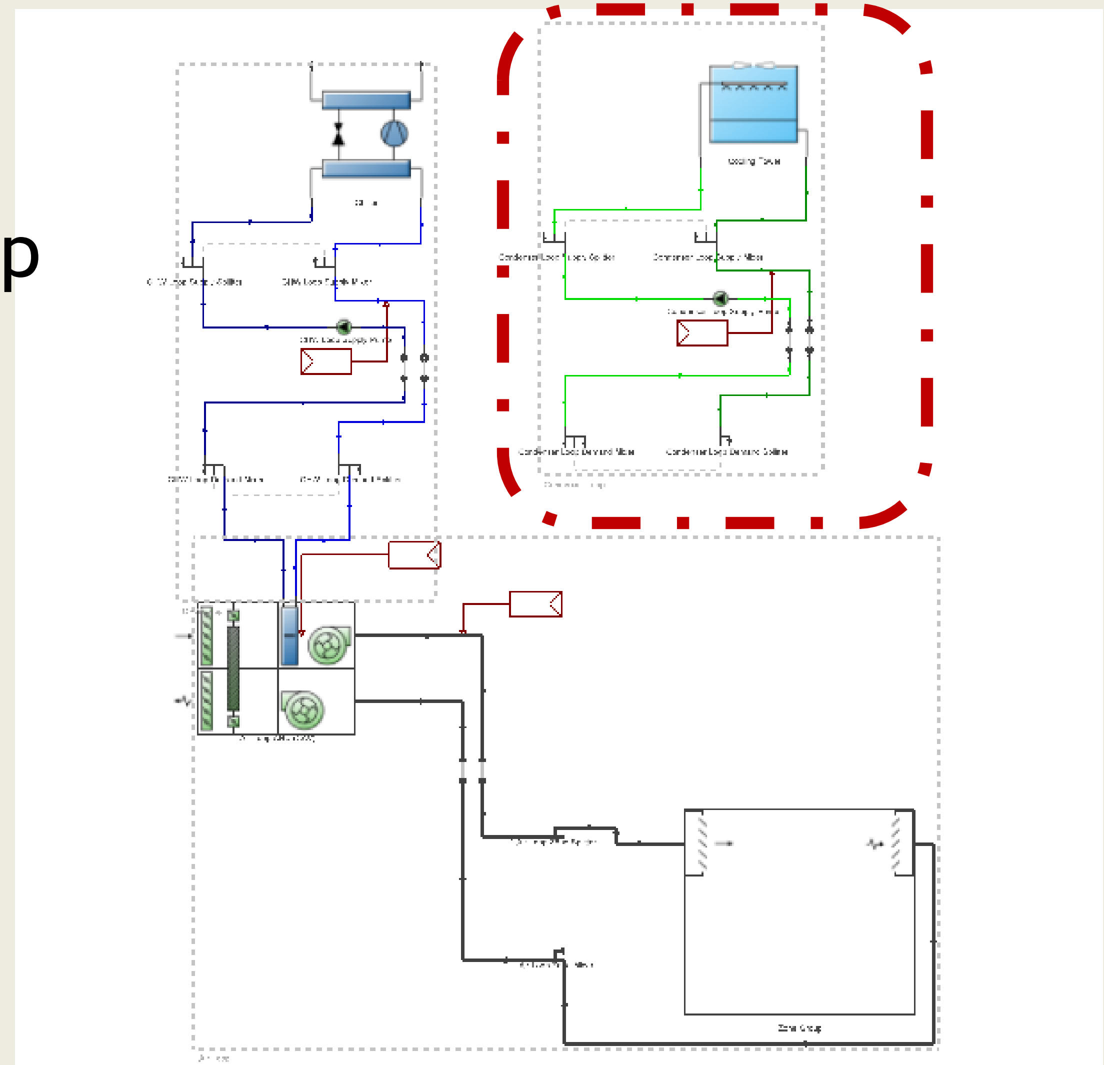
STEP 2: SLAB COOLING MODELING – D O A S

- Go to navigate tab
- Select CHW loop – D O A S demand side supply
  - Connect chilled water loop to cooling coil



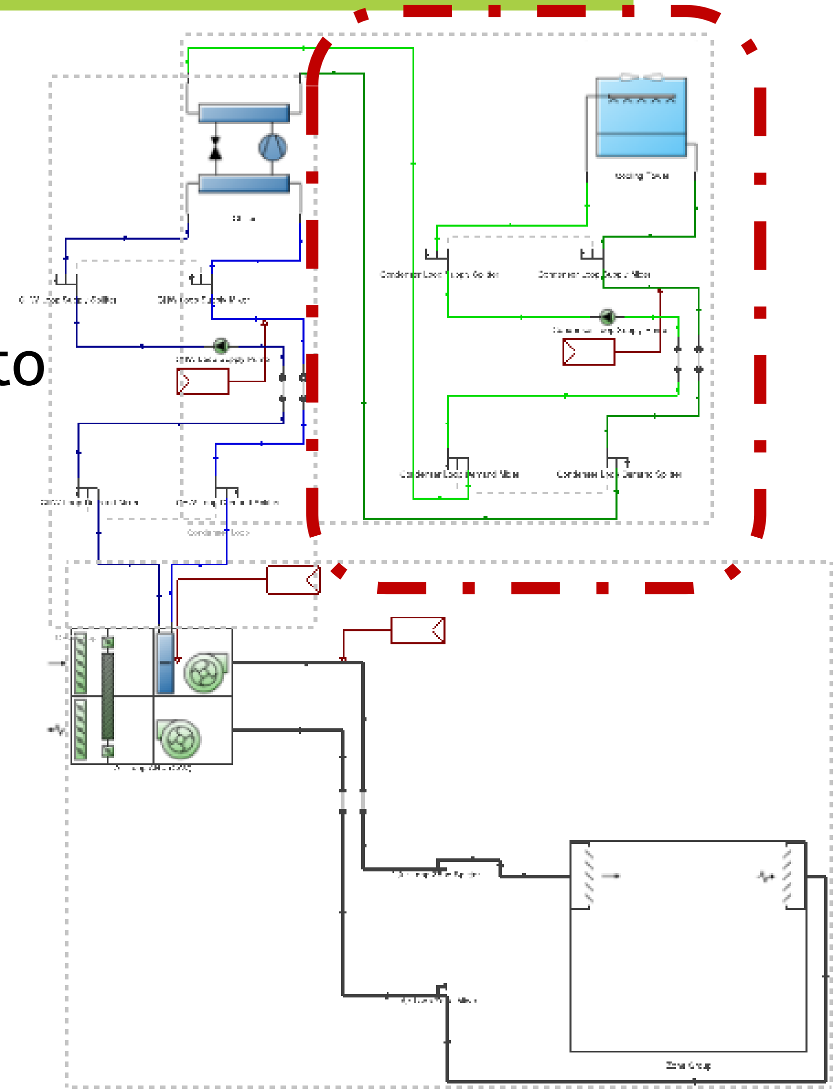
STEP 2: SLAB COOLING MODELING – D O A S

- Go to info tab
  - Add condenser loop
- Select condenser loop

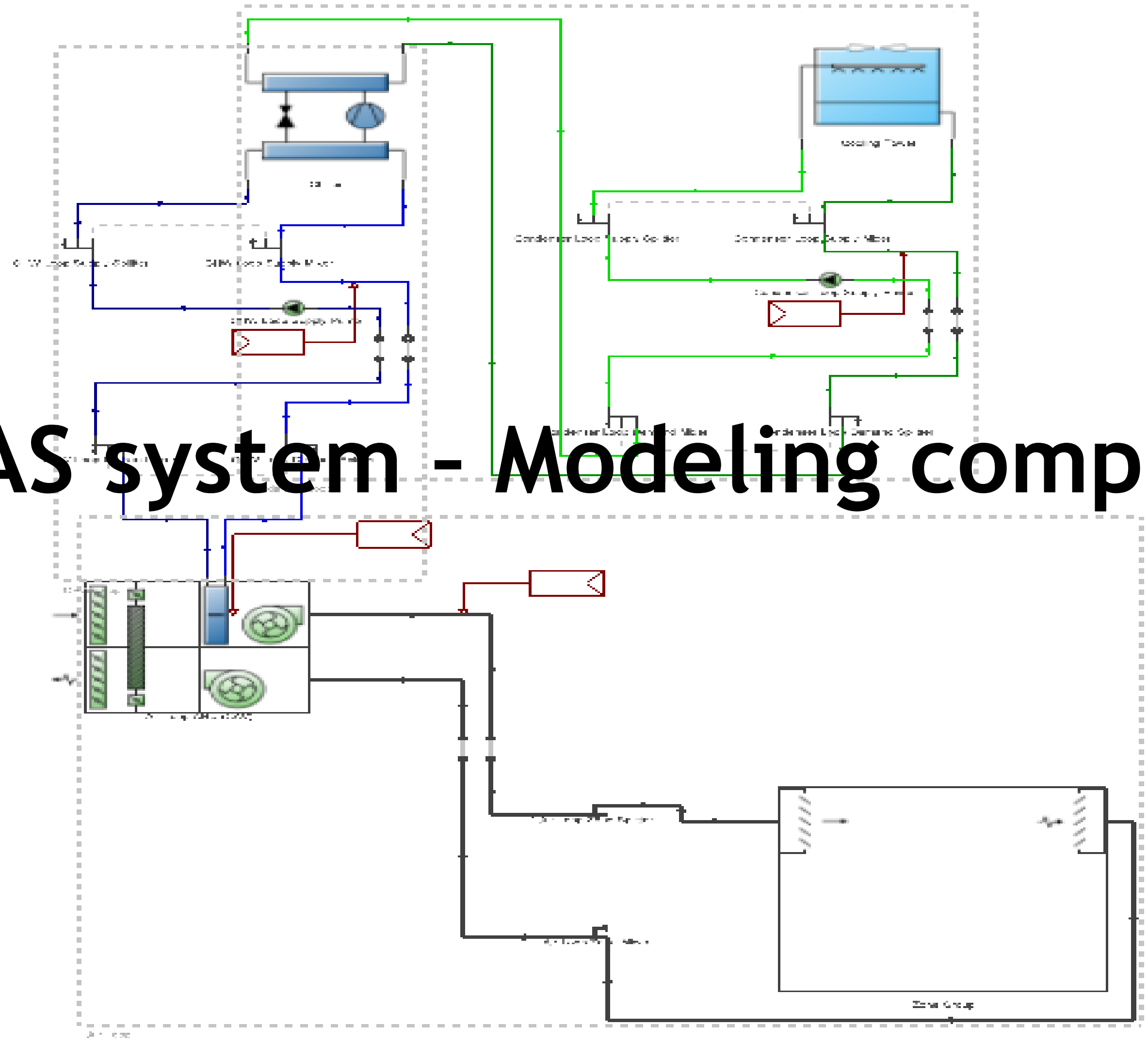


STEP 2: SLAB COOLING MODELING – D O A S

- Go to navigate tab
- Select Condenser loop demand side supply
  - Connect cooling tower to the chiller



Step 2: Slab cooling modeling – D O A S

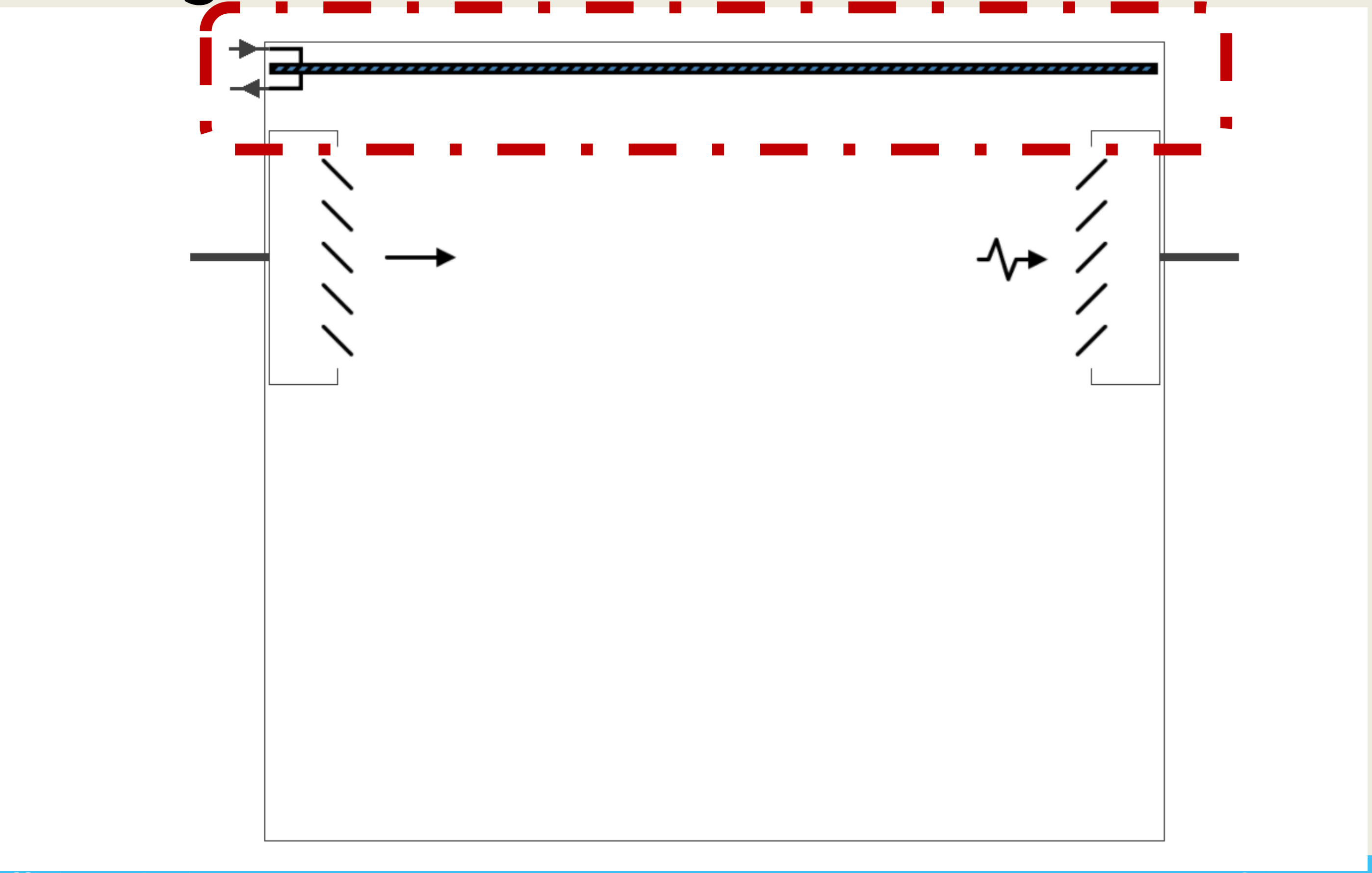


DOAS system – Modeling completed

Step 2: Slab cooling modeling – Radiant system

Radiant system modeling

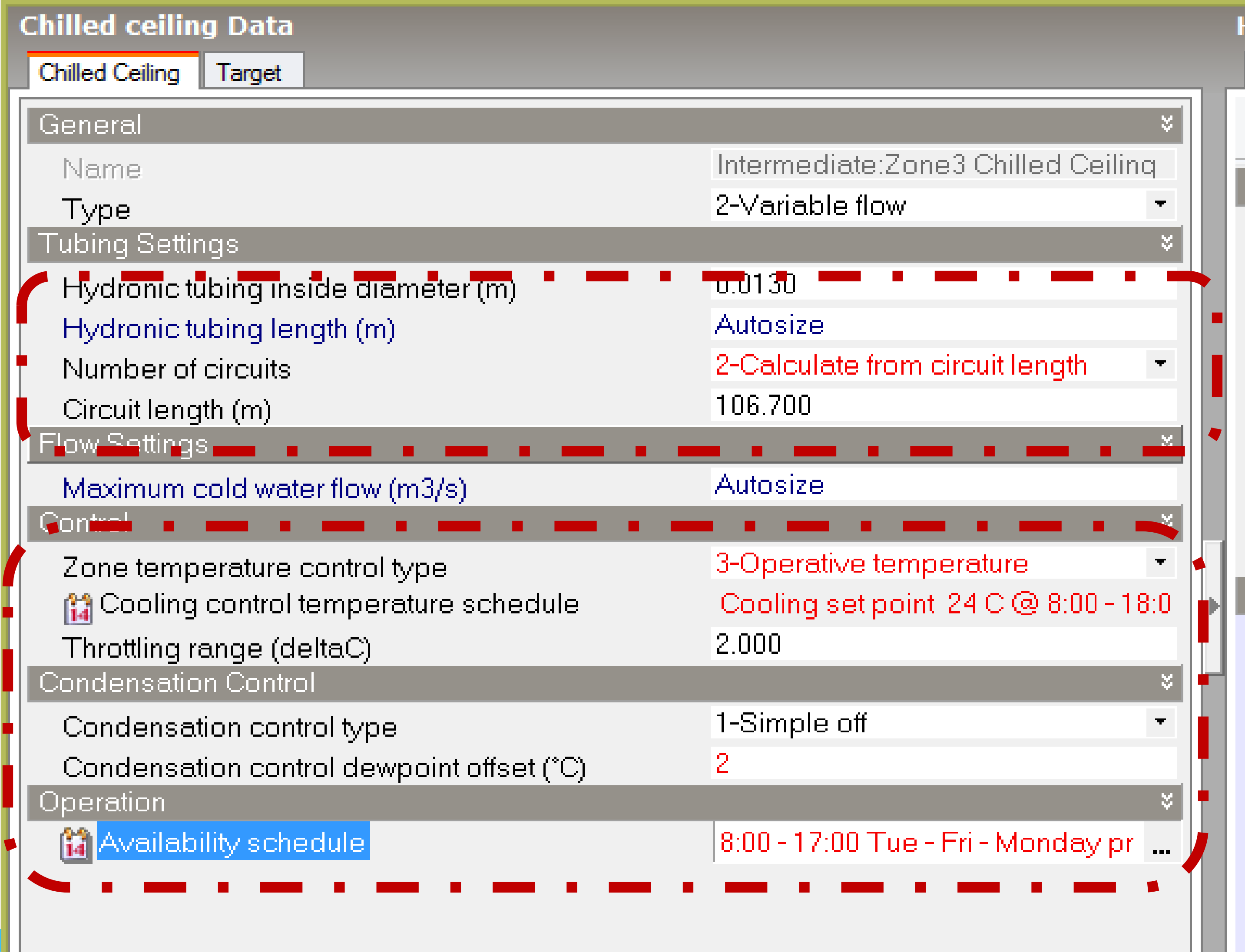
- Add Chilled ceiling at zone level



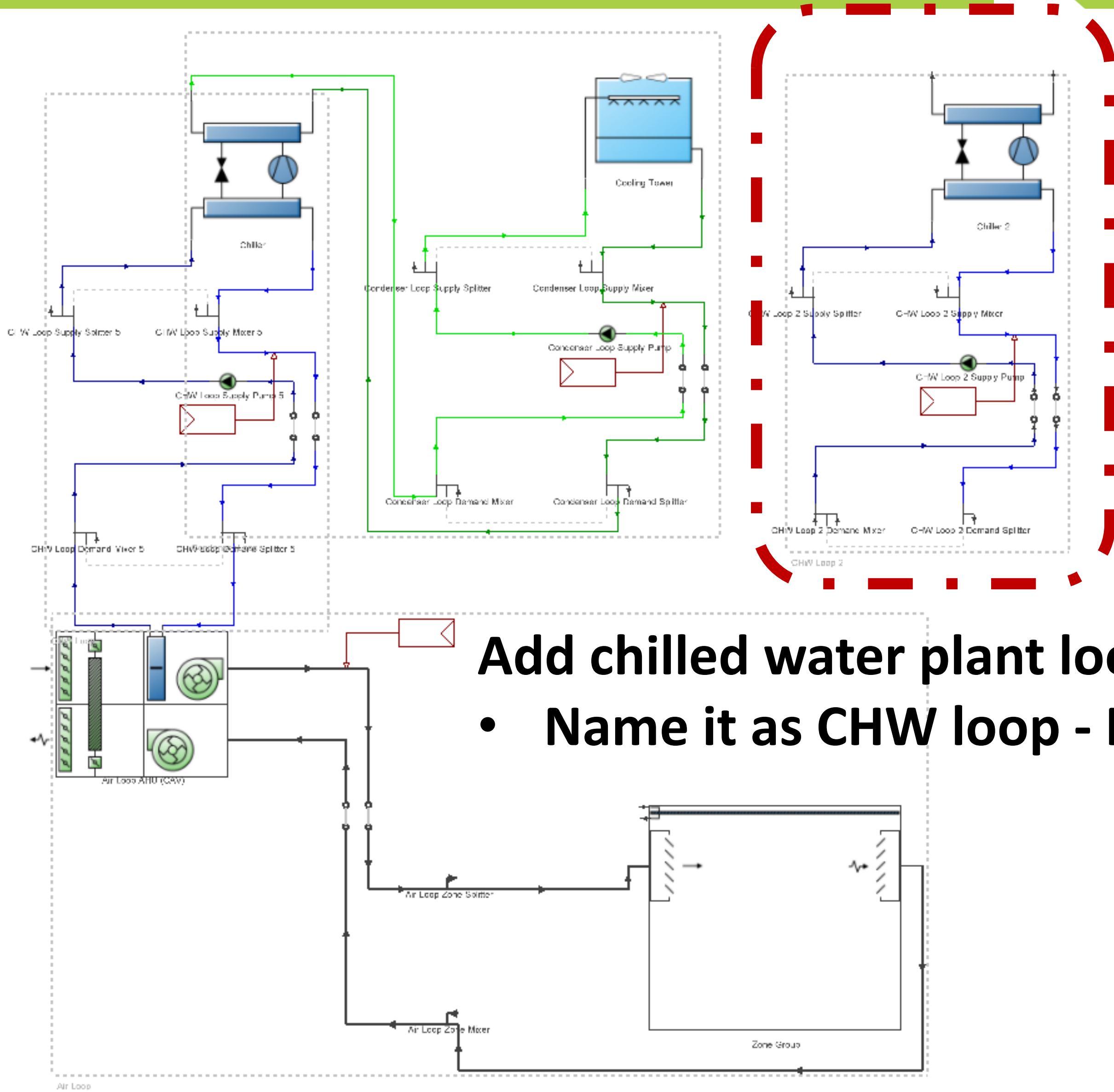
Step 2: Slab cooling modeling – Radiant system

Define parameters for chilled ceiling

- Tube dia., circuit length limited to 107 m,
- Zone control operative temperature
- Add cooling set point schedule
- Dew point offset (2^0C)
- Define operation schedule
- Target “All”



Step 2: Slab cooling modeling – Radiant system

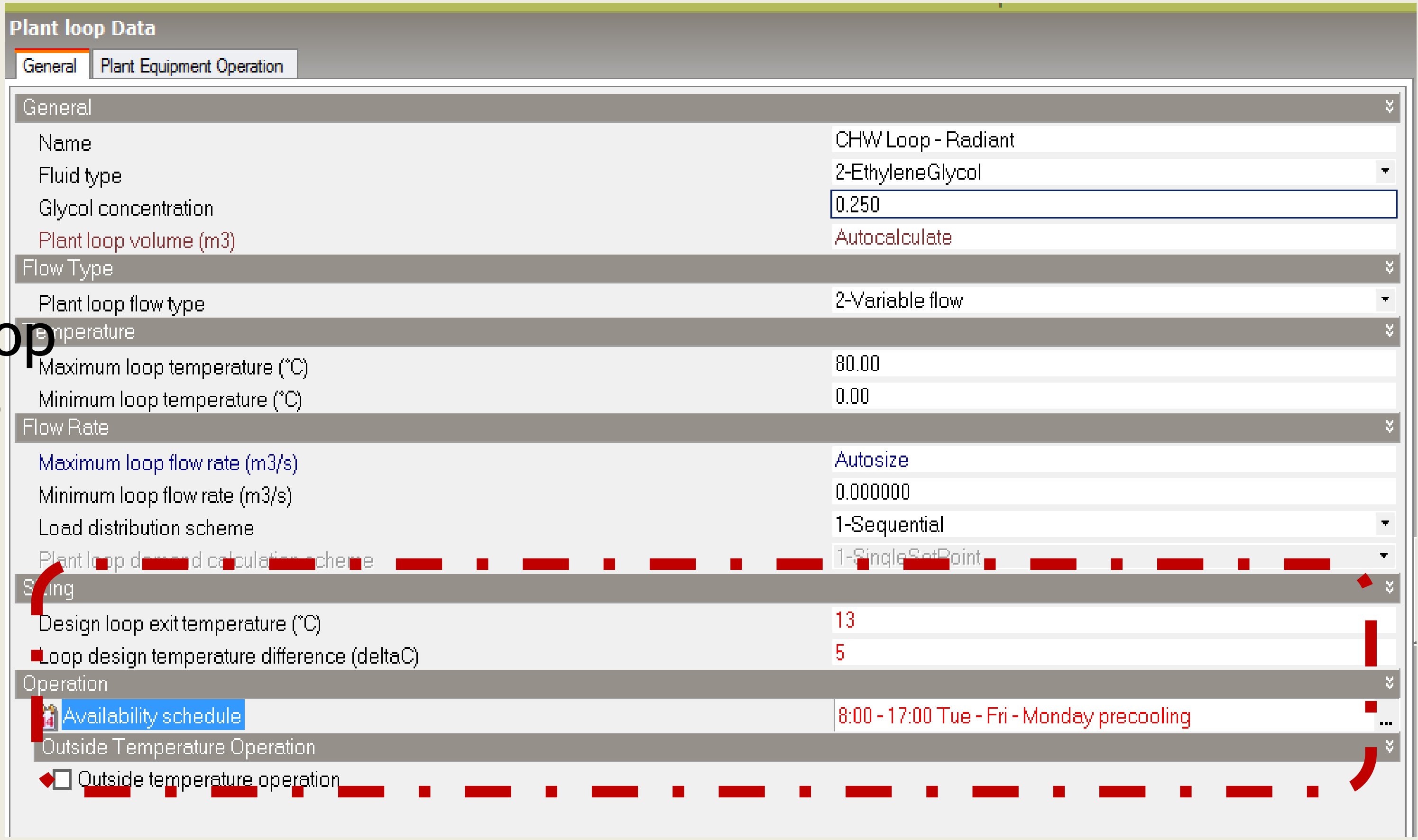


Add chilled water plant loop

- Name it as CHW loop - Radiant

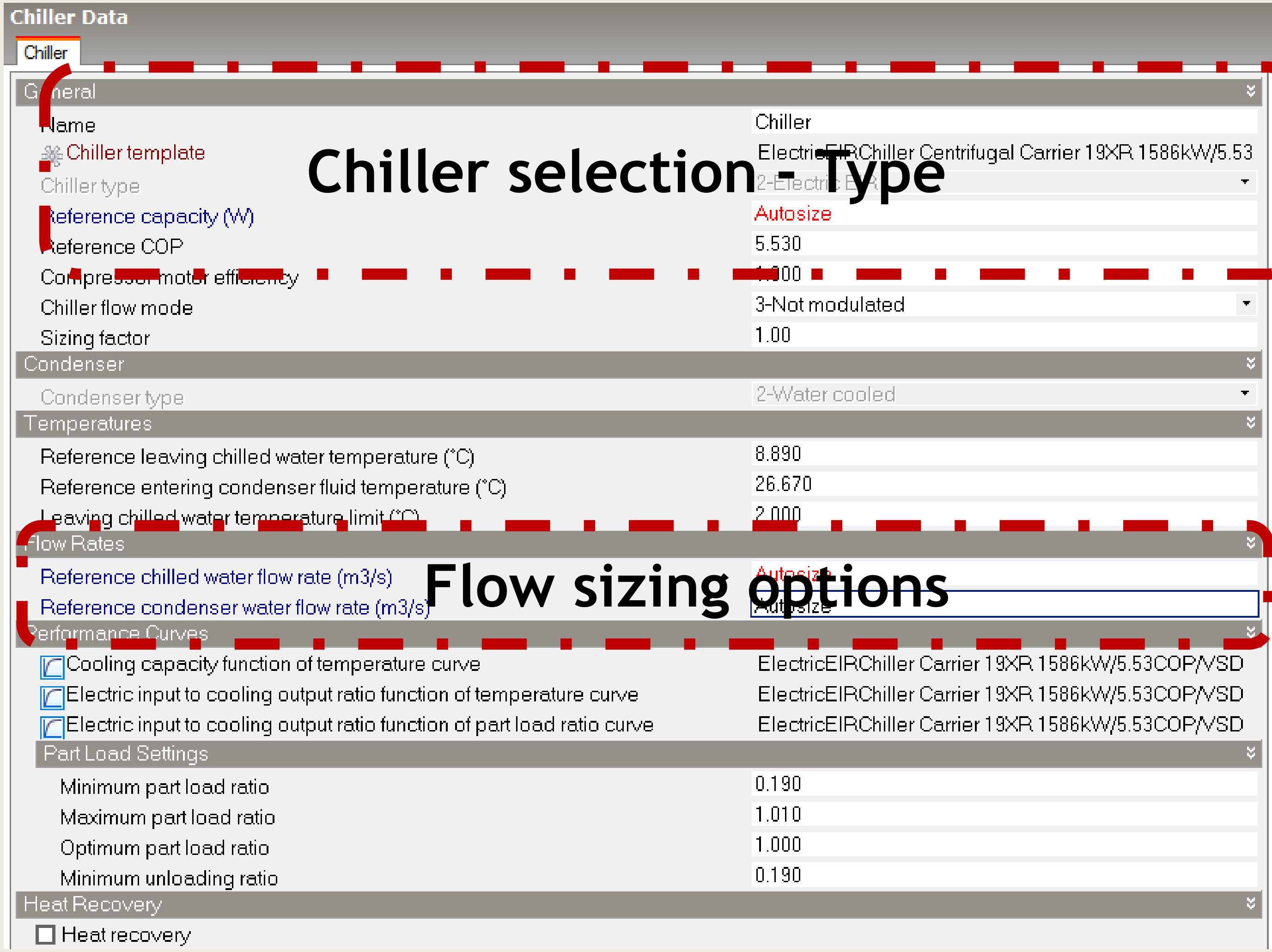
Step 2: Slab cooling modeling – Radiant system

- Radiant CHW loop
  - Define chilled water loop schedule
  - Specify values under sizing header



Step 2: Slab cooling modeling – Radiant system

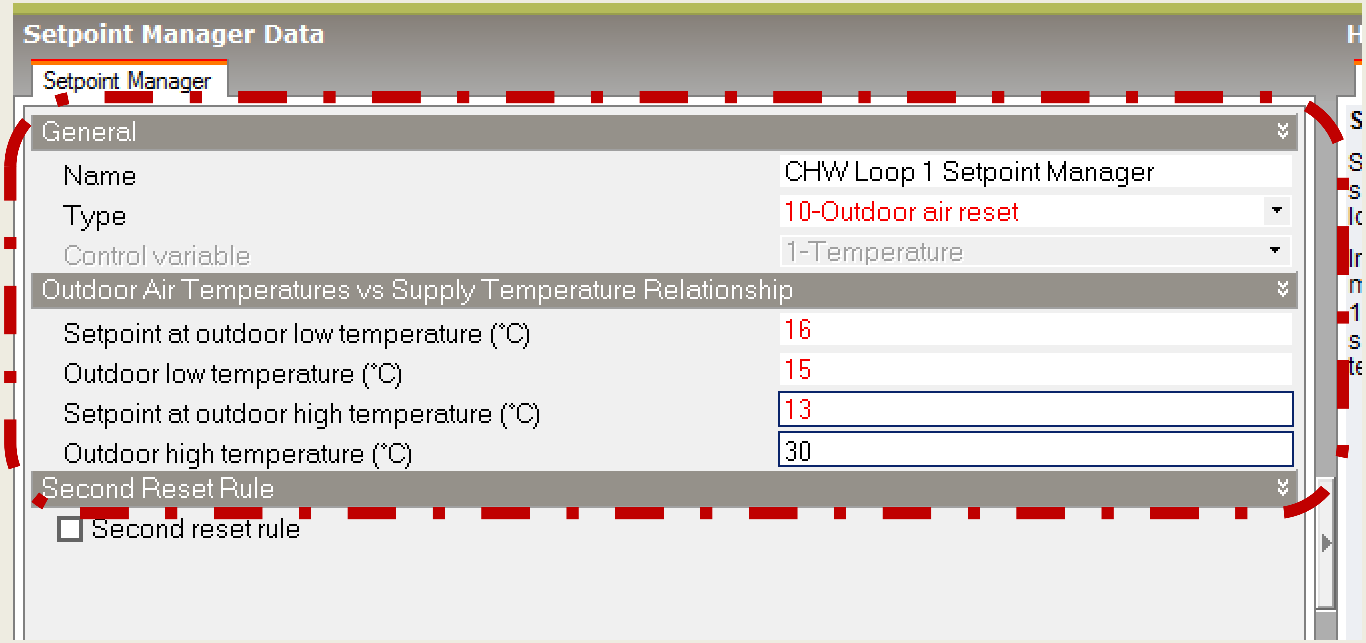
- Radiant CHW loop
  - Chiller selection - VSD
  - Auto-size Capacity
  - Auto-size flow rates



Step 2: Slab cooling modeling – Radiant system

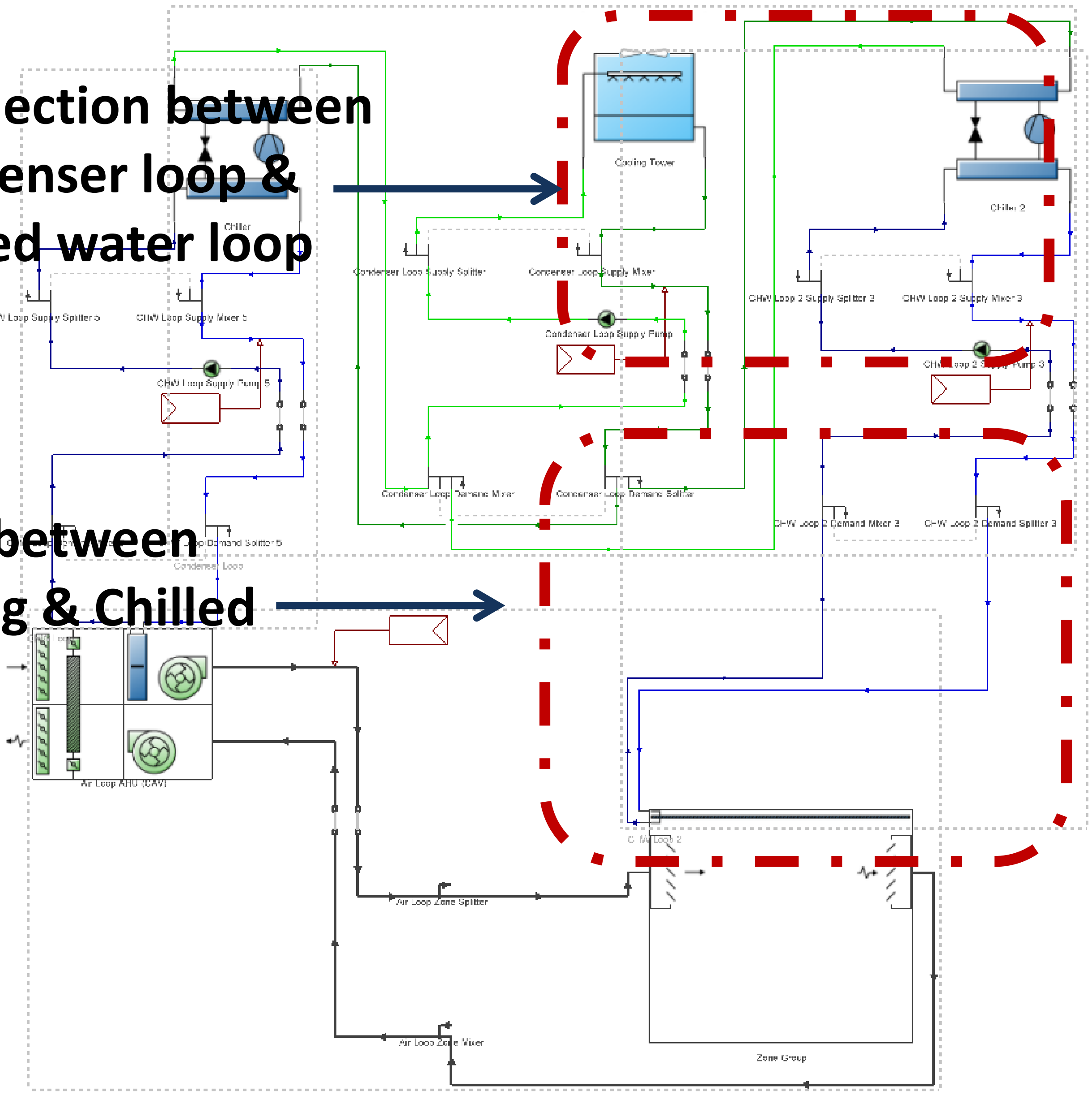
Radiant Chilled water loop

– Control: Outdoor air set point

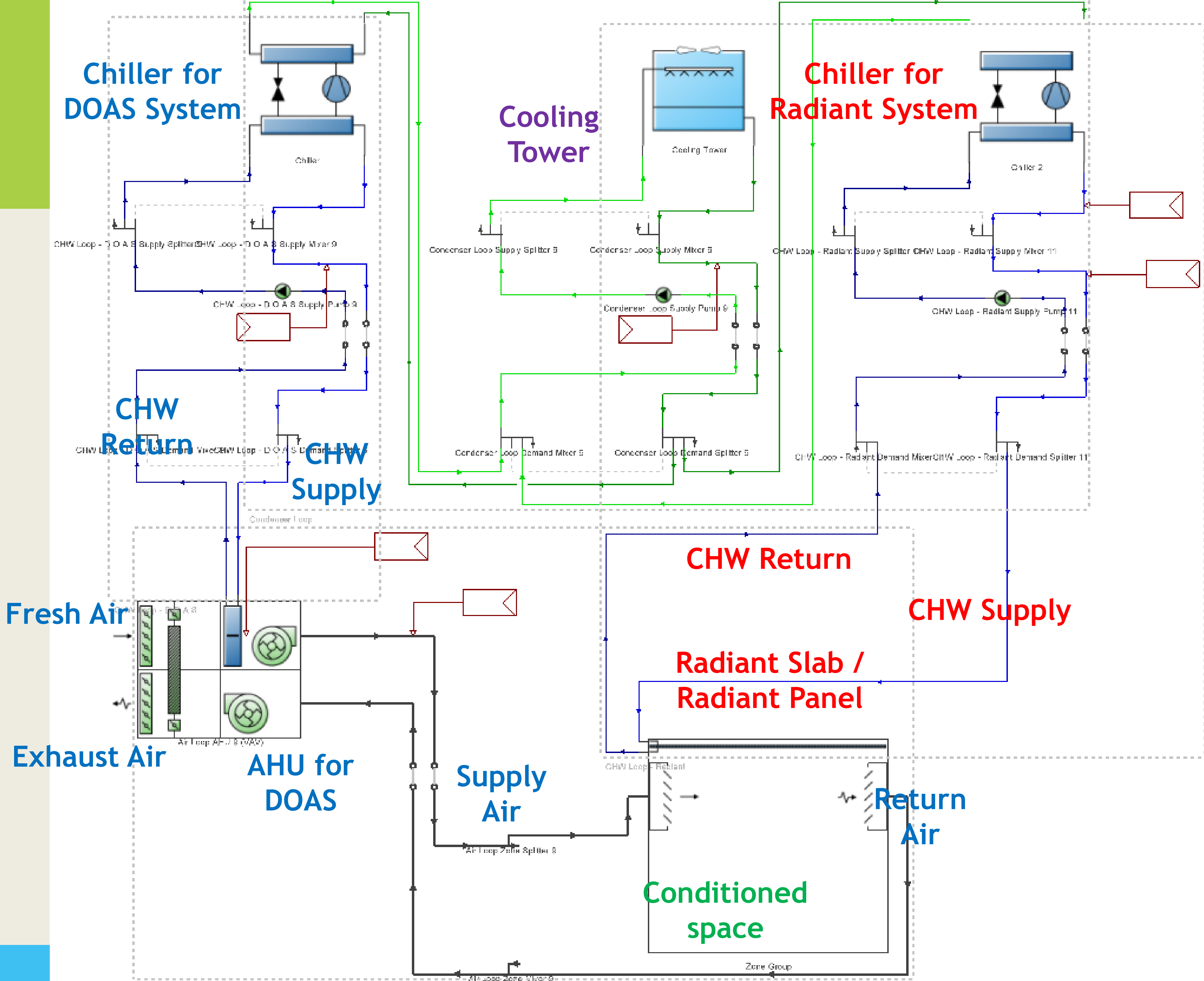


Connection between condenser loop & Chilled water loop

Connection between chilled ceiling & Chilled water loop



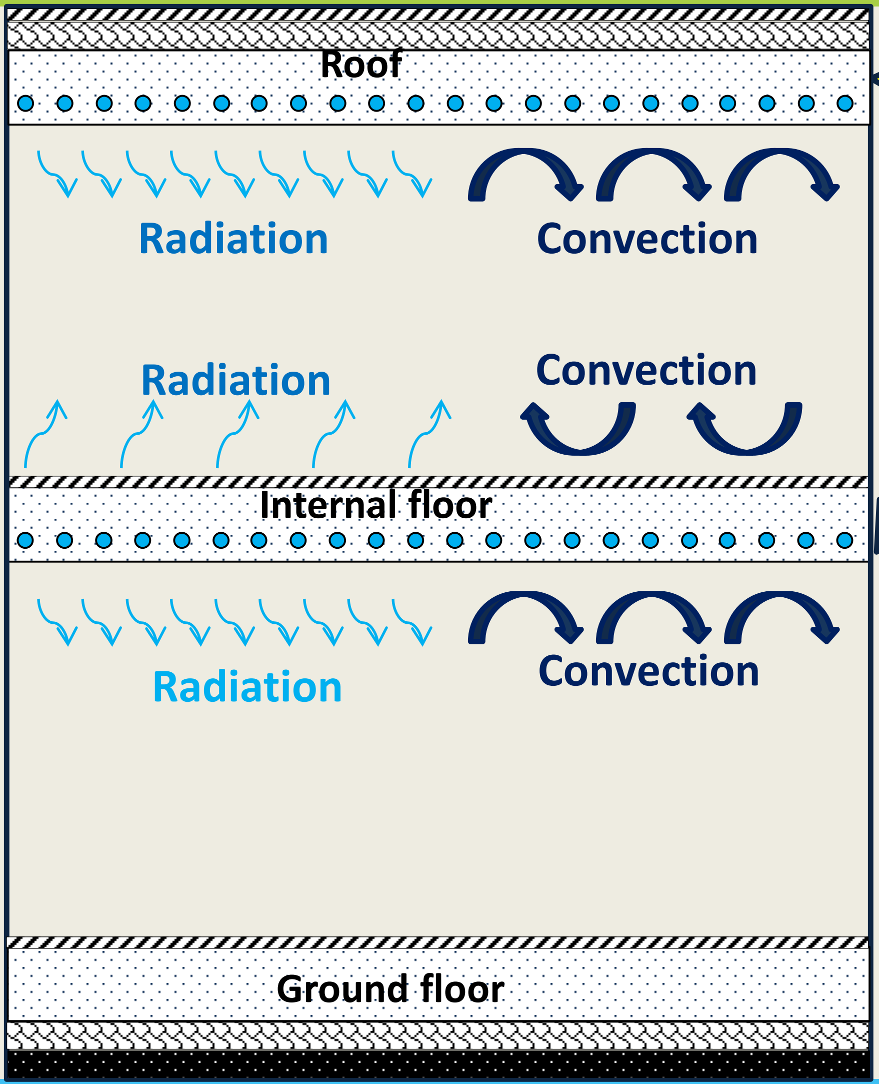
OVERALL SYSTEM MODELING

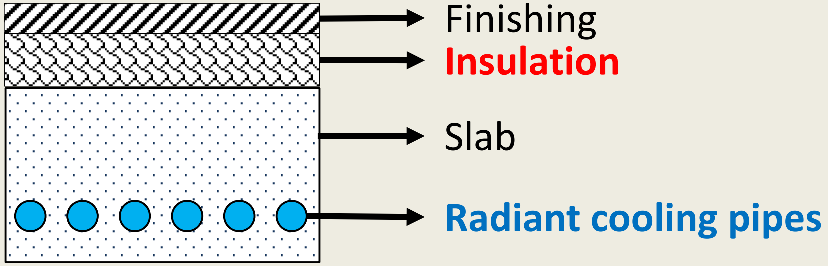

Chiller for DOAS System
Cooling Tower
Chiller for Radiant System
Chiller
Cooling Tower
Chiller 2
CHW Return
CHW Supply
Fresh Air
Exhaust Air
AHU for DOAS
CHW Return
CHW Supply
Radiant Slab / Radiant Panel
Supply Air
Return Air
Conditioned space
Condenser Loop
Zone Group

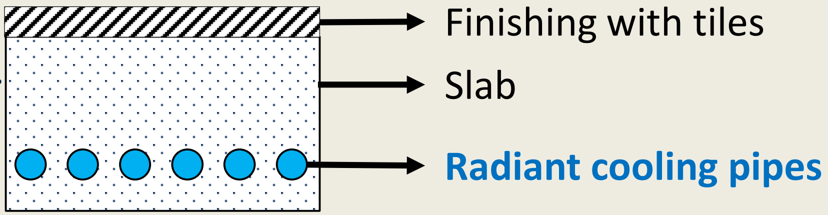
Step 2: Slab cooling modeling – Internal source activation

- In design builder, chilled pipes are considered as internal source
- Add internal source at ceiling/roof
  - Go to construction tab
  - Enable internal heat source option for ceiling/roof

Radiant Slab Cooling Schematic



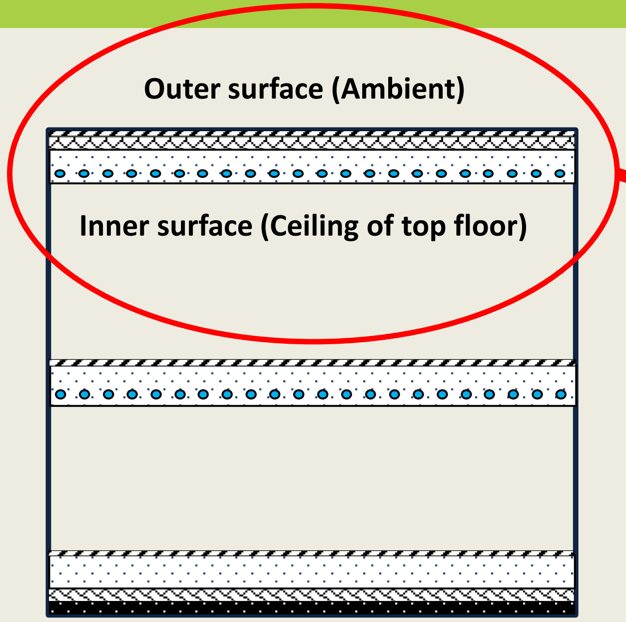


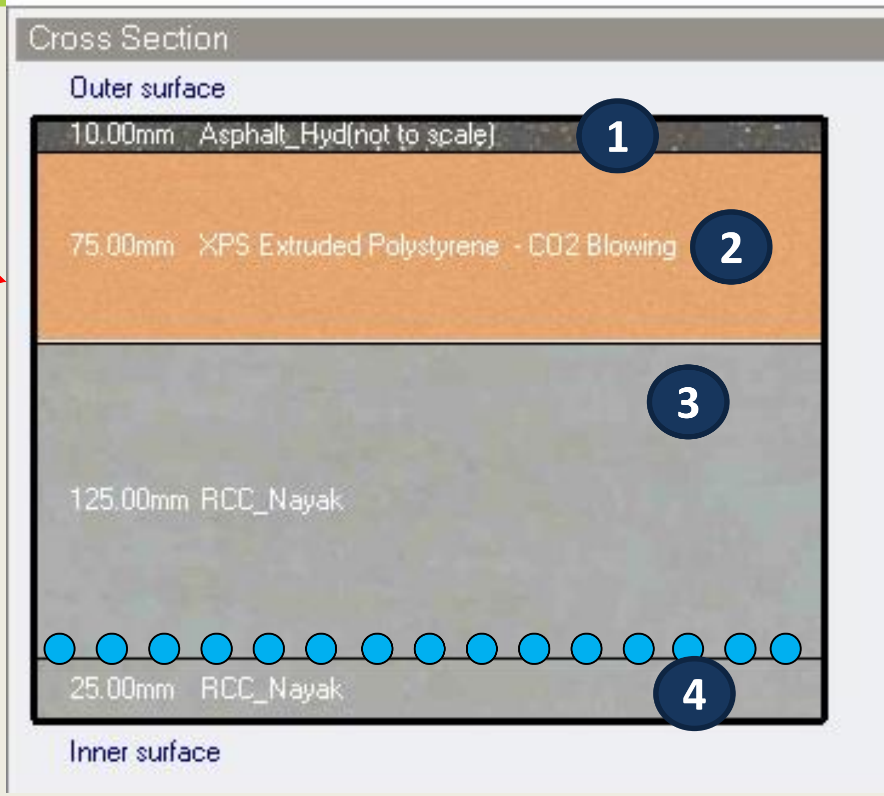


Modelling of slab cooling construction

- **Roof**
- **Internal floors**

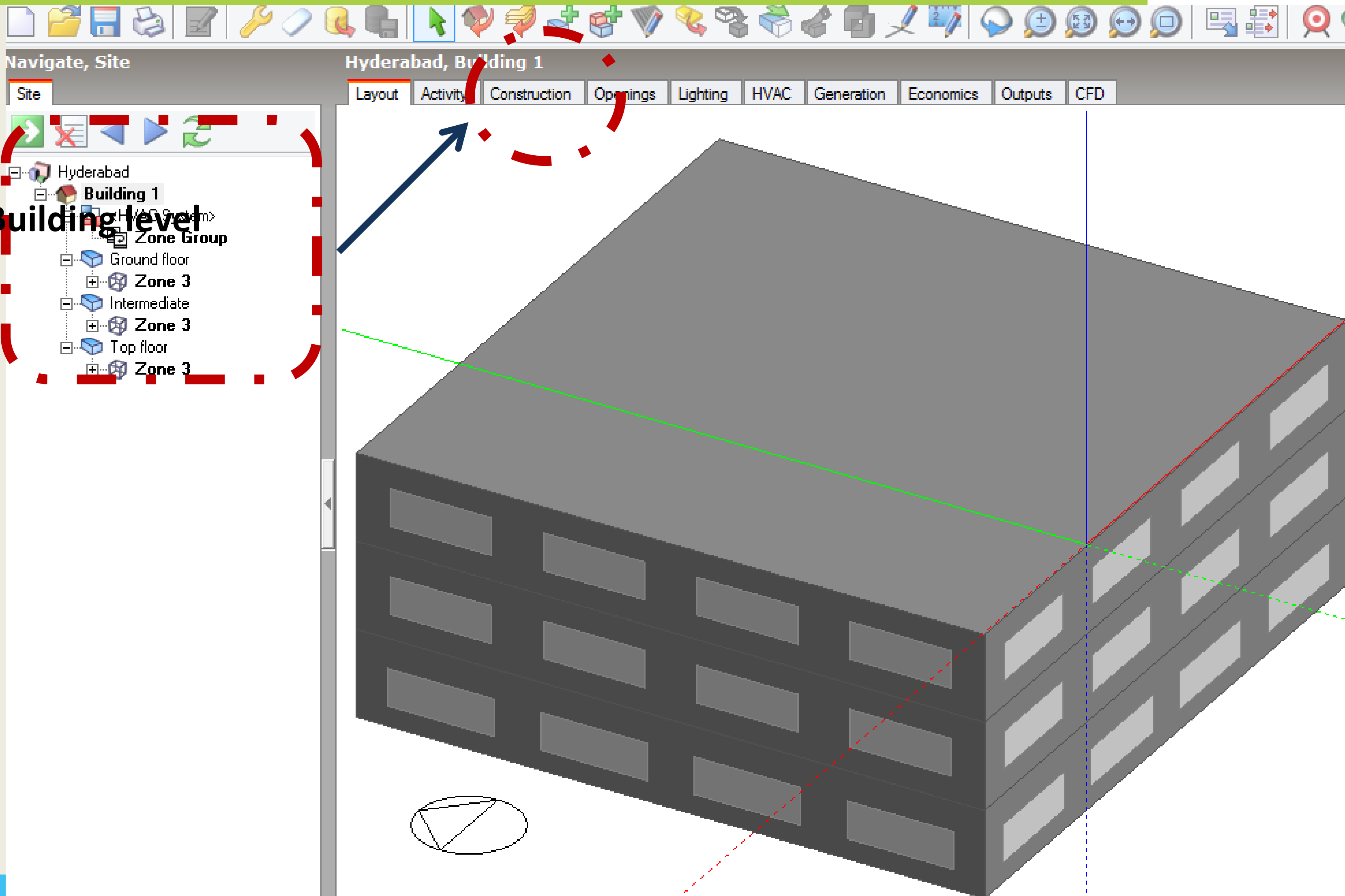
Design Builder – Roof slab construction



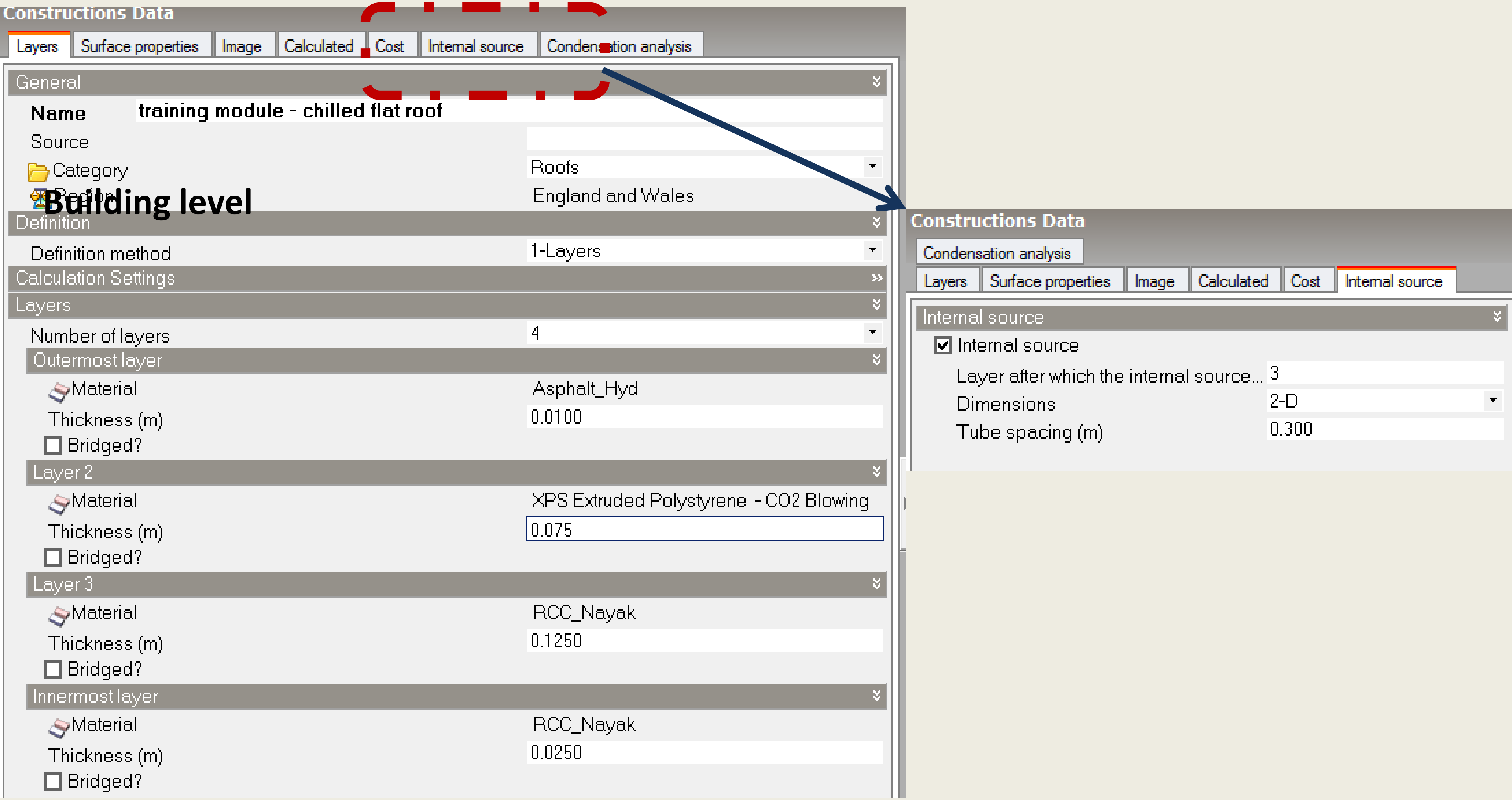


- Construction is defined layer by layer
- Layer numbering always starts from outer surface
- Insert the cooling pipes (internal source) above the inner surface, which gives more cooling effect to the zone below

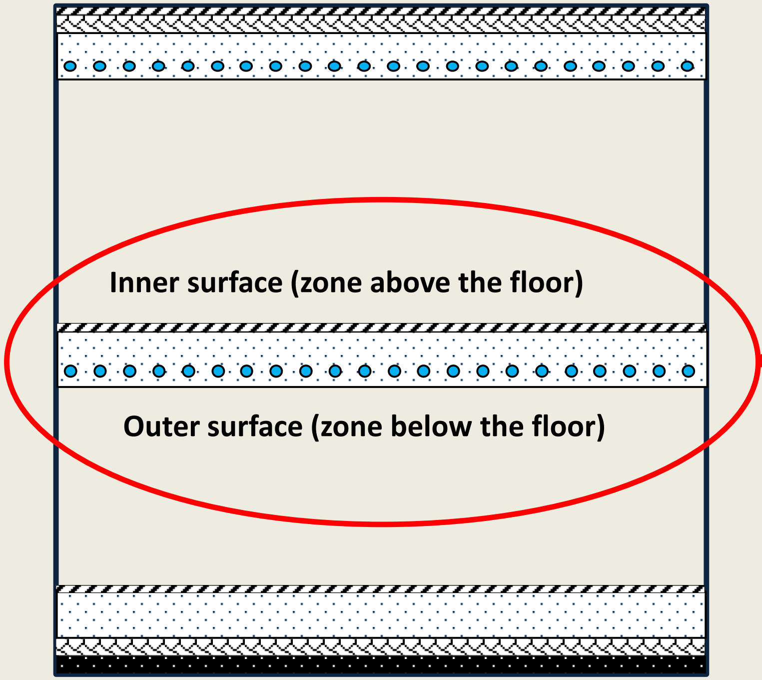
Design Builder – Roof slab Construction

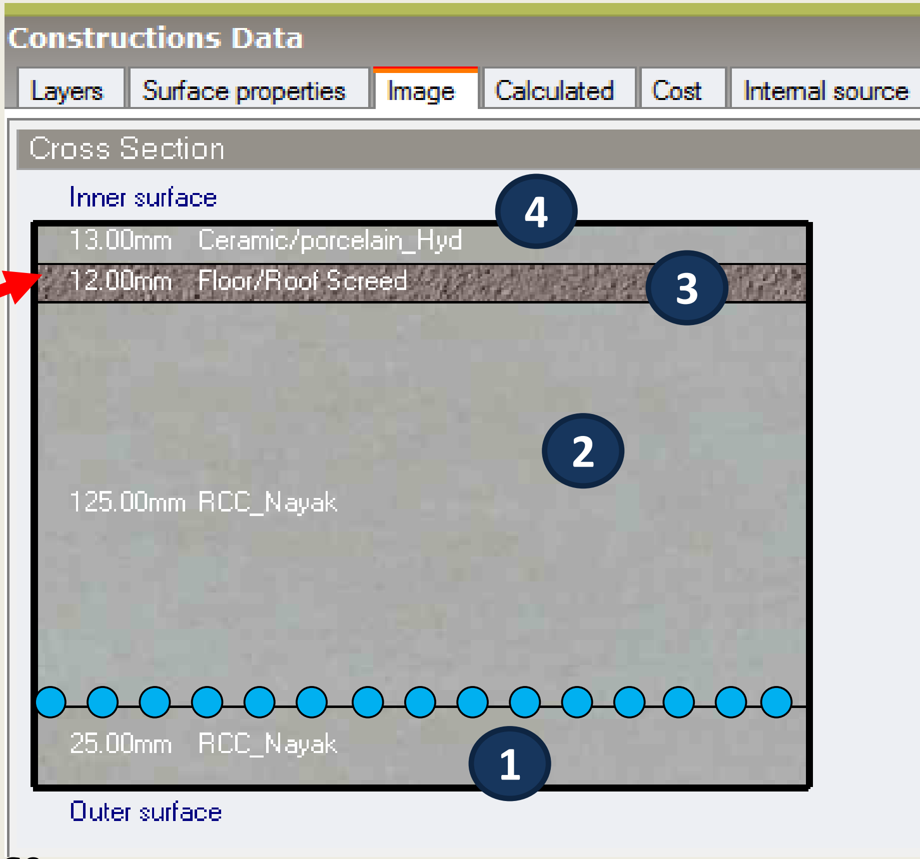


Design Builder – Roof slab Construction



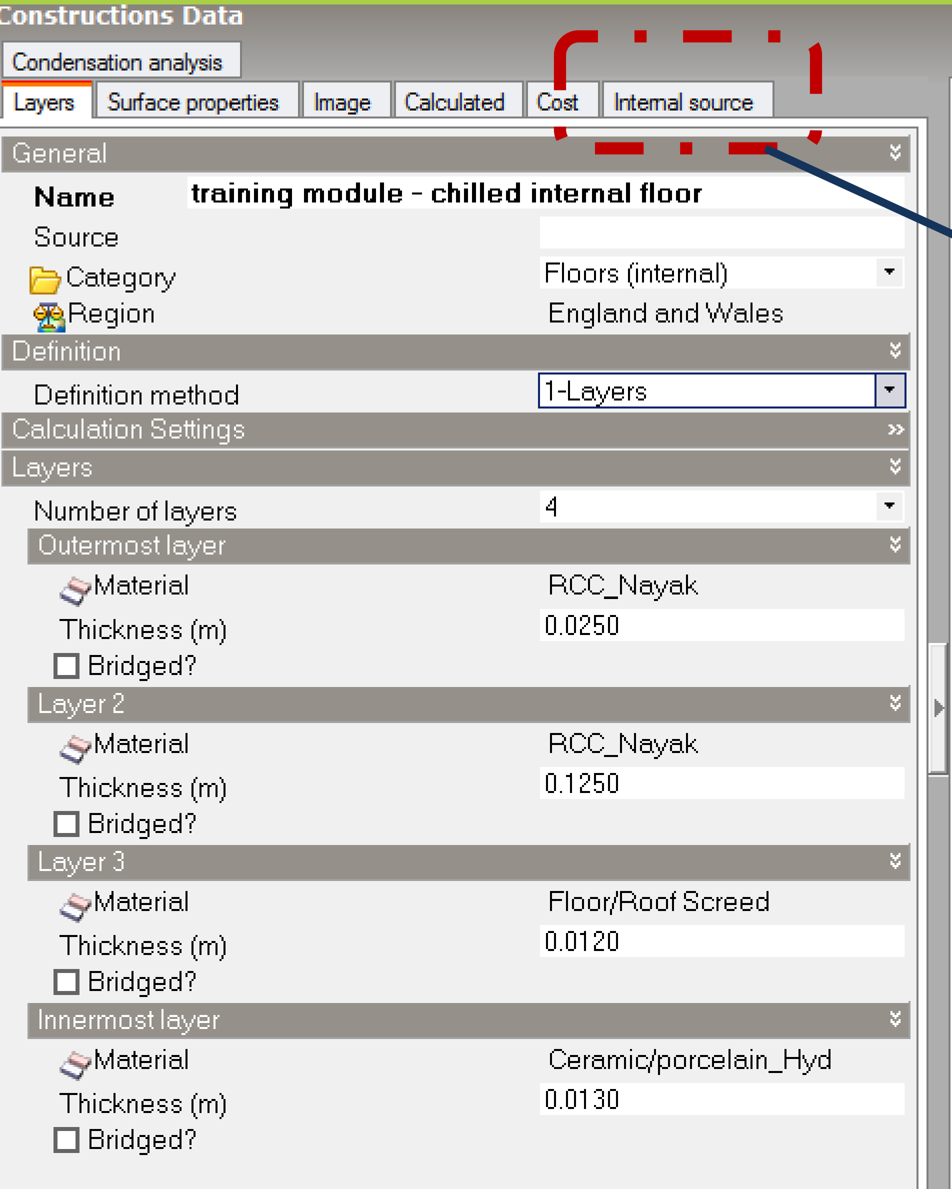
Design Builder – Internal floor slab construction

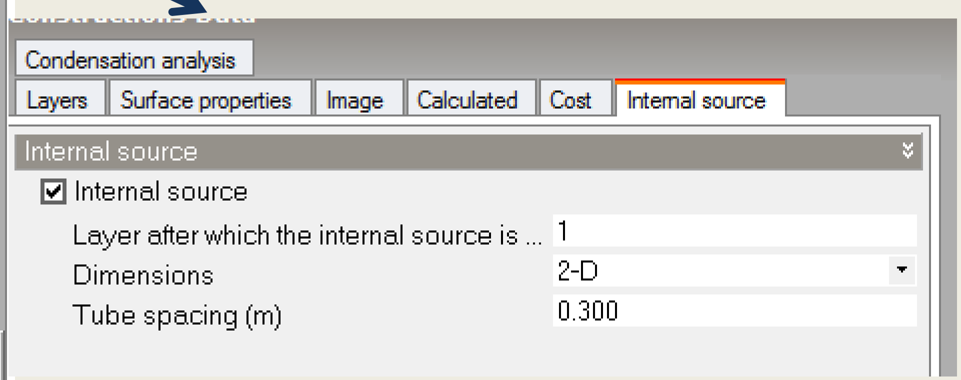




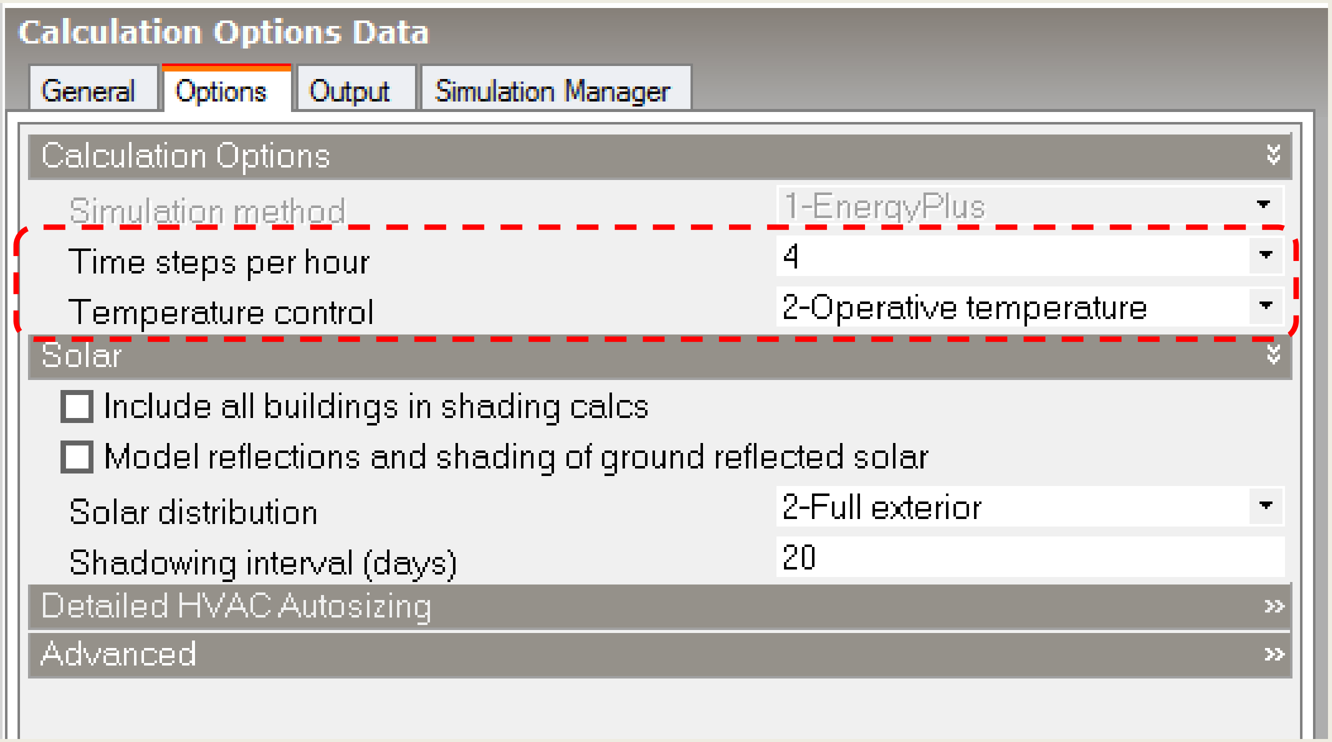
- Construction is defined layer by layer
- Layer numbering always starts from outer surface
- Insert the cooling pipes (internal source) above the outer surface, implies more cooling effect to the zone below

Design Builder – Internal floor slab construction



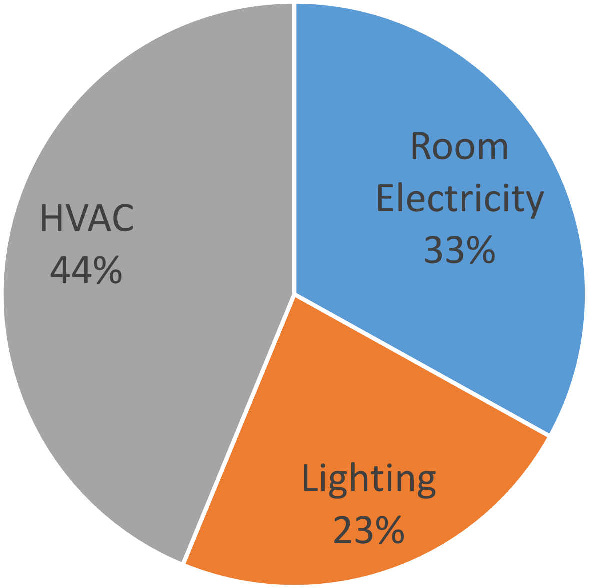


Model Ready for Simulation



Slab cooling - Simulation results

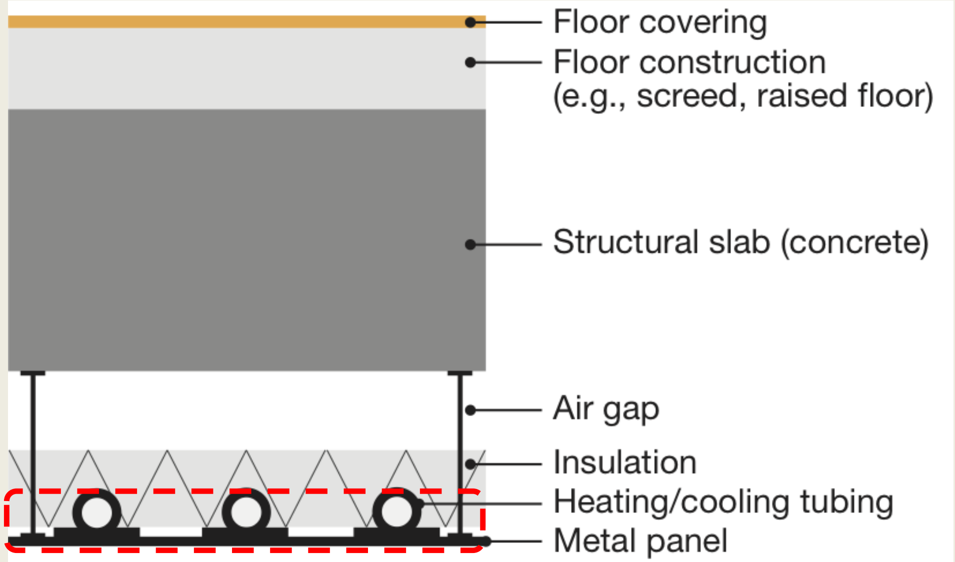
No	End use	Energy Consumption (kWh/year)
1	Lighting	46500
2	Equipment	32550
3	HVAC	61551
4	Total	140602
5	EPI (total)	79
6	EPI (HVAC)	34.5



No	Chiller	Load share
1	DOAS	37%
2	Radiant	63%

INPUTS FOR RADIANT PANEL

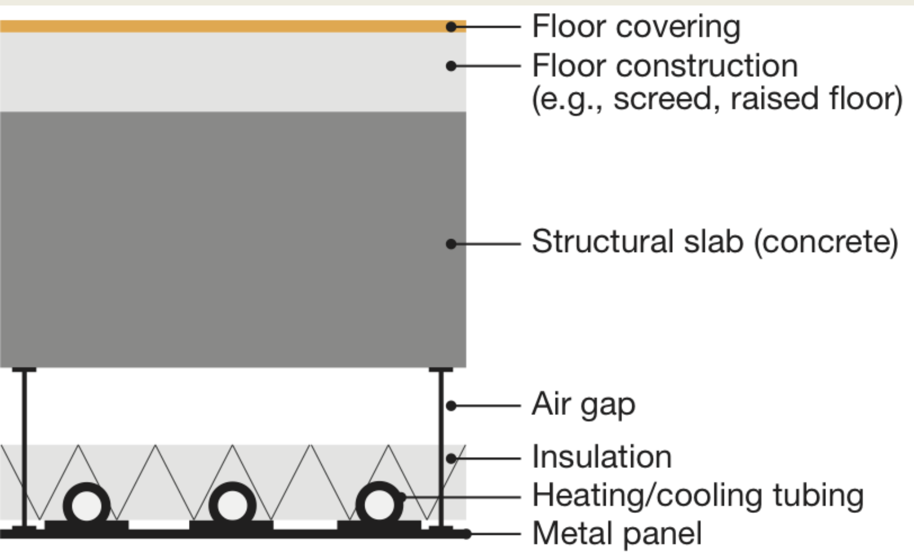
Radiant panels modelling

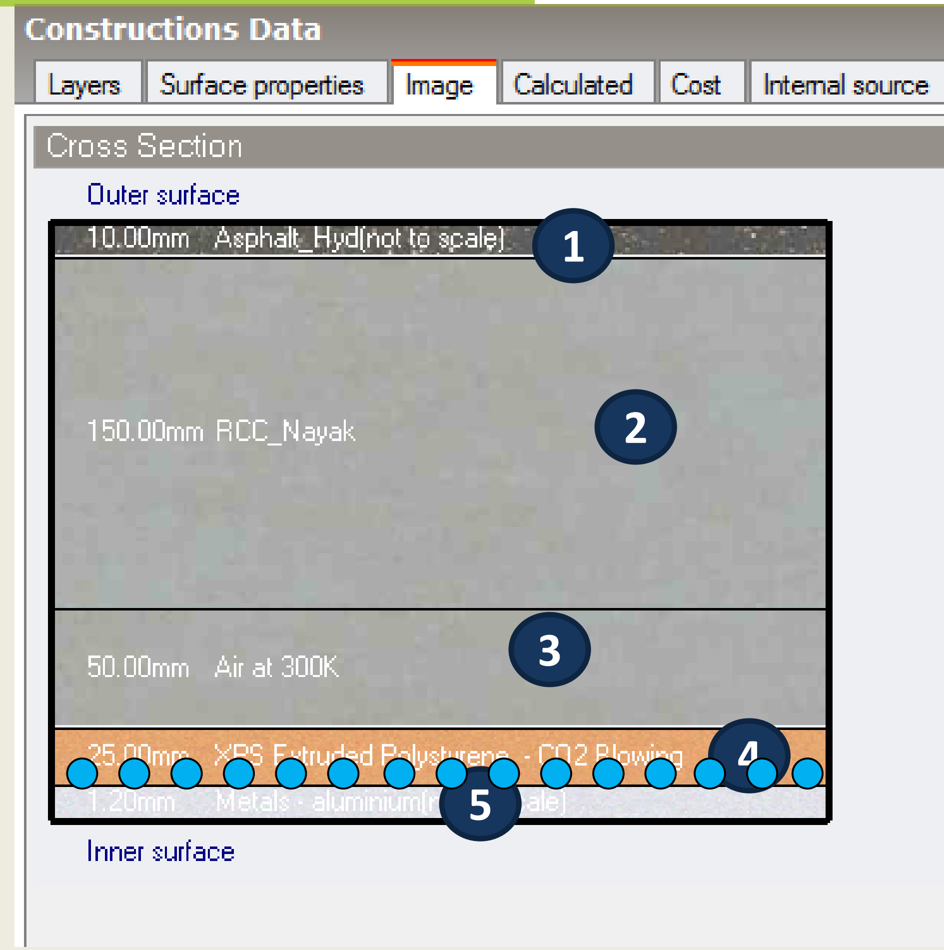


Panel cooling systems

Source: Jingjuan Feng, PhD Thesis, "Design and Control of Hydronic Radiant Cooling Systems", University of California, Berkeley

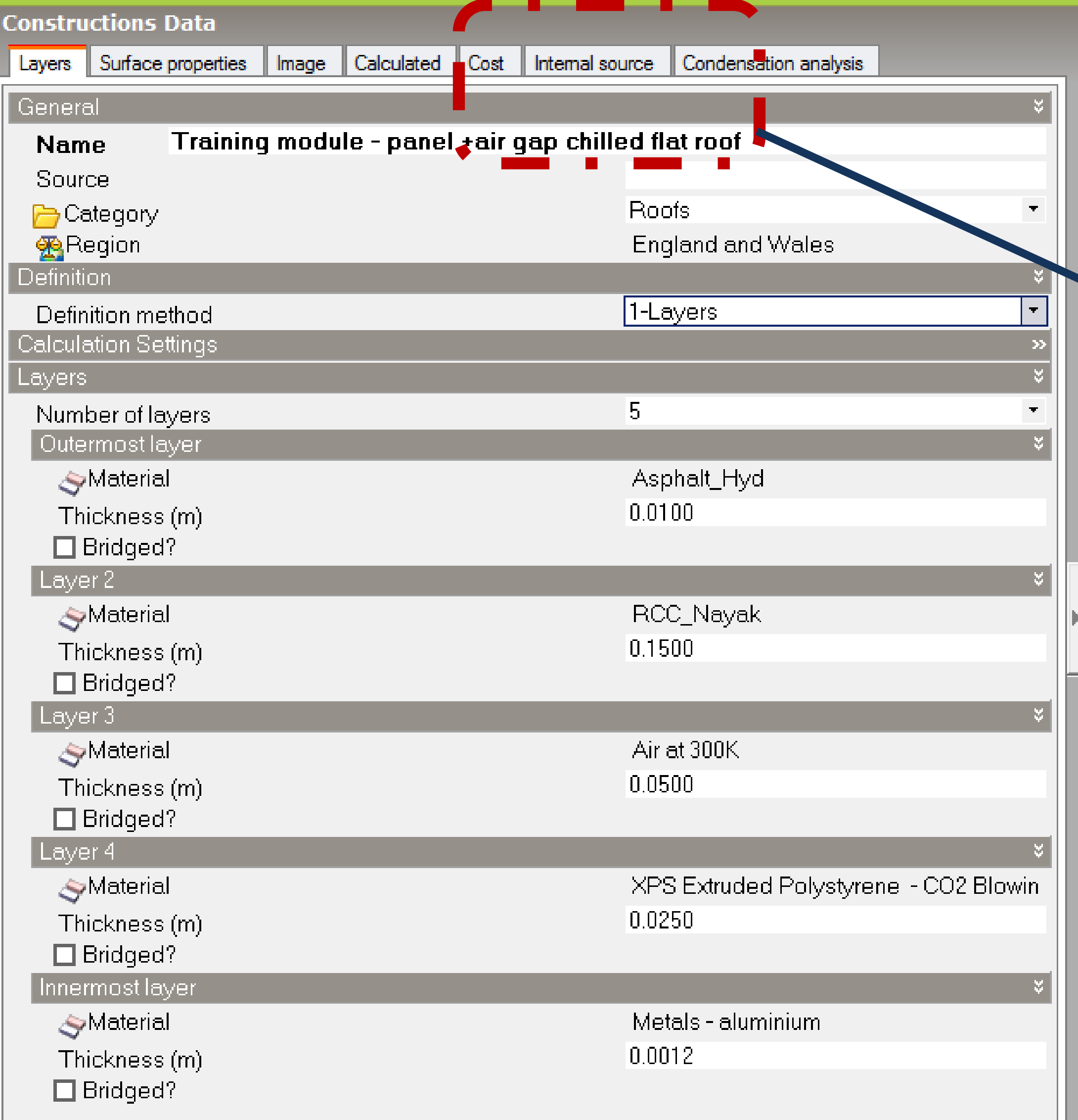
Design Builder – Roof panel construction

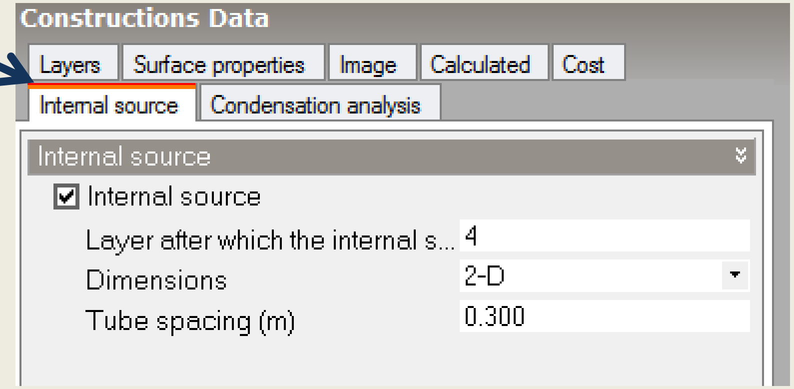




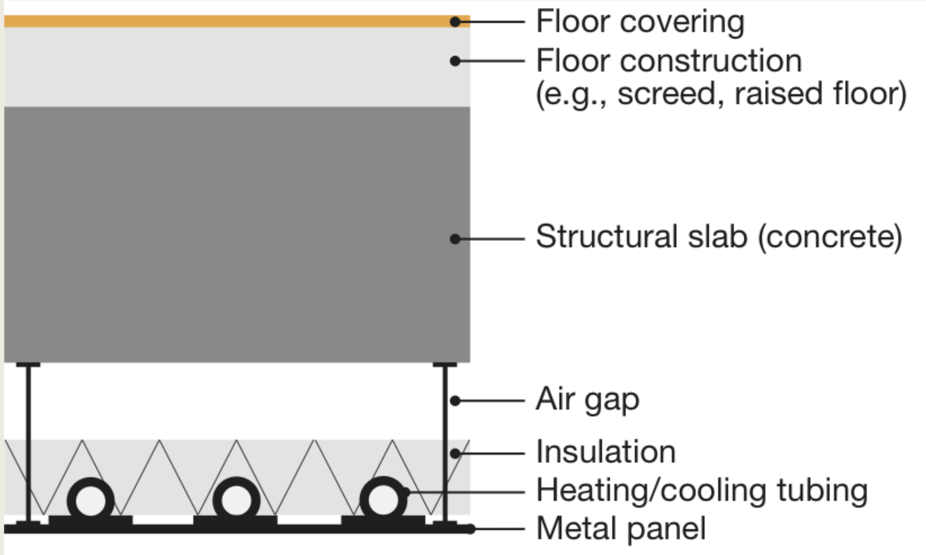
- Insert the cooling pipes (internal source) above the aluminum panel

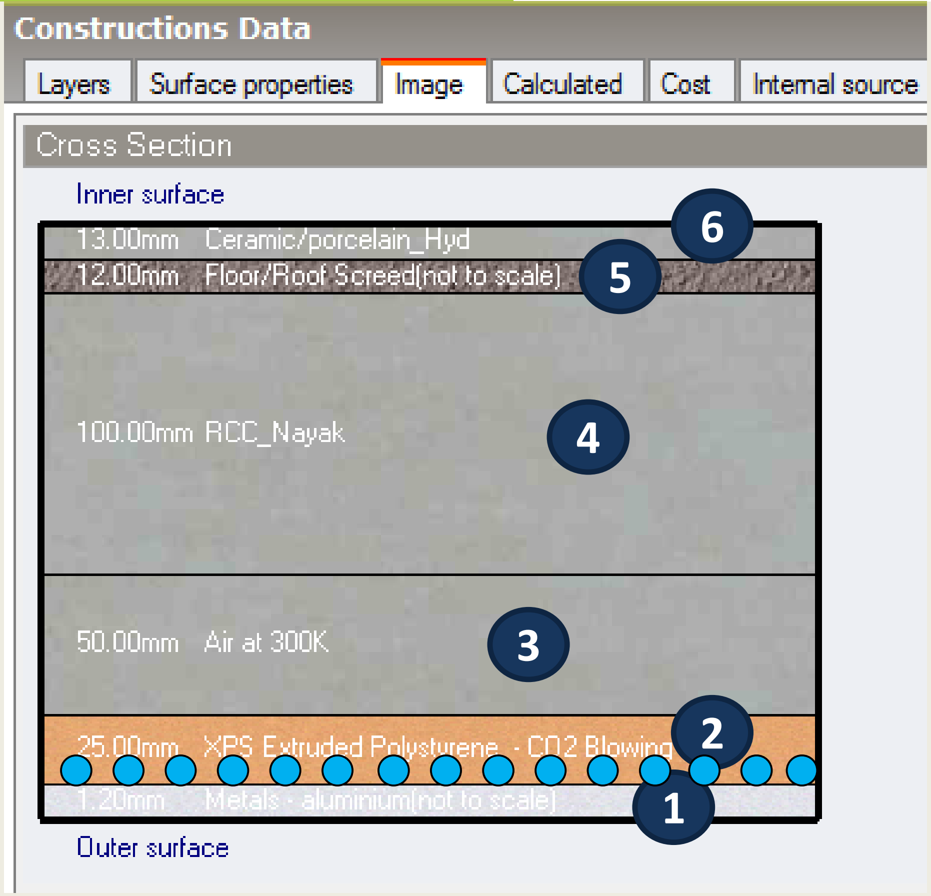
Design Builder – Roof panel construction





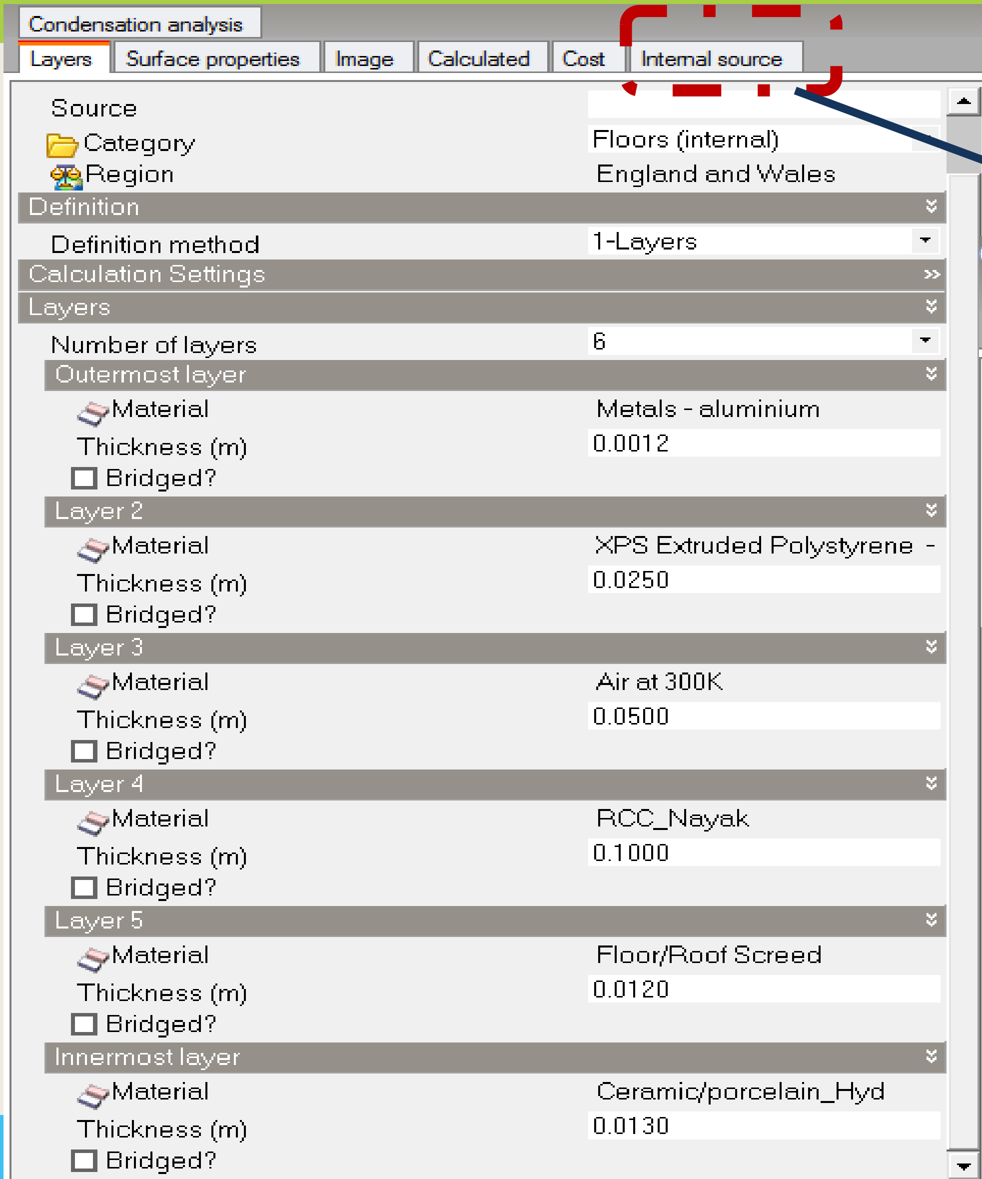
DESIGN BUILDER – INTERNAL FLOOR PANEL CONSTRUCTION

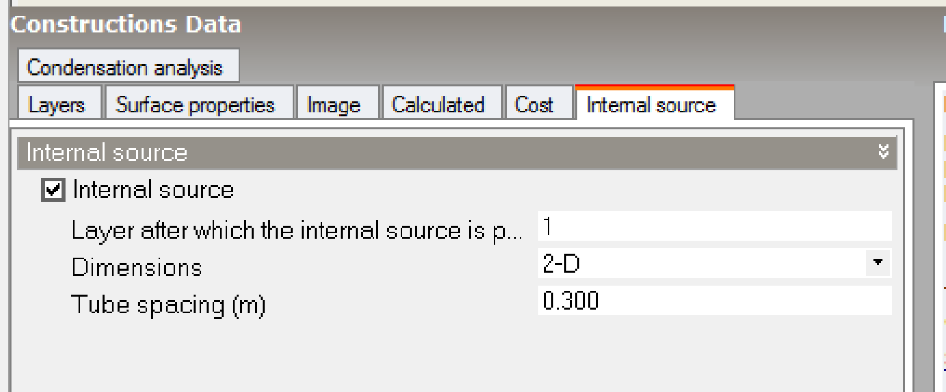




- Insert the cooling pipes (internal source) above the aluminum panel

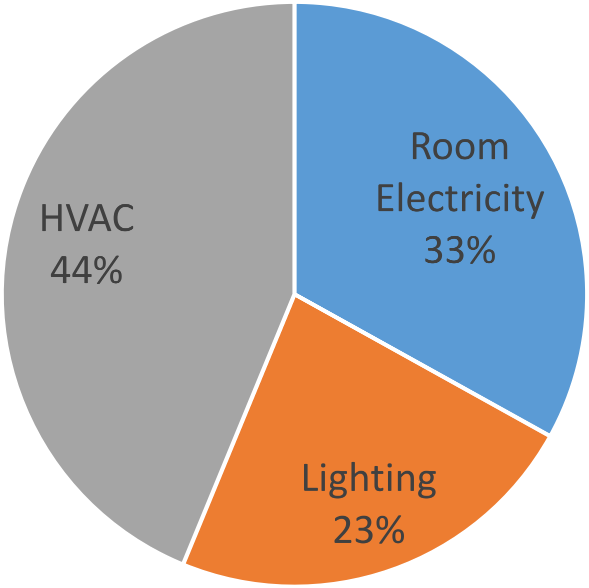
Design Builder – Internal floor panel construction





Panel cooling - Simulation results

No	End use	Energy Consumption (kWh/year)
1	Lighting	46500
2	Equipment	32550
3	HVAC	58880
4	Total	137930
5	EPI (total)	77
6	EPI (HVAC)	33



No	Chiller	Load share
1	DOAS	37%
2	Radiant	63%

THANK YOU