Autodesk CFD Simulation for Data Center

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AUTODESK. UNIVERSITY

About the speaker

Dr. Munirajulu. M

23+ years industry experience in CFD analysis

Speaker at AU 2017, 2018 Las Vegas & AU2019 India

Using Autodesk CFD Simulation for MEP design

Focus areas: Data Center Cooling, Basement Car Park Ventilation, DG room ventilation, Smoke simulation in buildings, Air-Conditioning and Thermal Comfort Analysis

Role of Autodesk CFD Simulation

- 3-D analysis
- Virtual design
- Performance issues
- What-if scenarios
- Design effectiveness

Key Objectives

Key Learning Objectives

- Characterize Data Center and Backup Power components
- Strategies for modeling air flow and heat transfer
- Set up simulation and visualize results
- Review results and evaluate design

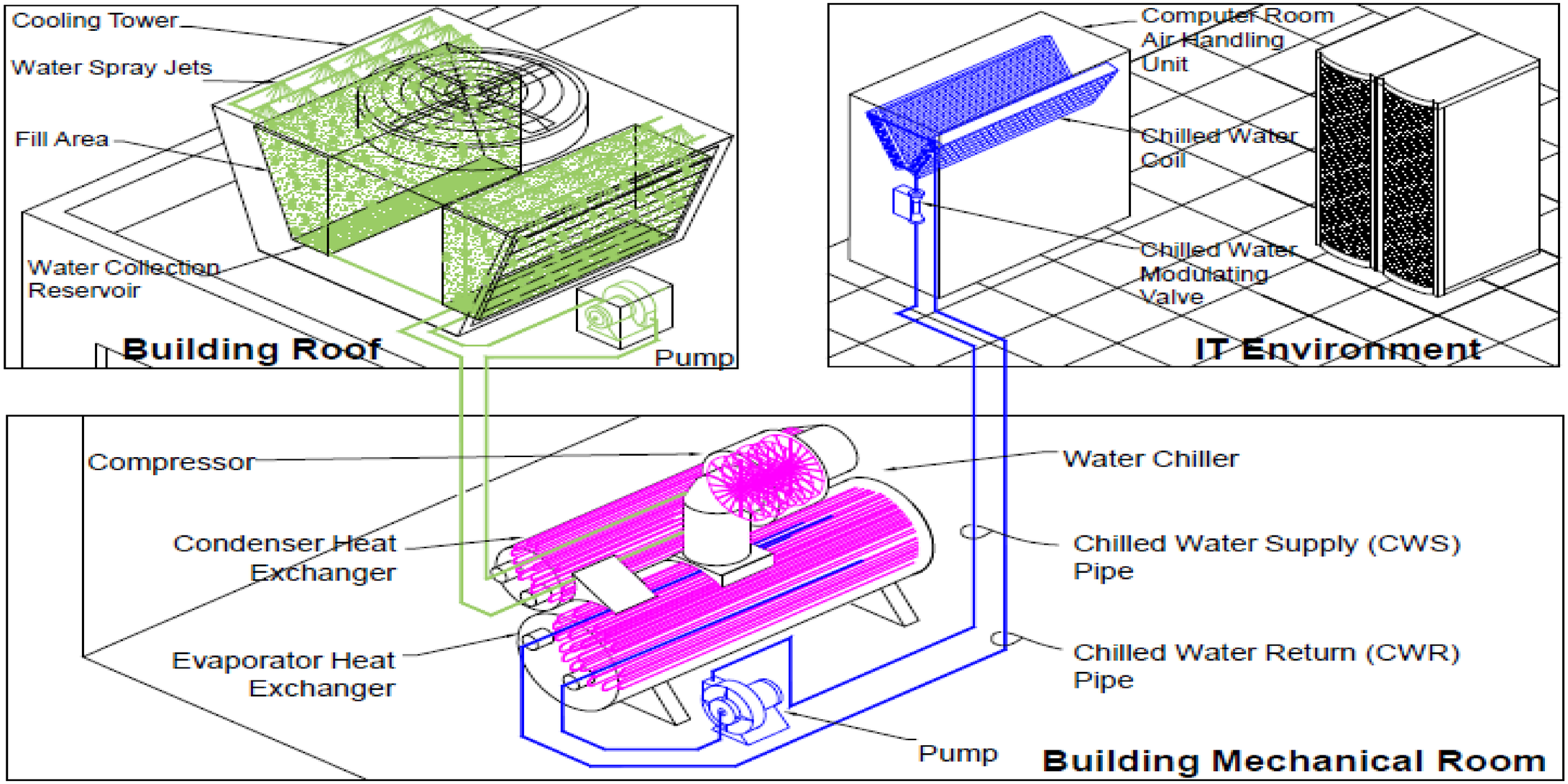
Data Center

CRITICAL ASSET
Big Data, Internet and Cloud based technologies

BUSINESS CONTINUITY
Up and running 24X7X365

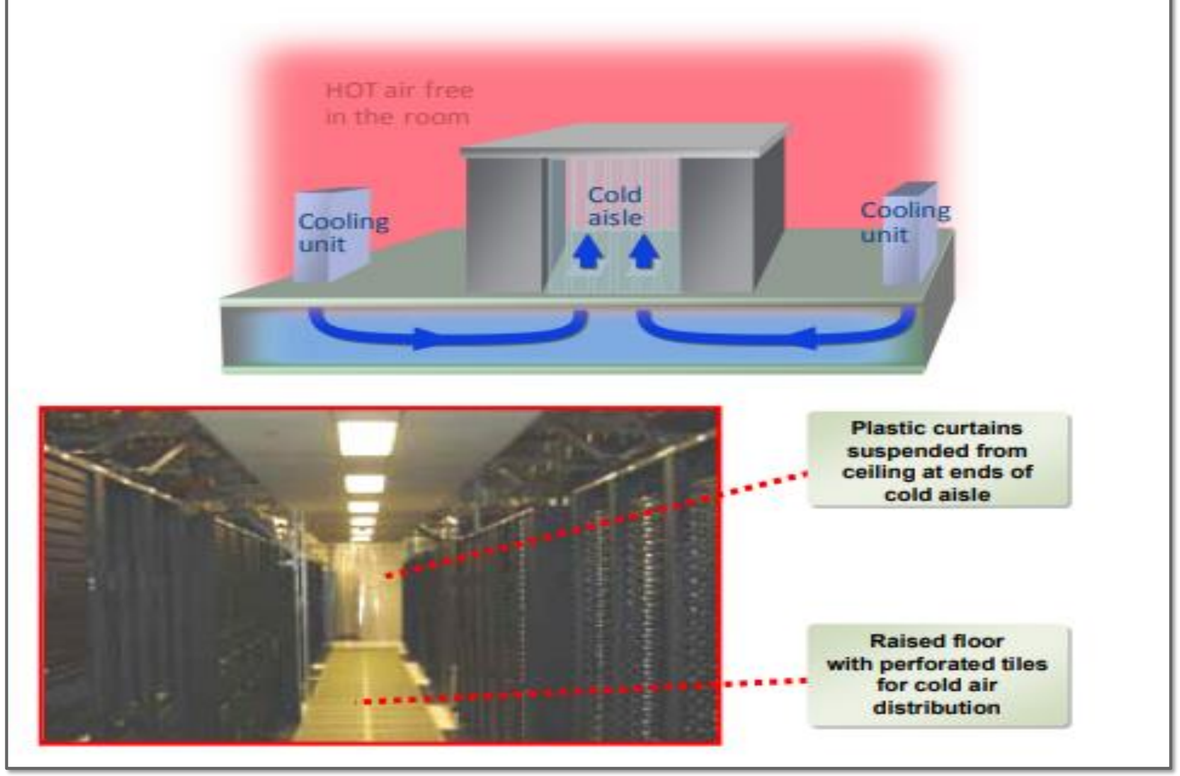
A Tier 4 data center is built to be completely fault tolerant and has redundancy for every component. It has an expected uptime of 99.995% (26.3 minutes of downtime annually). 2N redundant power and cooling

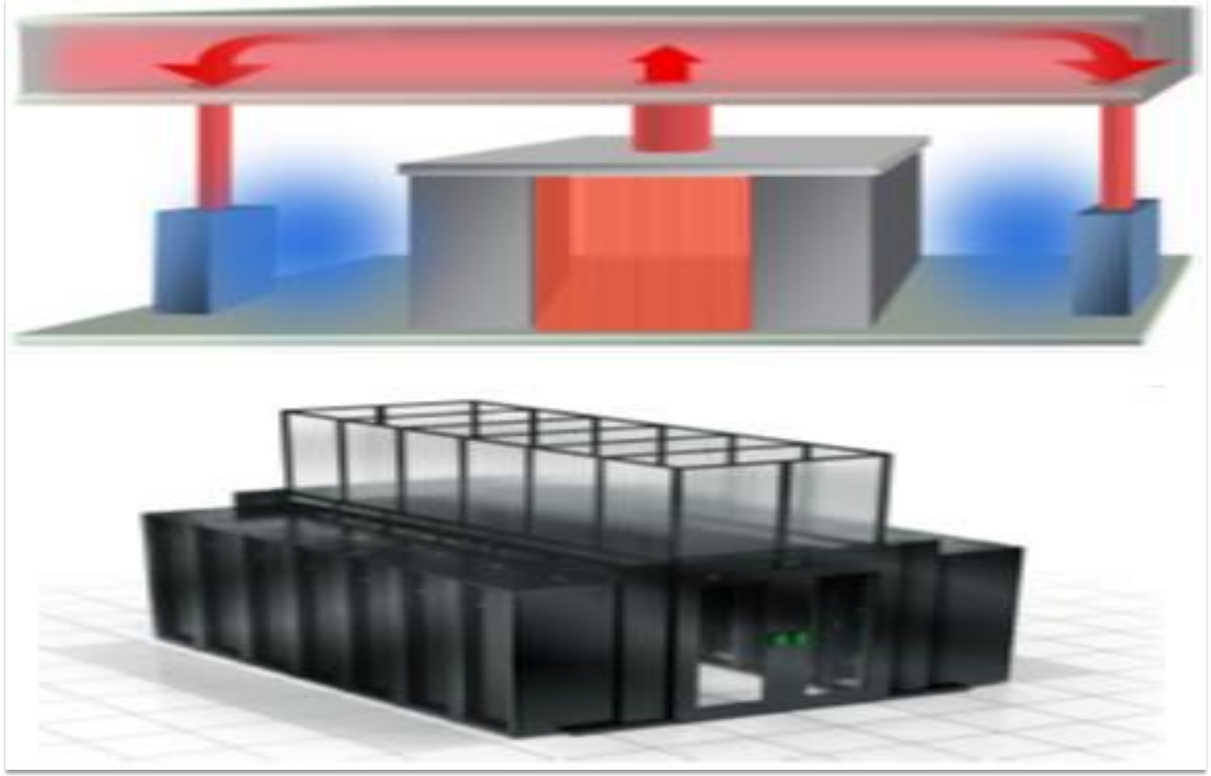
IMPORTANT FACTORS
Cooling and Backup Power infrastructure



Data Center Cooling System

Source: **The Different Technologies for Cooling Data Centers Revision 2 by Tony Evans - Schneider Electric**





CAC

Cold Aisle Containment (CAC)-

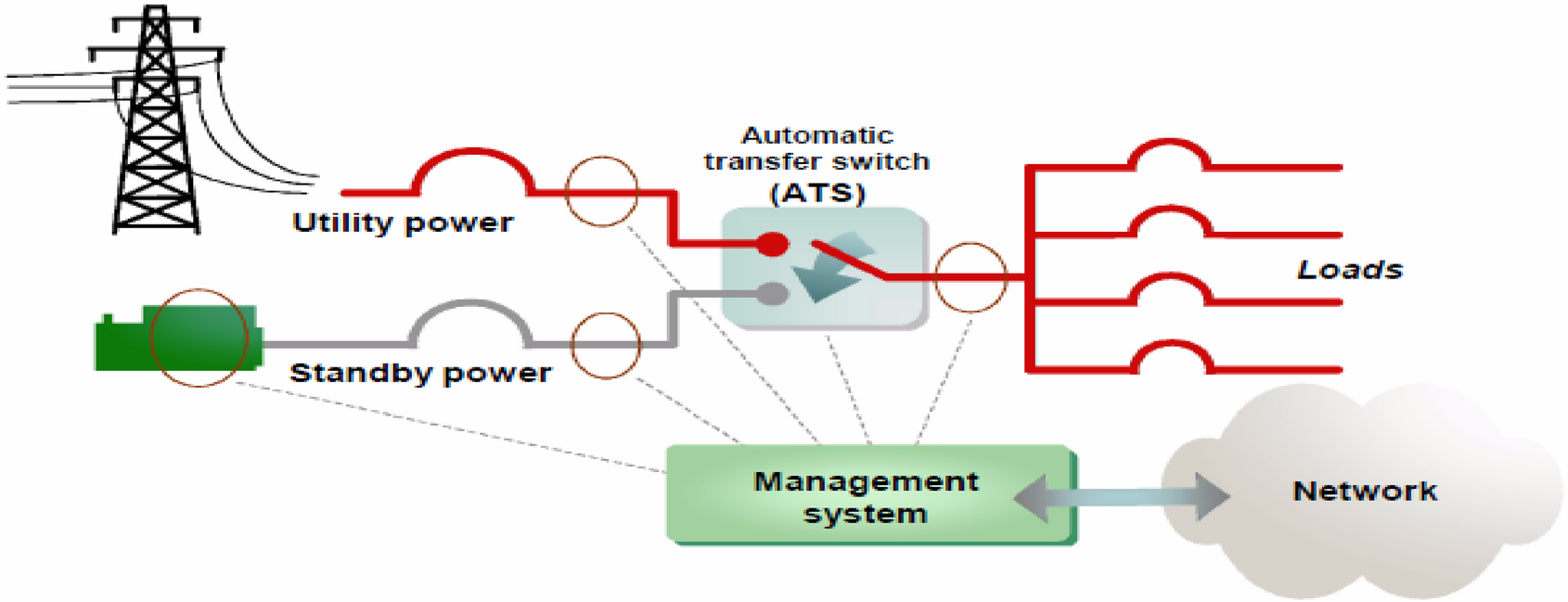
used for raised floor design

HAC

Hot Aisle Containment (HAC)-

used for hard floor design

Source: **Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency Revision 5 by John Niemann, Kevin Brown, and Victor Avelar- Schneider Electric**



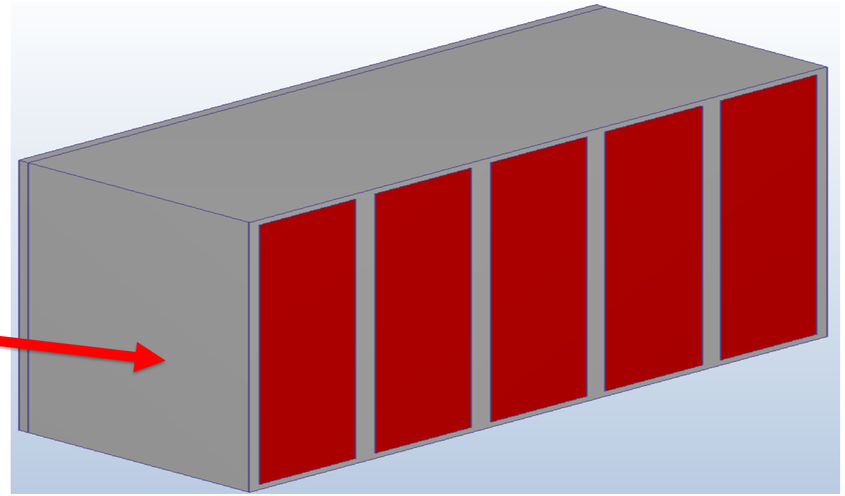
Backup Power

Provides power when there is interruption of main/utility power

Source: **Fundamental Principles of Generators for Information Technology Revision 1 by Robert Wolfgang - Schneider Electric**

Component Characterization

Data Center Components



Server Racks- Physical Model

Autodesk CFD Model

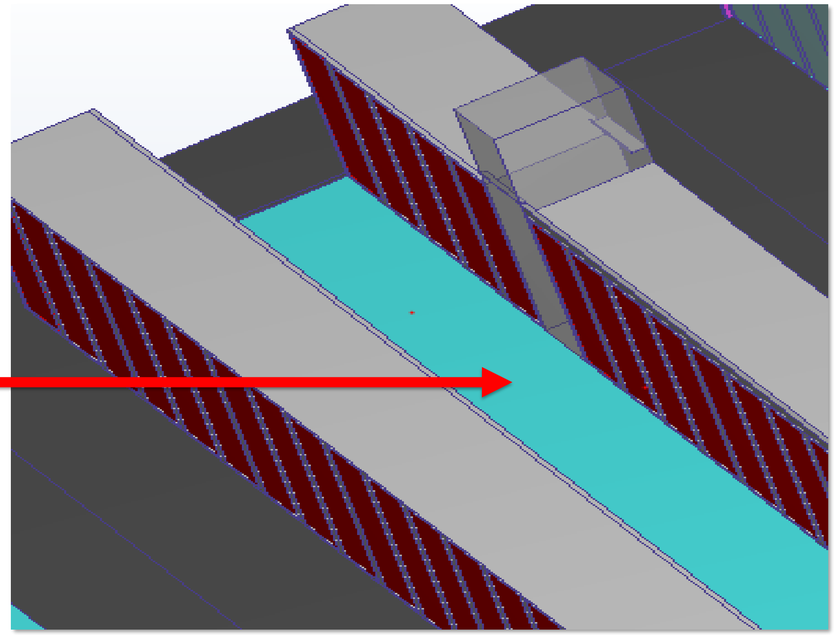
Data Center Components

PAHU - Physical Model

Autodesk CFD Model

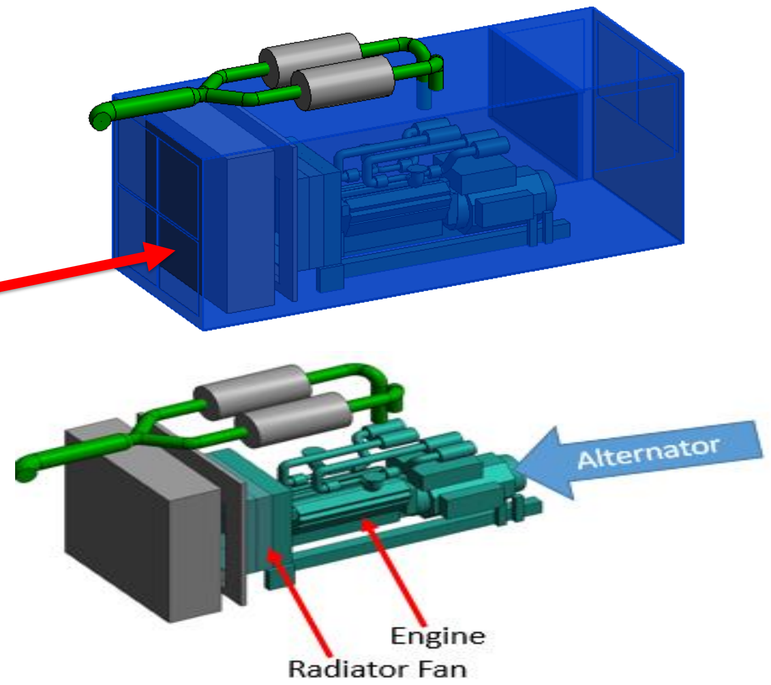
Data Center Components

Supply Floor Grill- Physical Model



Autodesk CFD Model

Backup Power Components



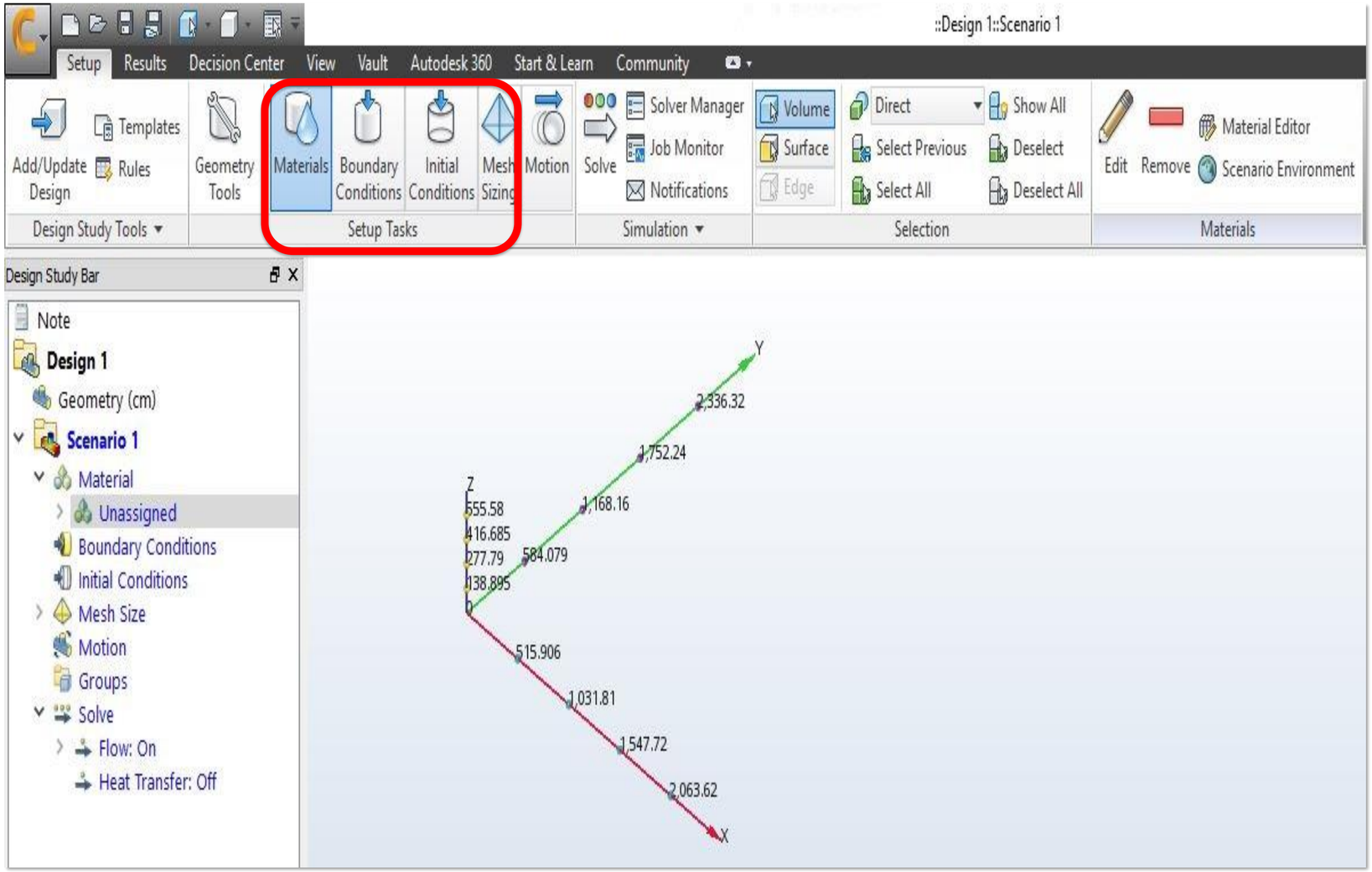
DG set- Physical Model

Autodesk CFD Model

Strategies for modeling airflow and heat transfer

Modeling strategies
Autodesk CFD Setup Workflow

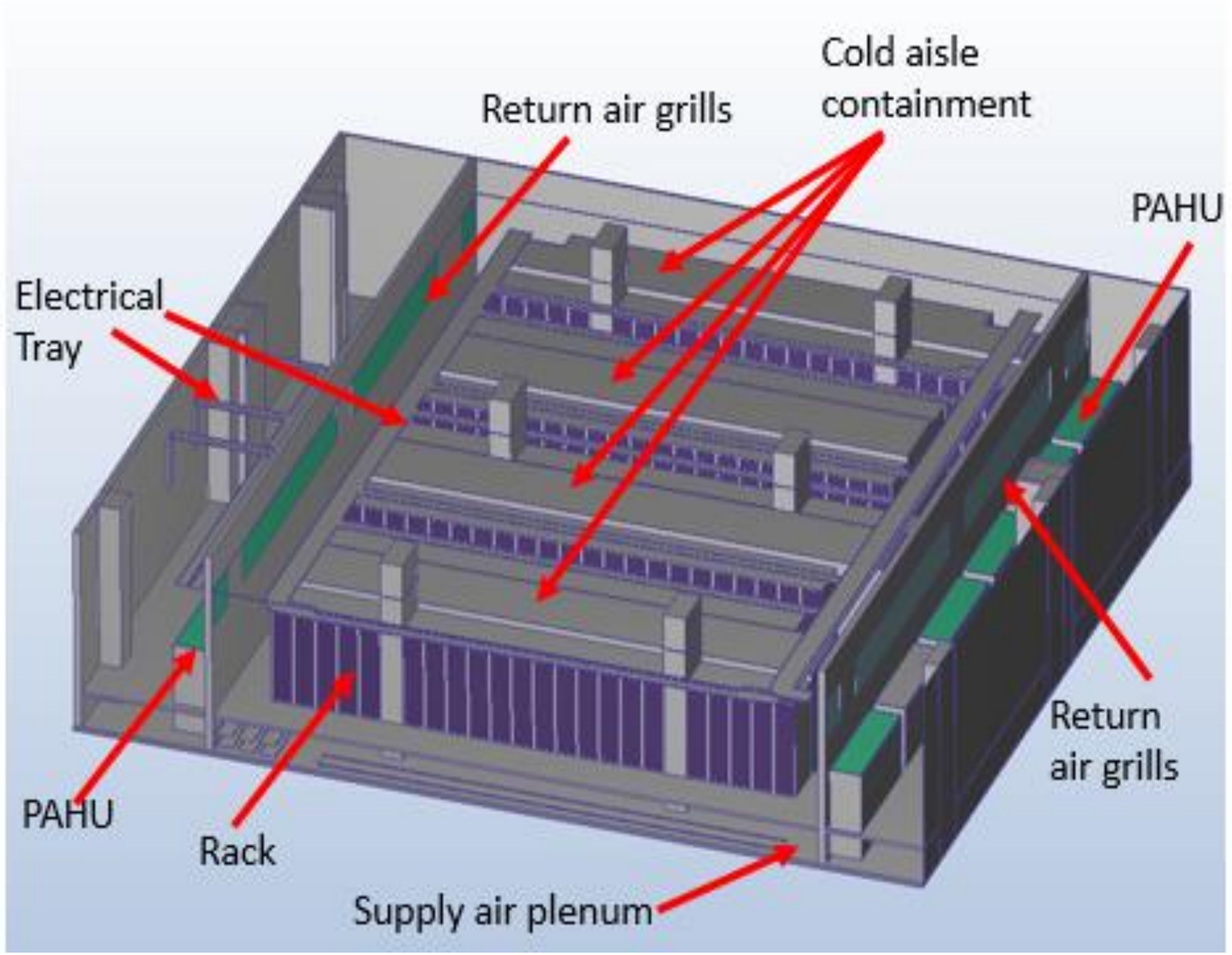
- CAD model
- Material assignment
- Boundary Conditions
- Meshing



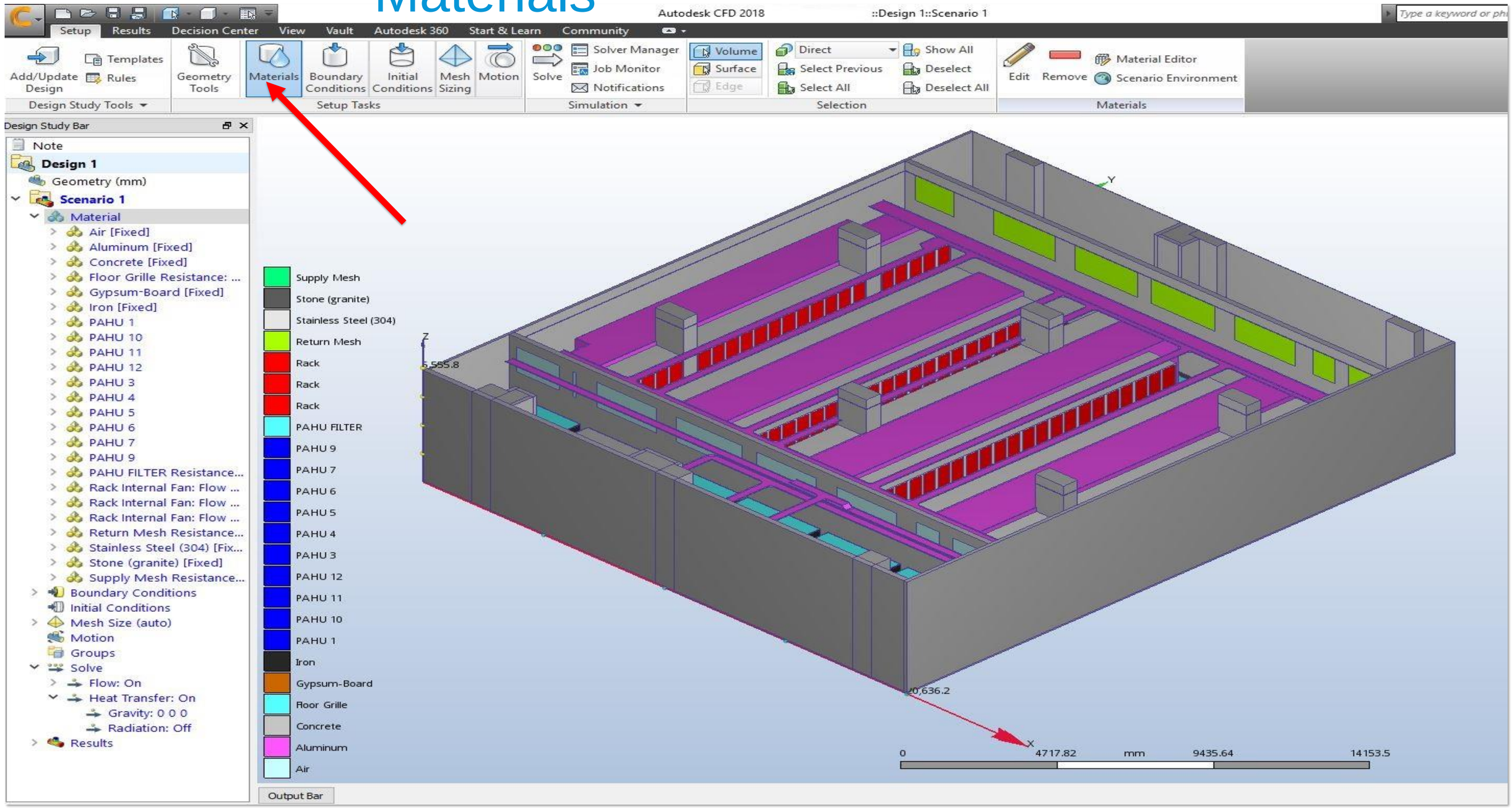
Data Center- CAD model

CAD model is created from Revit

- Includes Server racks, PAHUs, supply and return grills
- Columns and other obstructions (e.g. cold aisle containment)

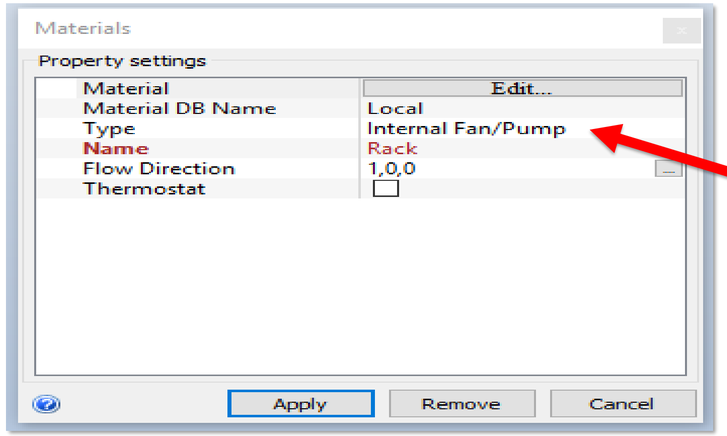


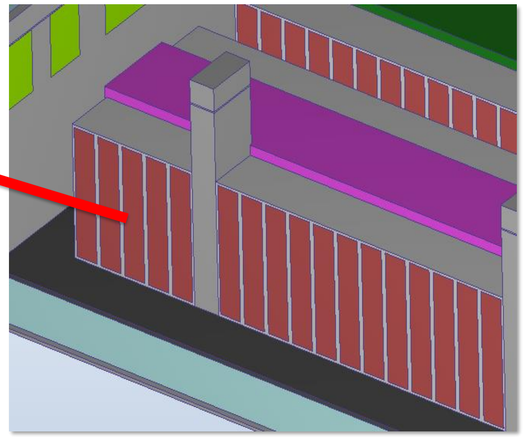
Materials

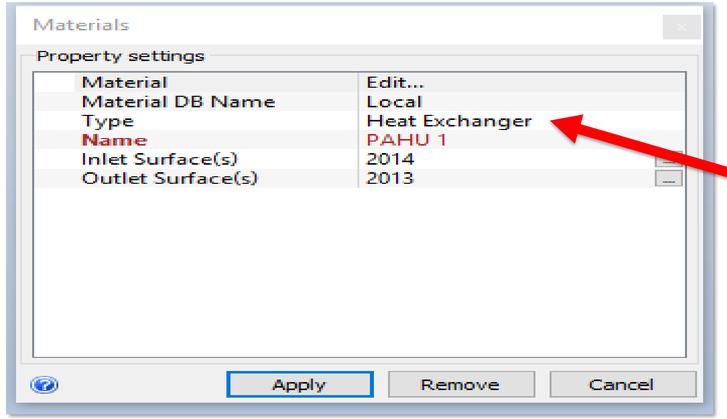

Autodesk CFD 2018
::Design 1::Scenario 1
Setup
Results
Decision Center
View
Vault
Autodesk 360
Start & Learn
Community
Add/Update Design
Templates
Rules
Geometry Tools
Materials
Boundary Conditions
Initial Conditions
Mesh Sizing
Motion
Solve
Solver Manager
Job Monitor
Notifications
Volume
Surface
Edge
Direct
Select Previous
Select All
Show All
Deselect
Deselect All
Edit
Remove
Material Editor
Scenario Environment
Design Study Tools
Setup Tasks
Simulation
Selection
Materials
Design Study Bar
Note
Design 1
Geometry (mm)
Scenario 1
Material
Air [Fixed]
Aluminum [Fixed]
Concrete [Fixed]
Floor Grille Resistance: ...
Gypsum-Board [Fixed]
Iron [Fixed]
PAHU 1
PAHU 10
PAHU 11
PAHU 12
PAHU 3
PAHU 4
PAHU 5
PAHU 6
PAHU 7
PAHU 9
PAHU FILTER Resistance...
Rack Internal Fan: Flow ...
Rack Internal Fan: Flow ...
Rack Internal Fan: Flow ...
Return Mesh Resistance...
Stainless Steel (304) [Fix...
Stone (granite) [Fixed]
Supply Mesh Resistance...
Boundary Conditions
Initial Conditions
Mesh Size (auto)
Motion
Groups
Solve
Flow: On
Heat Transfer: On
Gravity: 0 0 0
Radiation: Off
Results
Supply Mesh
Stone (granite)
Stainless Steel (304)
Return Mesh
Rack
Rack
Rack
PAHU FILTER
PAHU 9
PAHU 7
PAHU 6
PAHU 5
PAHU 4
PAHU 3
PAHU 12
PAHU 11
PAHU 10
PAHU 1
Iron
Gypsum-Board
Floor Grille
Concrete
Aluminum
Air
Z
Y
X
0
4717.82
mm
9435.64
14153.5
Output Bar

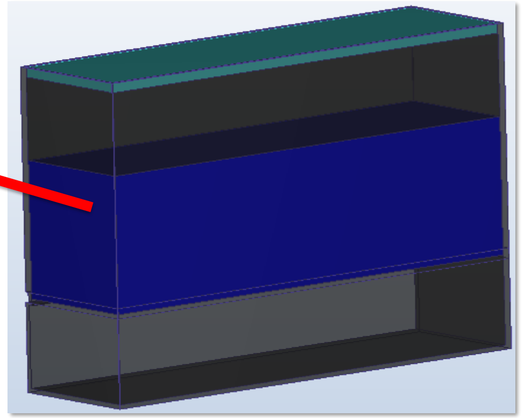
Data Center- Materials

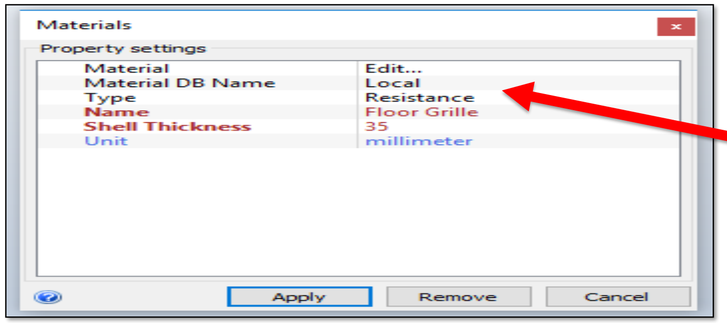
- Server rack is assigned “ Internal fan/Pump” material with flow rate (CFM)
- PAHU is assigned “Heat Exchanger” material with constant flow rate with “Set Point Temperature” for supply.
- PAHU filter is assigned “Resistance” material with free area ratio of 0.4 in “Through-Flow” direction. In other directions “0” free area ratio is assigned to account for flow only in the specified direction.
- Supply floor grills are assigned as “Resistance” material with free area ration of 0.46.

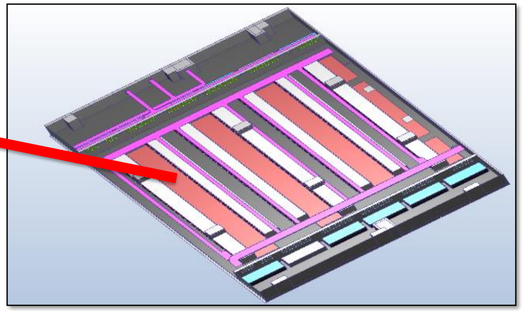




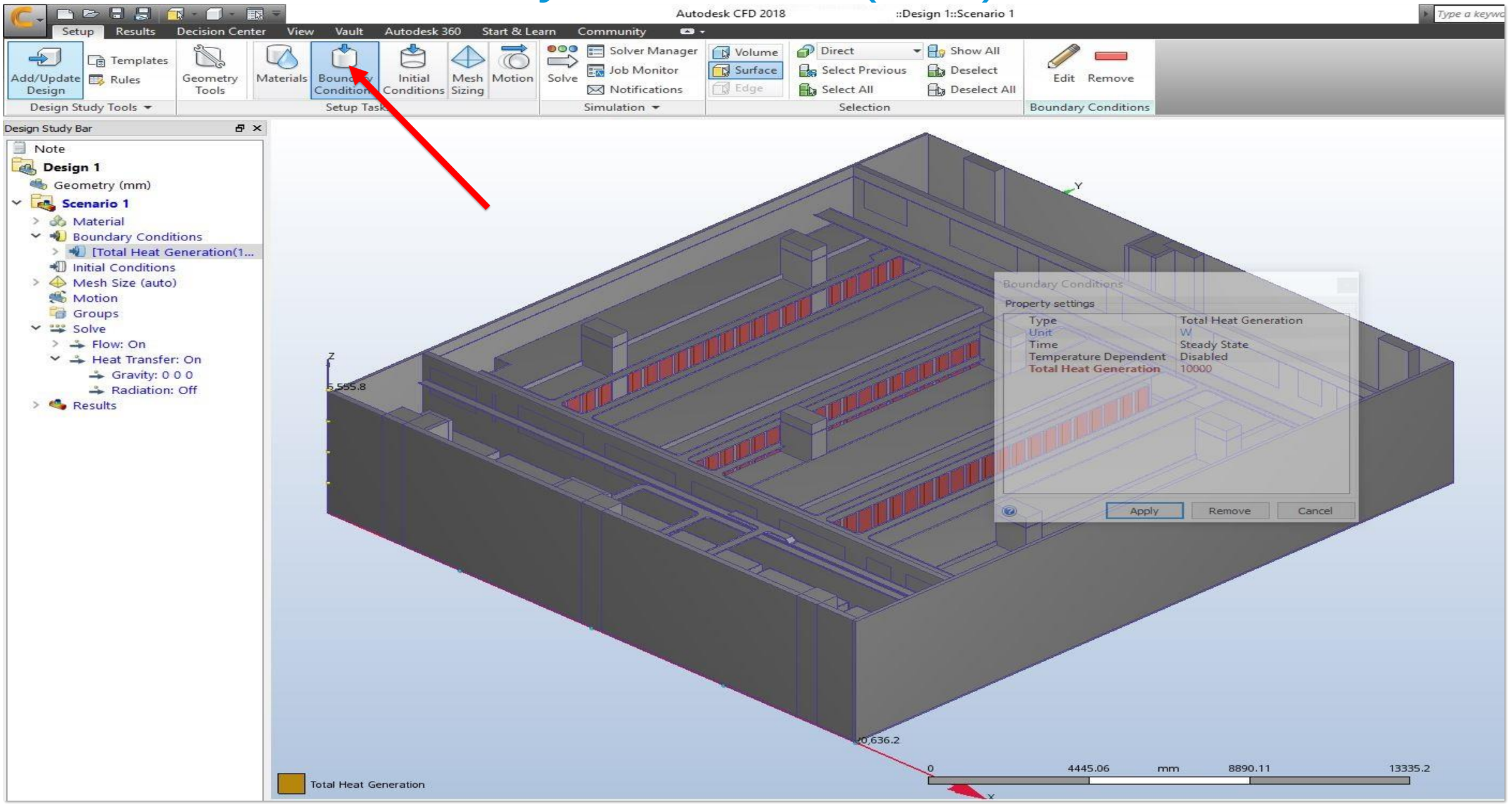






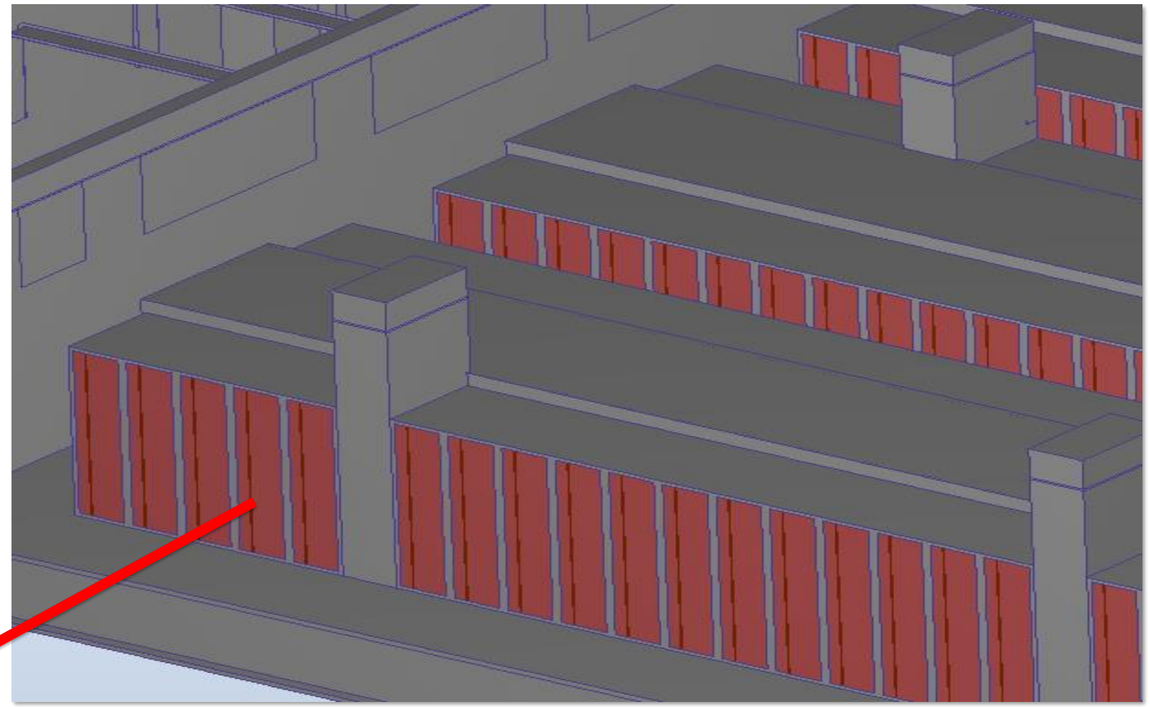


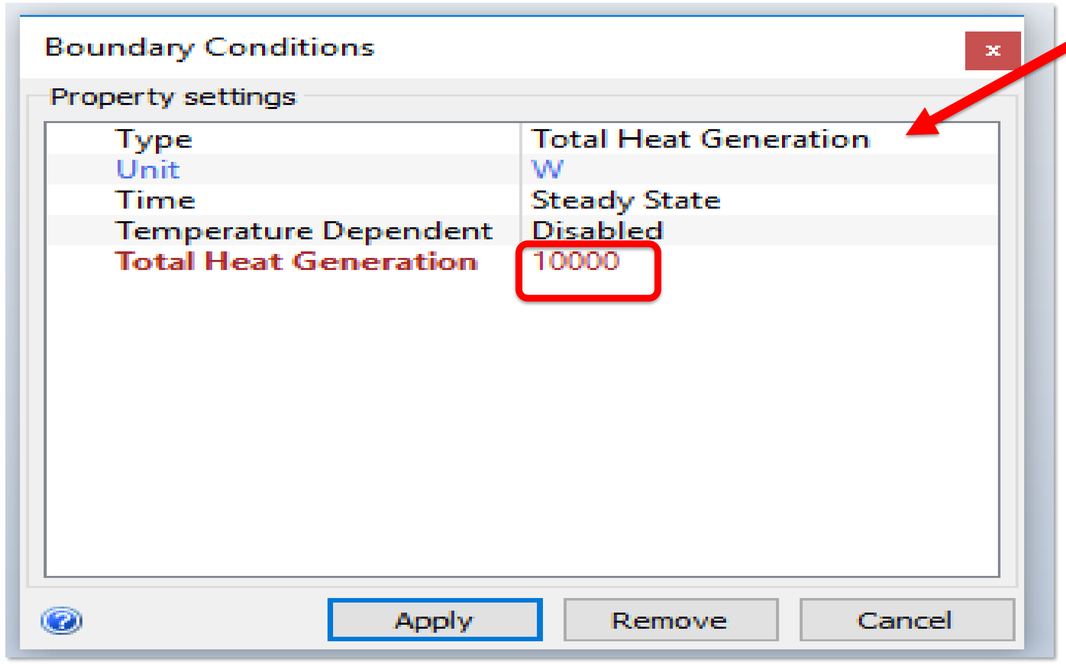
Boundary Conditions (BCs)



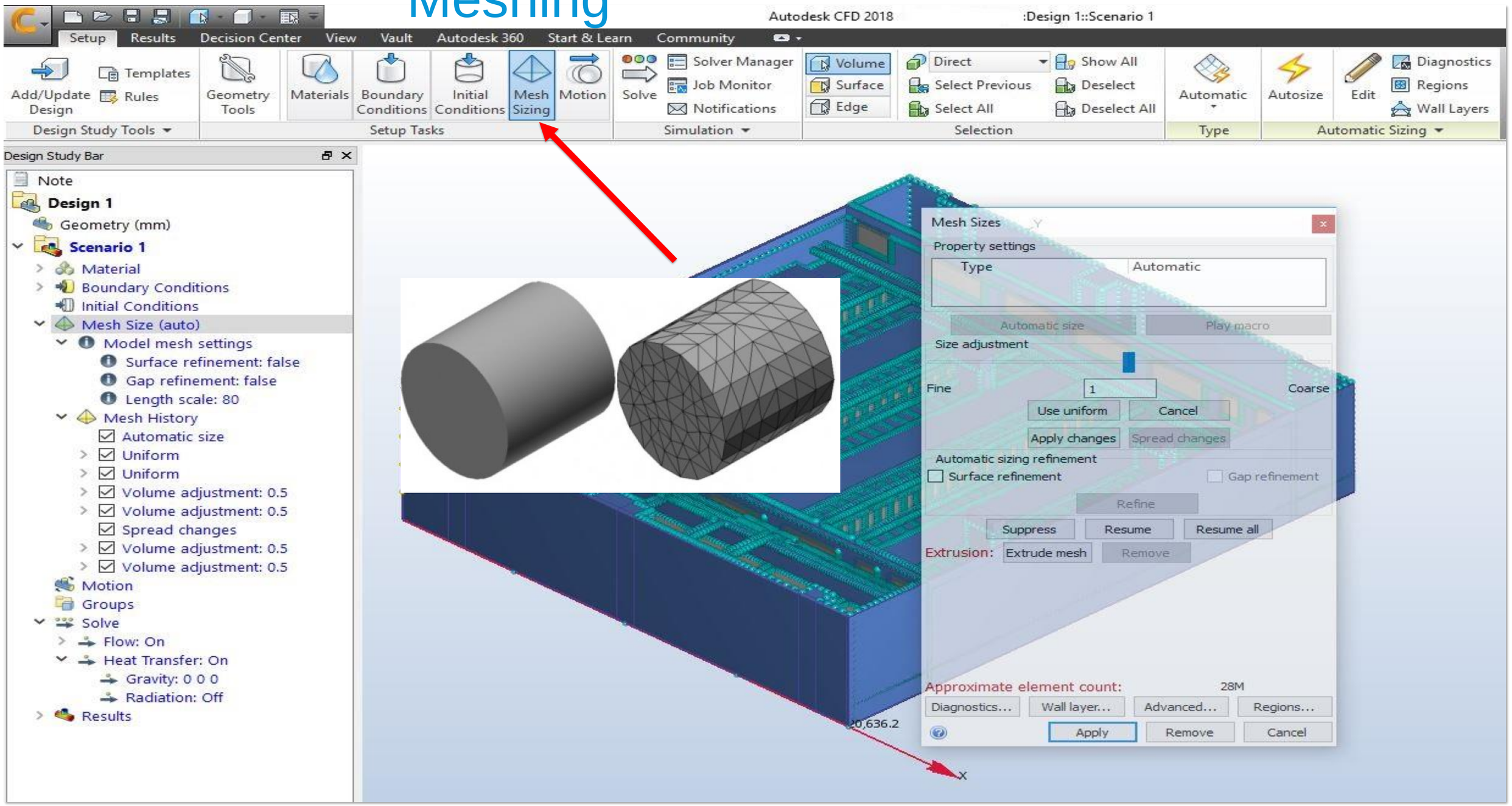
Data Center- BCs

10 kW heat generation BC applied for racks





Meshing


Autodesk CFD 2018
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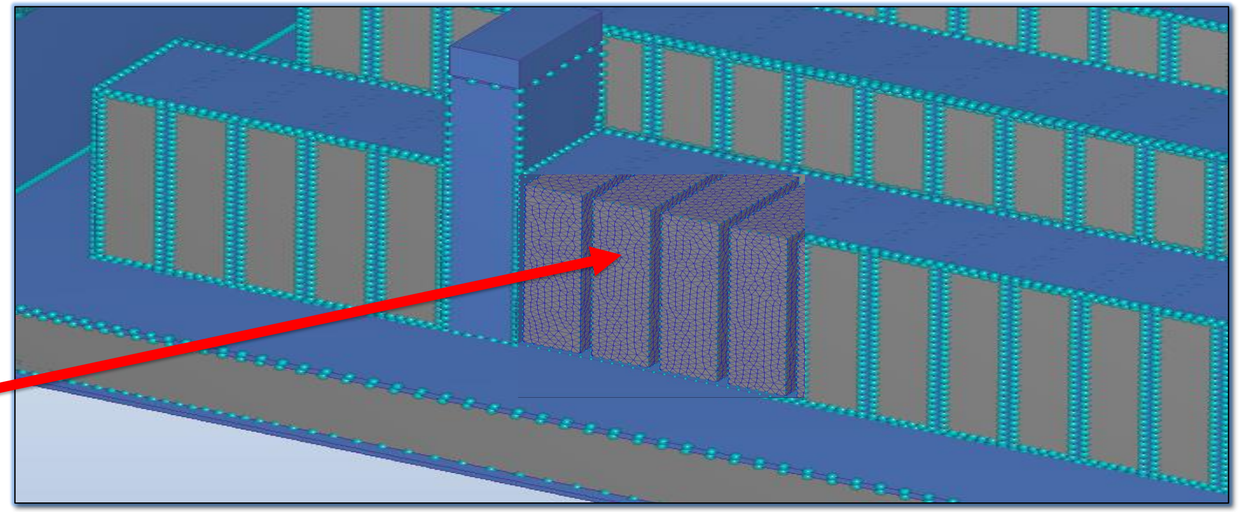
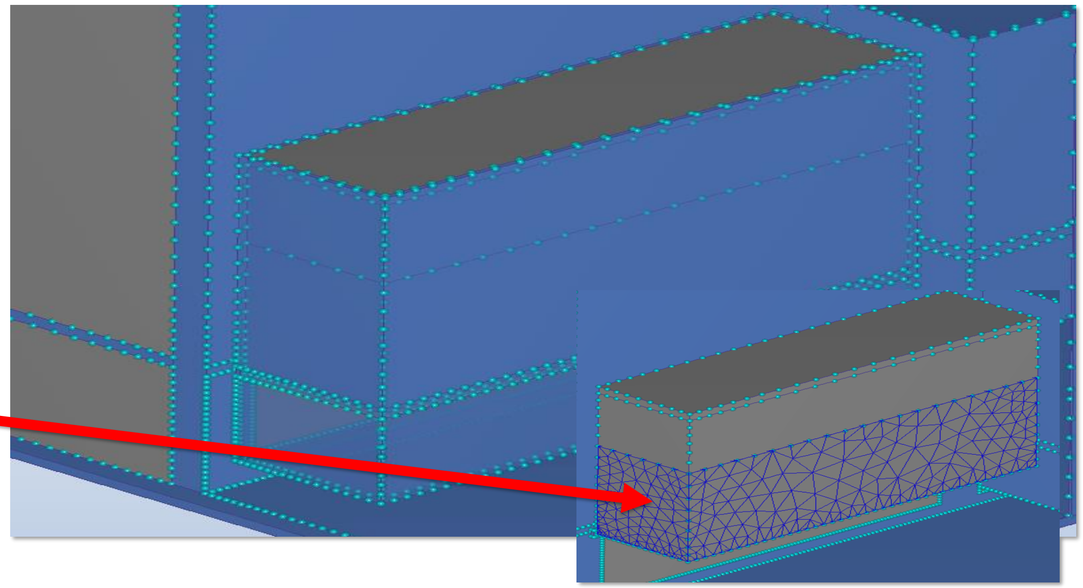
Initial Conditions
Mesh Sizing
Motion
Solve
Solver Manager
Job Monitor
Notifications
Volume
Surface
Edge
Direct
Select Previous
Select All
Show All
Deselect
Deselect All
Automatic
Autosize
Edit
Diagnostics
Regions
Wall Layers
Design Study Tools
Setup Tasks
Simulation
Selection
Type
Automatic Sizing
Design Study Bar
Note
Design 1
Geometry (mm)
Scenario 1
Material
Boundary Conditions
Initial Conditions
Mesh Size (auto)
Model mesh settings
Surface refinement: false
Gap refinement: false
Length scale: 80
Mesh History
Automatic size
Uniform
Uniform
Volume adjustment: 0.5
Volume adjustment: 0.5
Spread changes
Volume adjustment: 0.5
Volume adjustment: 0.5
Motion
Groups
Solve
Flow: On
Heat Transfer: On
Gravity: 0 0 0
Radiation: Off
Results
Mesh Sizes
Property settings
Type
Automatic
Automatic size
Play macro
Size adjustment
Fine
1
Coarse
Use uniform
Cancel
Apply changes
Spread changes
Automatic sizing refinement
Surface refinement
Gap refinement
Refine
Suppress
Resume
Resume all
Extrusion:
Extrude mesh
Remove
Approximate element count:
28M
Diagnostics...
Wall layer...
Advanced...
Regions...
Apply
Remove
Cancel
20,636.2
X

Data Center- Meshing

- Uniform fine mesh (at least 4-5 elements) on server racks to capture heat transfer and air flow over these parts



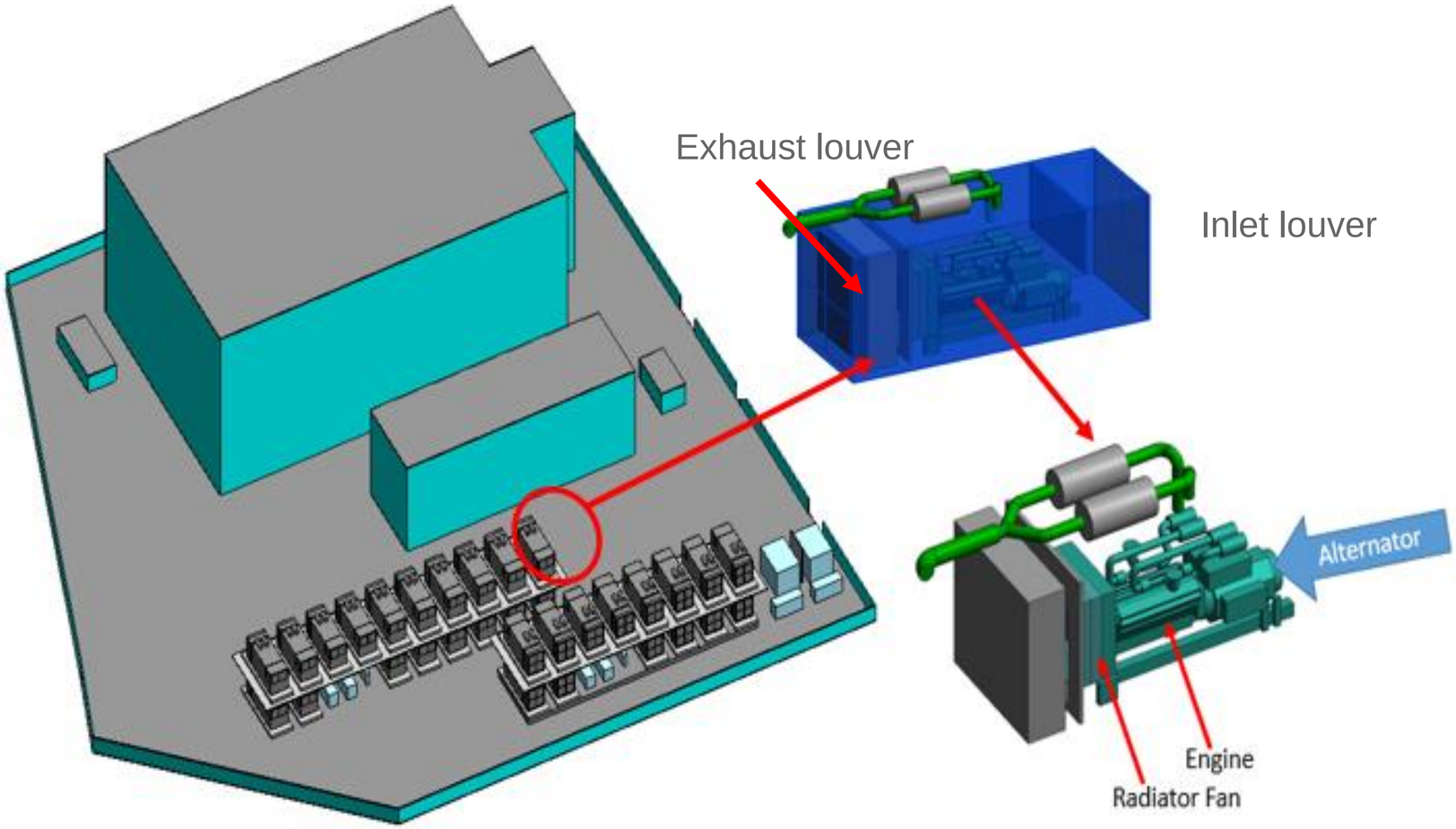
- Uniform mesh (at least 4-5 elements) to capture effective heat absorption in PAHU(Heat Exchanger)



Backup Power Generator- CAD model

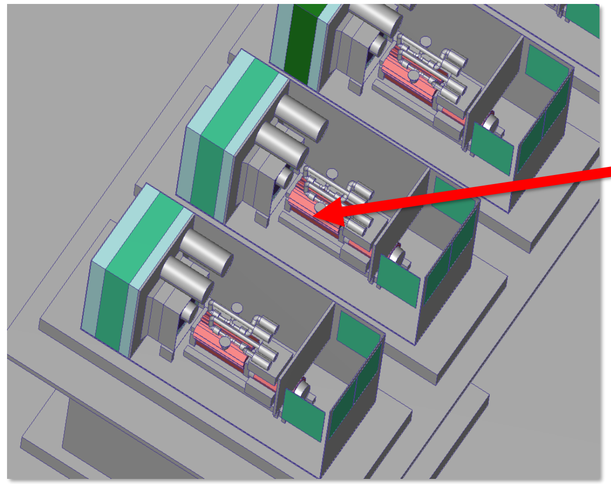
CAD model is created from Revit

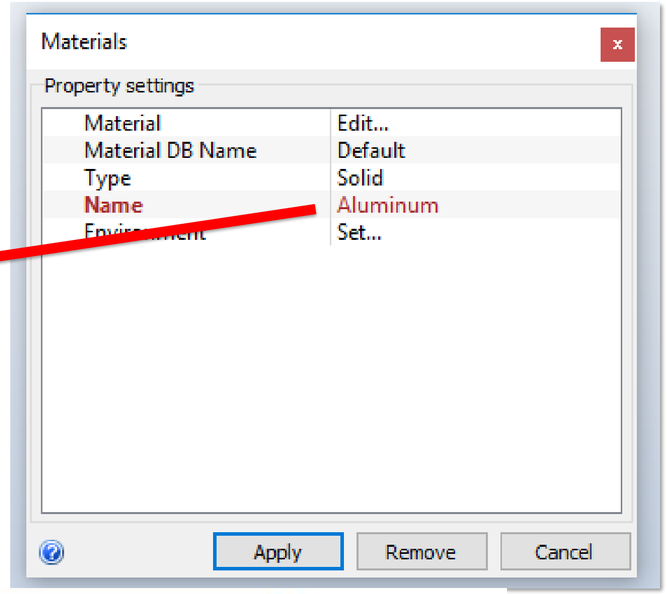
- DG set includes simplified engine and alternator parts as volume heat generating elements.
- Other significant parts includes radiator, radiator fan and inlet / exhaust louvers in the DG enclosure

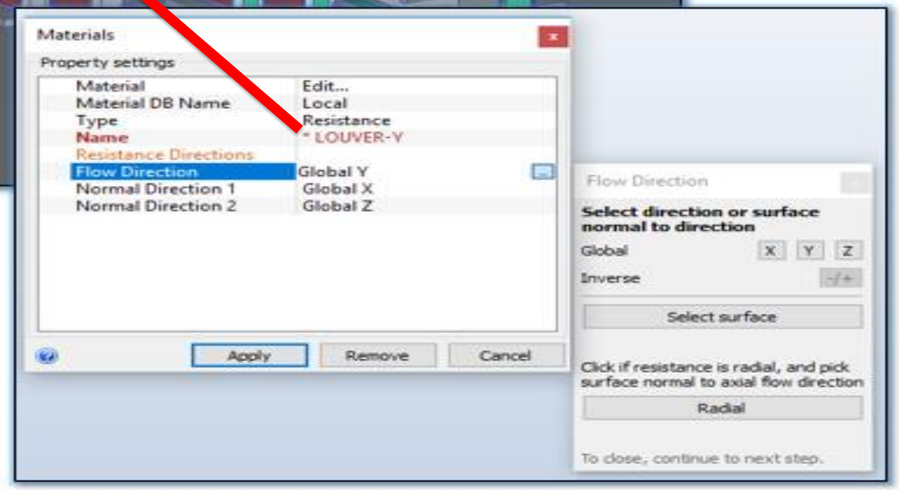


Backup Power Generator- Materials

- Air domain - air with fixed properties
- Engine and alternator - Aluminum material
- Air inlet and outlet louvers - “Resistance” material with free area ratio of 0.5 in “Through-Flow” direction.
- Radiator coil - “Resistance” material with free area ratio of 0.65 in “Through-Flow” direction.



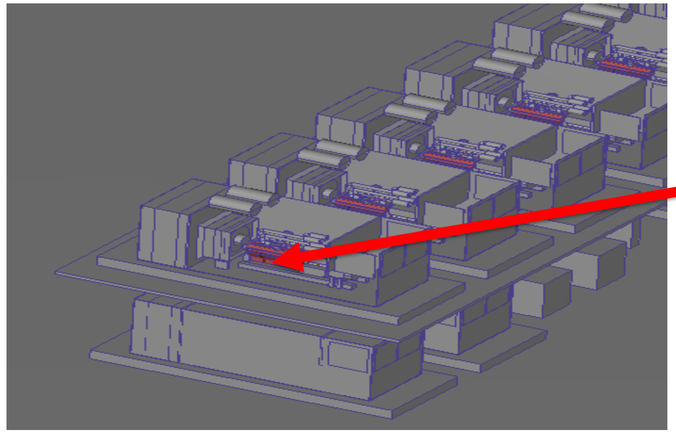


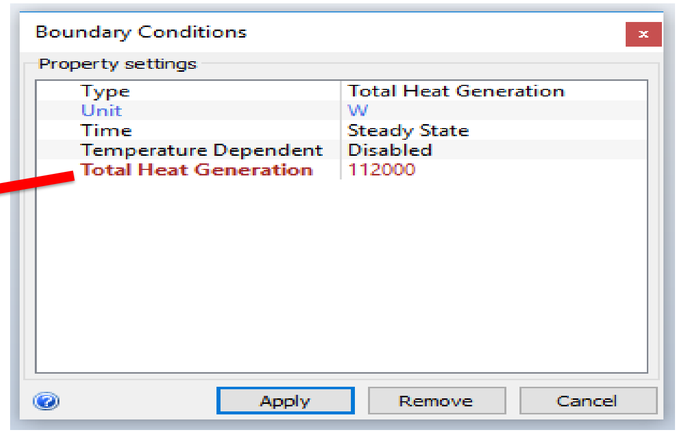


Backup Power Generator- BCs

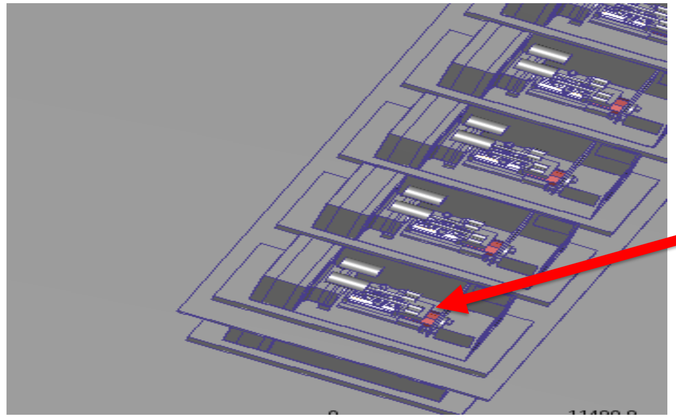
Total heat generation for engine, alternator and radiator coil

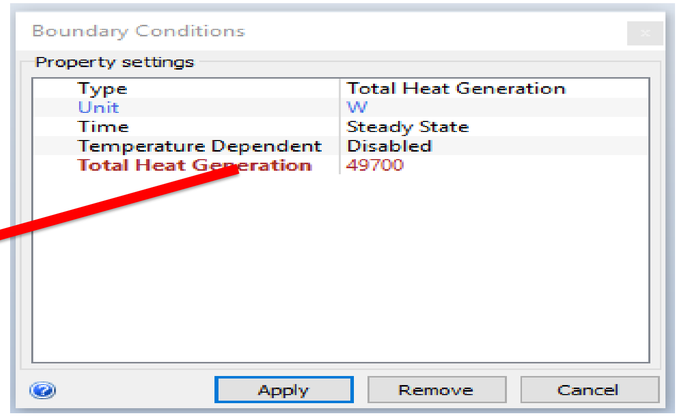
- 112 kW heat generation BC applied for Engine



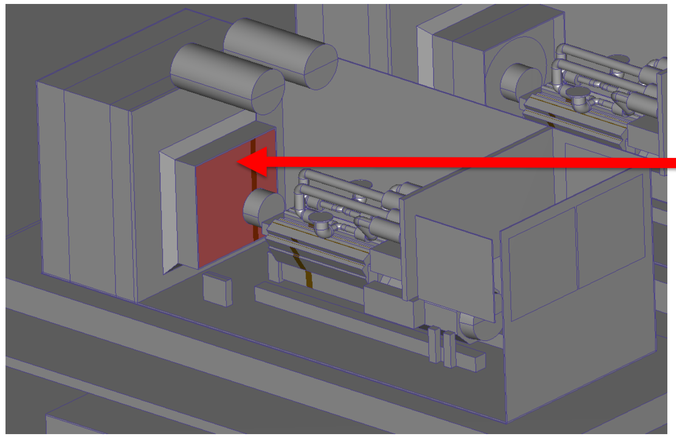


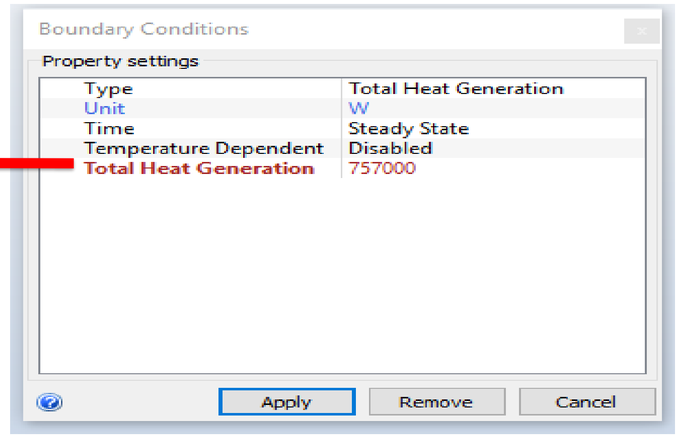
- 49.7 kW heat generation BC applied for Alternator





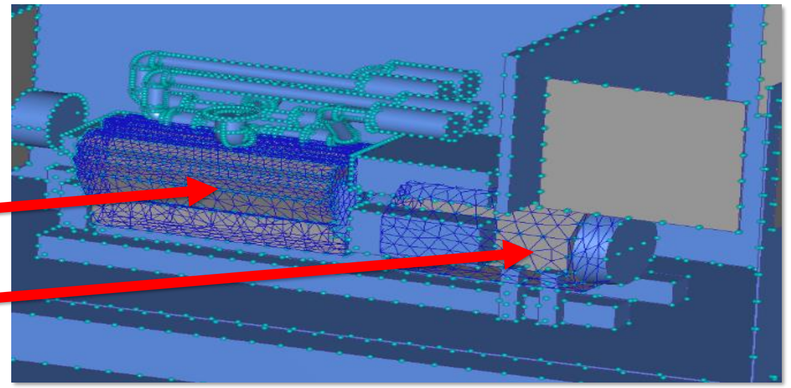
- 757 kW heat generation BC applied for Radiator



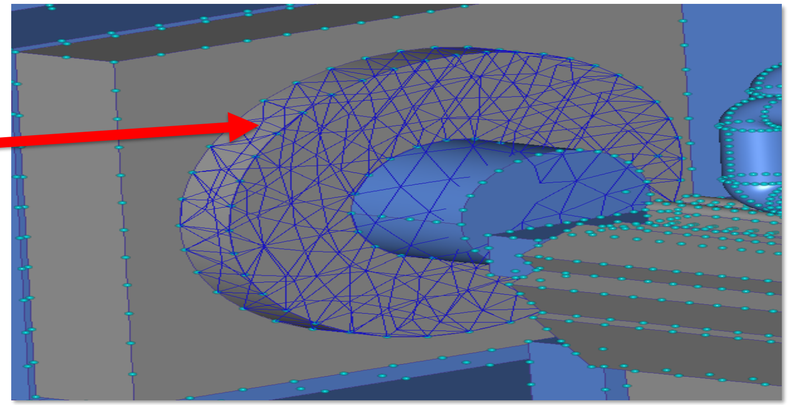


Backup Power Generator- Meshing

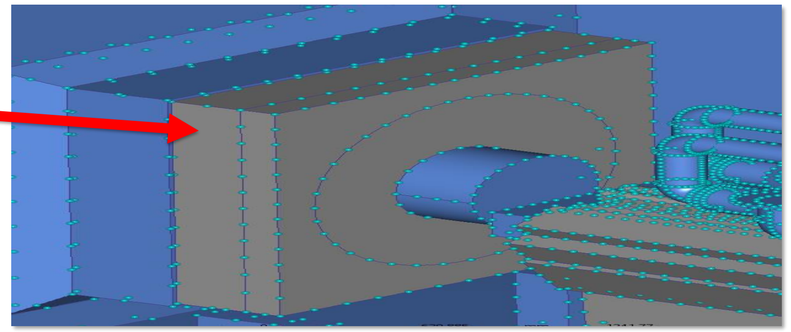
- Fine mesh applied on engine and alternator parts to capture heat outflow and air flow over these parts



- Uniform mesh to capture internal fan flow effects on radiator fan



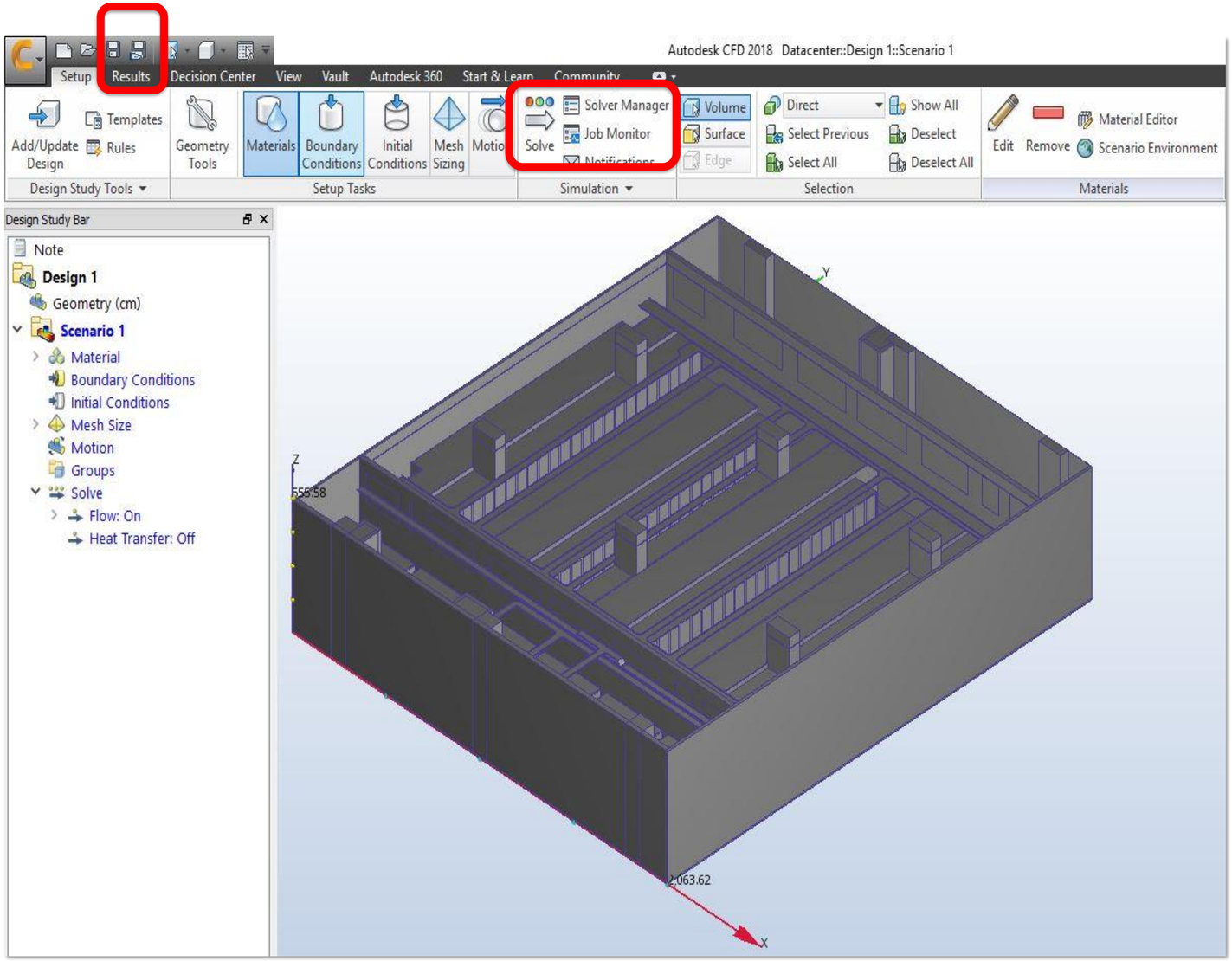
- Uniform mesh to capture flow through radiator coil.



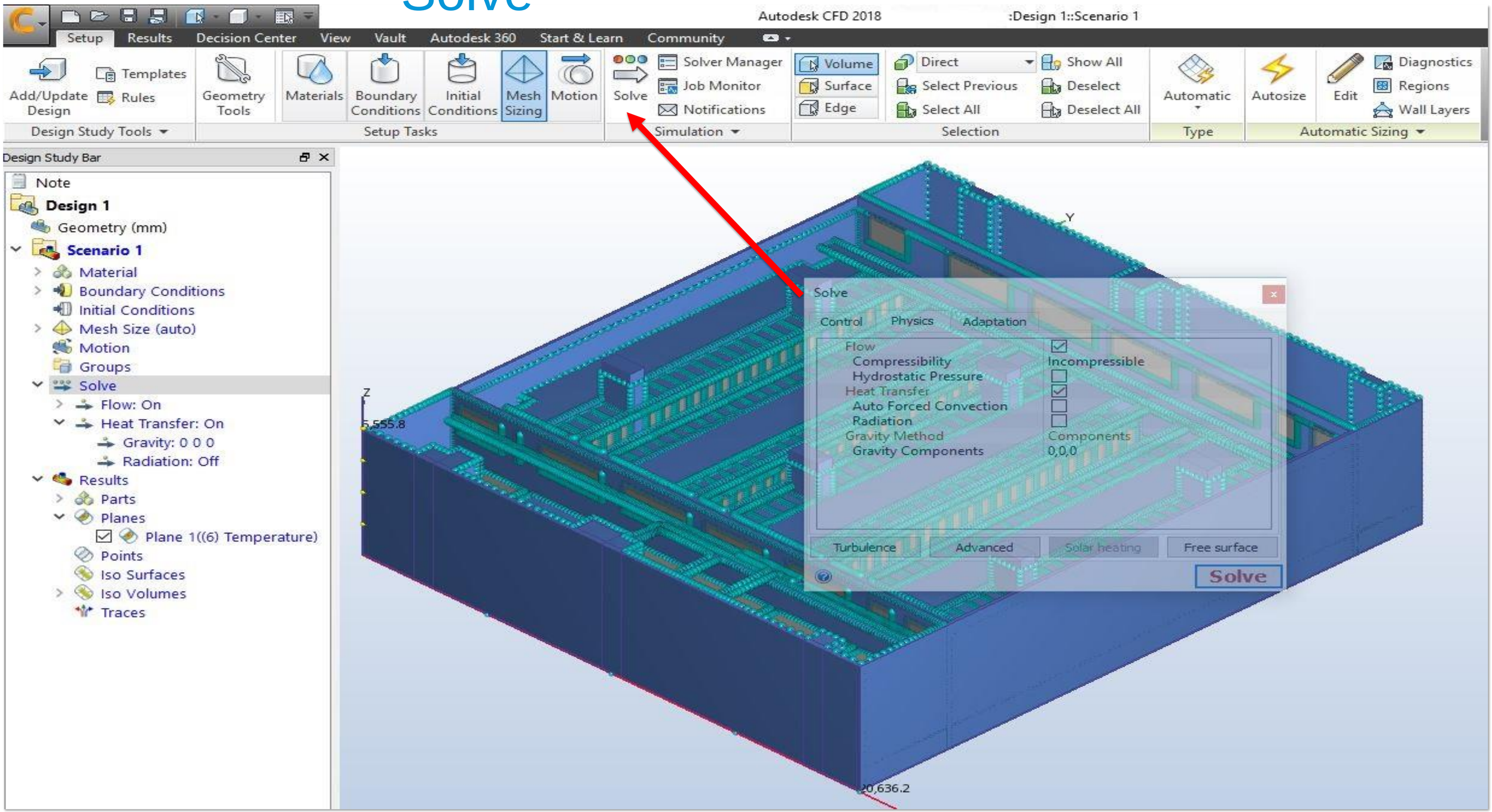
Set up simulation and visualize results

Simulation and results
Autodesk CFD Solve and Results Workflow

- Solver control
- Physics (Flow and Heat Transfer)
- Results – Global / Plane
- Results – Airflow Velocity and Temperature



Solve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Solver Manager
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Notifications
Volume
Surface
Edge
Direct
Select Previous
Select All
Show All
Deselect
Deselect All
Automatic
Autosize
Edit
Diagnostics
Regions
Wall Layers
Design Study Tools
Setup Tasks
Simulation
Selection
Type
Automatic Sizing
Design Study Bar
Note
Design 1
Geometry (mm)
Scenario 1
Material
Boundary Conditions
Initial Conditions
Mesh Size (auto)
Motion
Groups
Solve
Flow: On
Heat Transfer: On
Gravity: 0 0 0
Radiation: Off
Results
Parts
Planes
Plane 1((6) Temperature)
Points
Iso Surfaces
Iso Volumes
Traces
Solve
Control
Physics
Adaptation
Flow
Compressibility
Incompressible
Hydrostatic Pressure
Heat Transfer
Auto Forced Convection
Radiation
Gravity Method
Components
Gravity Components
0,0,0
Turbulence
Advanced
Solar heating
Free surface
Solve
Y
Z
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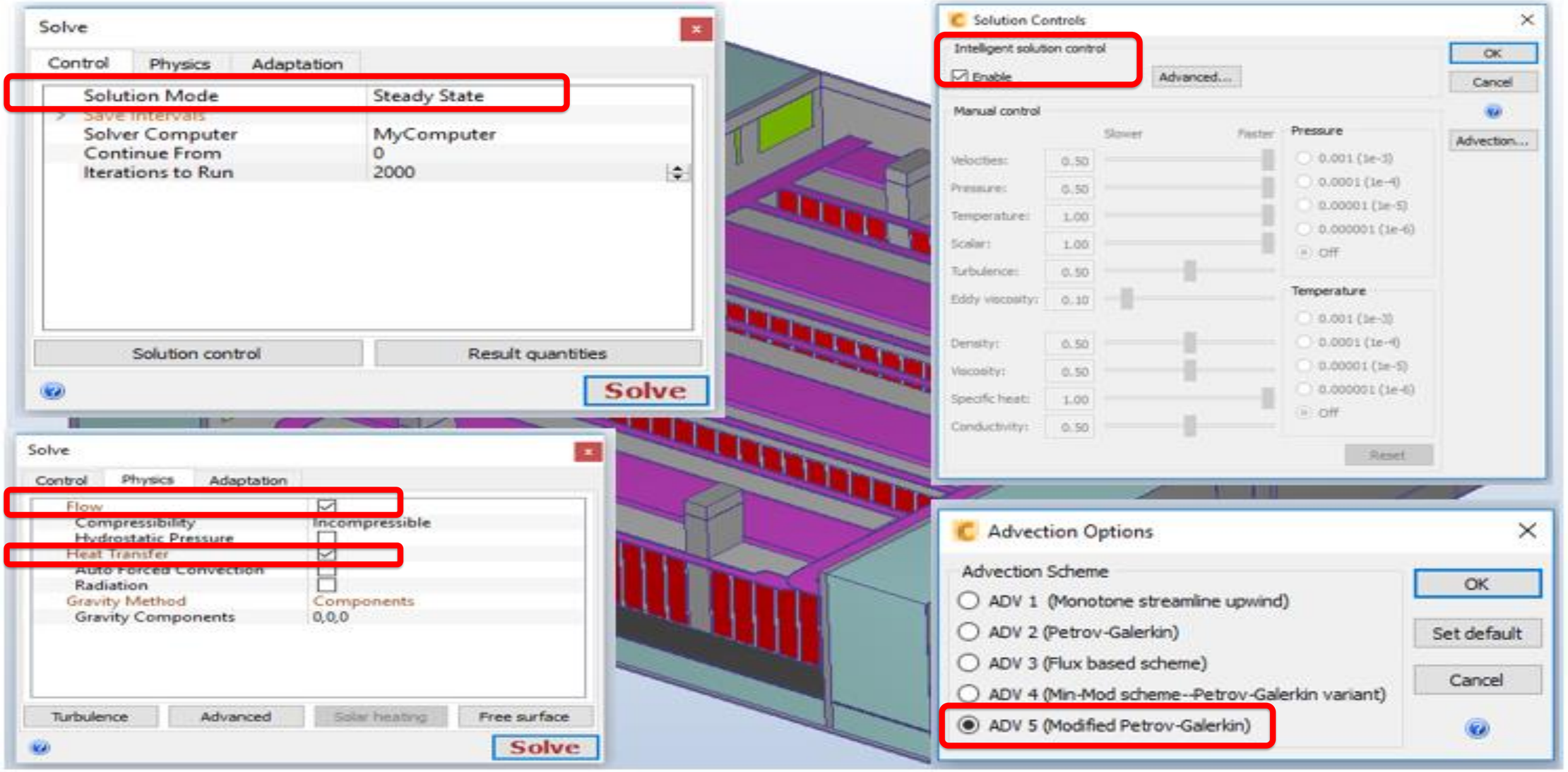
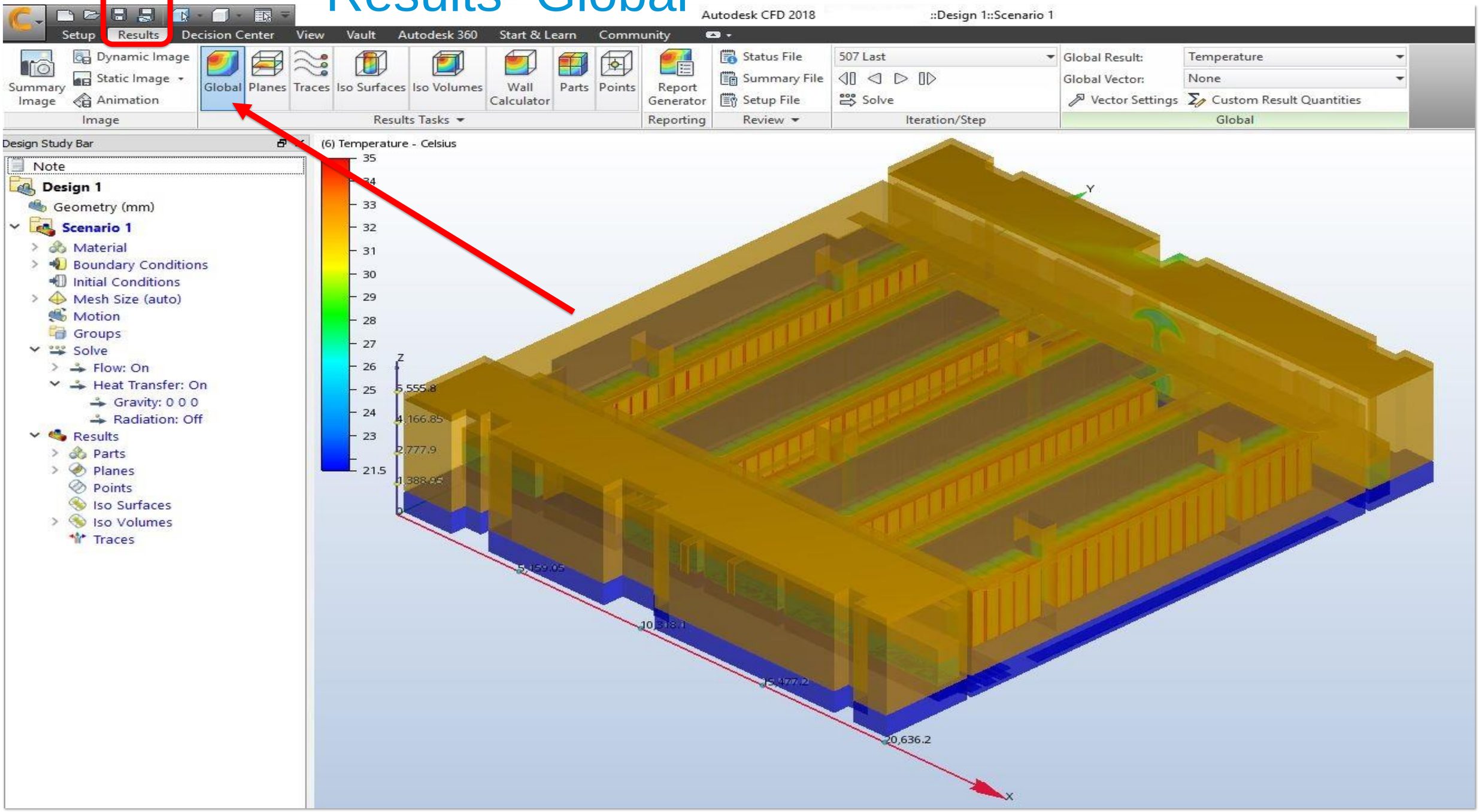
20,636.2

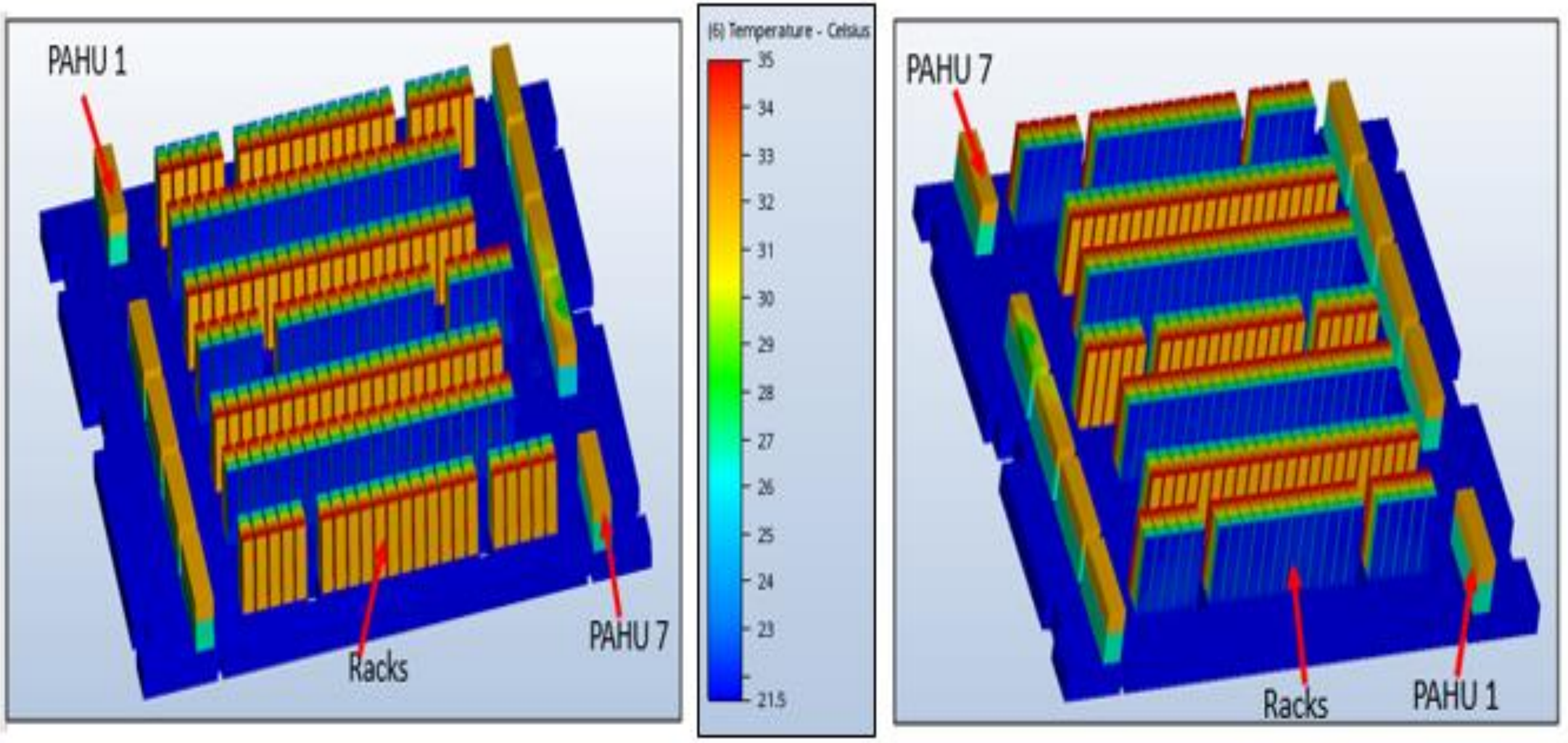


Data Center - Solver settings

Steady state solution, Intelligent Solution Control, Flow and Heat Transfer, Forced Convection (Gravity method unselected)

Results- Global

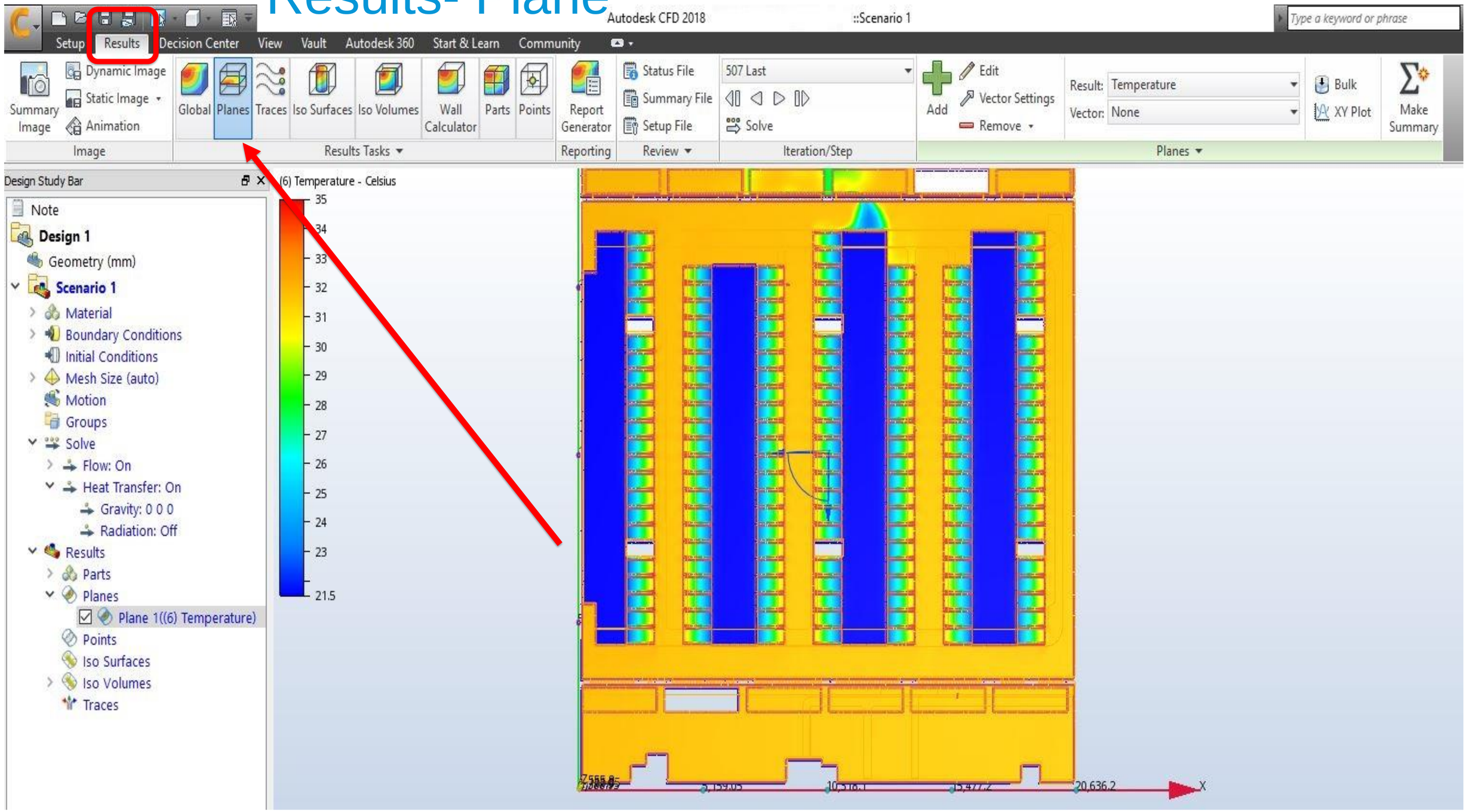


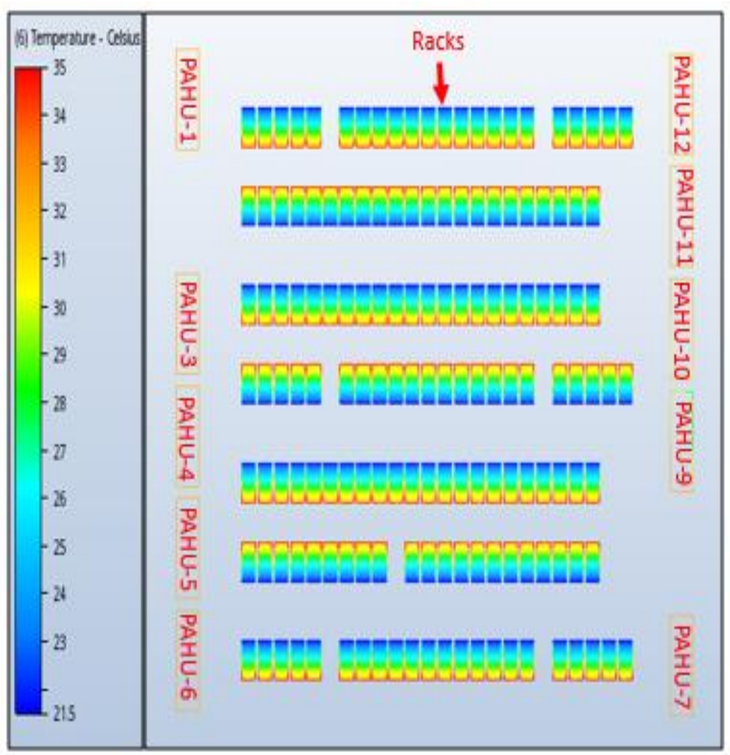


Data Center - Results- Temperature

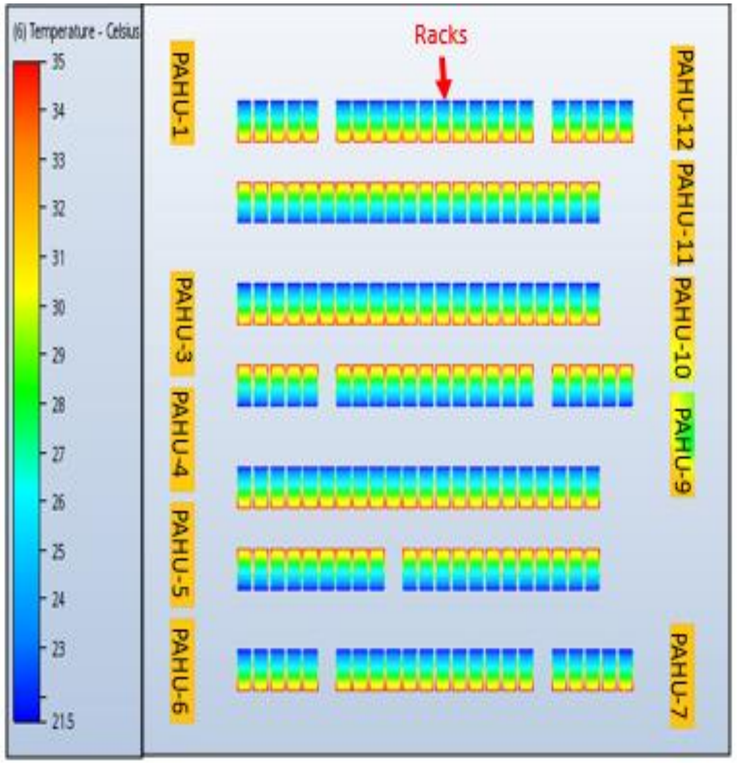
Global results to display server rack temperature throughout the model. Useful to get overall information about server rack inlet and exit temperature

Results- Plane

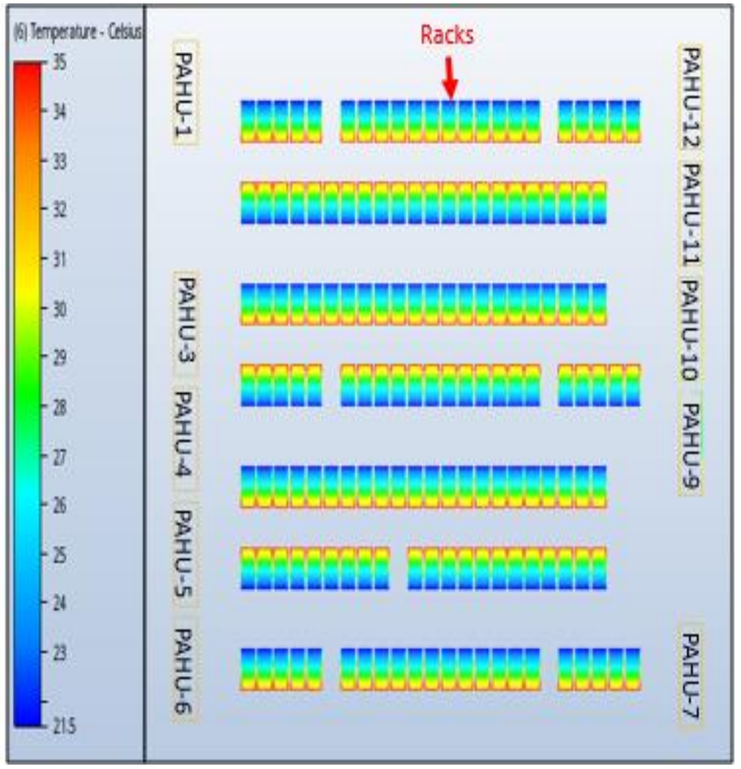




@bottom of rack



@middle of rack

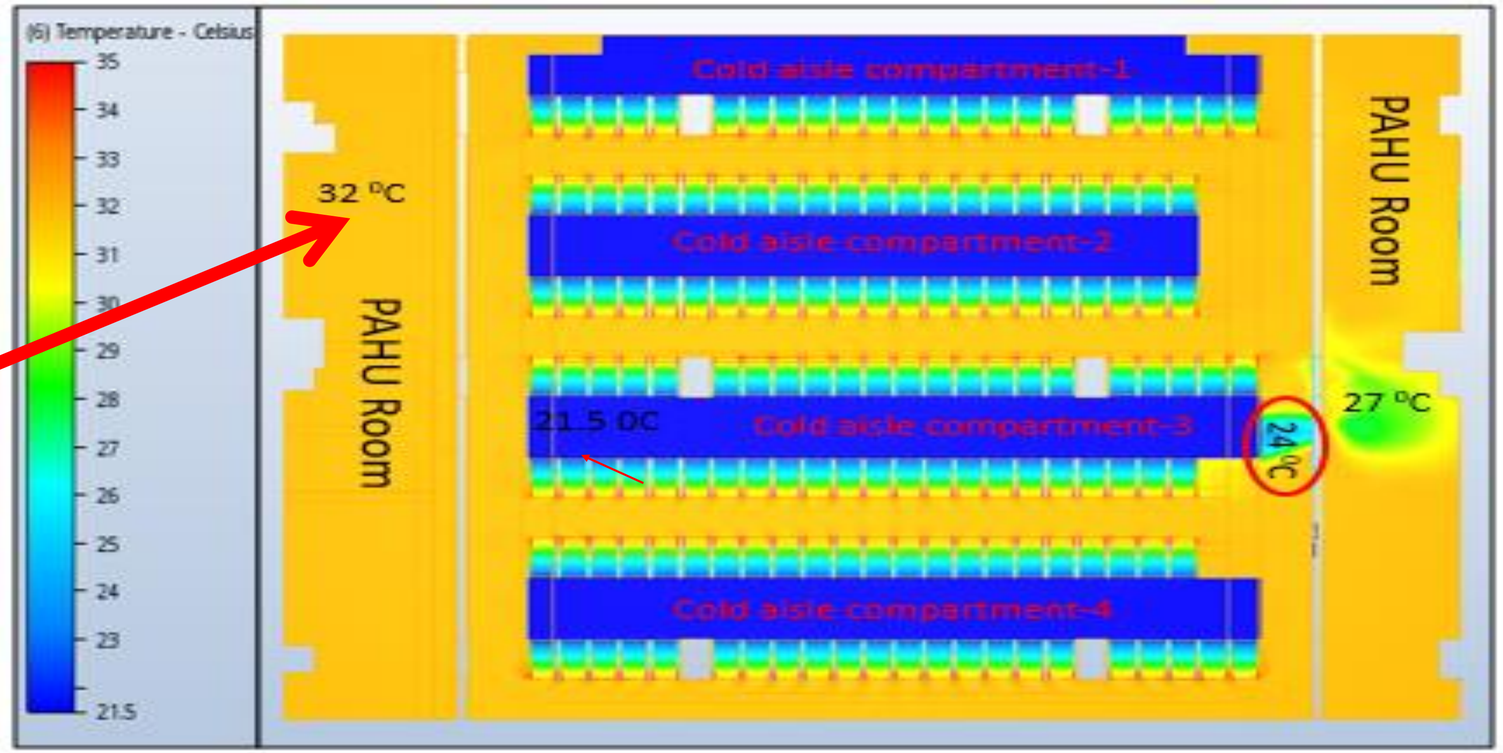


@top of rack

Data Center - Results- Temperature

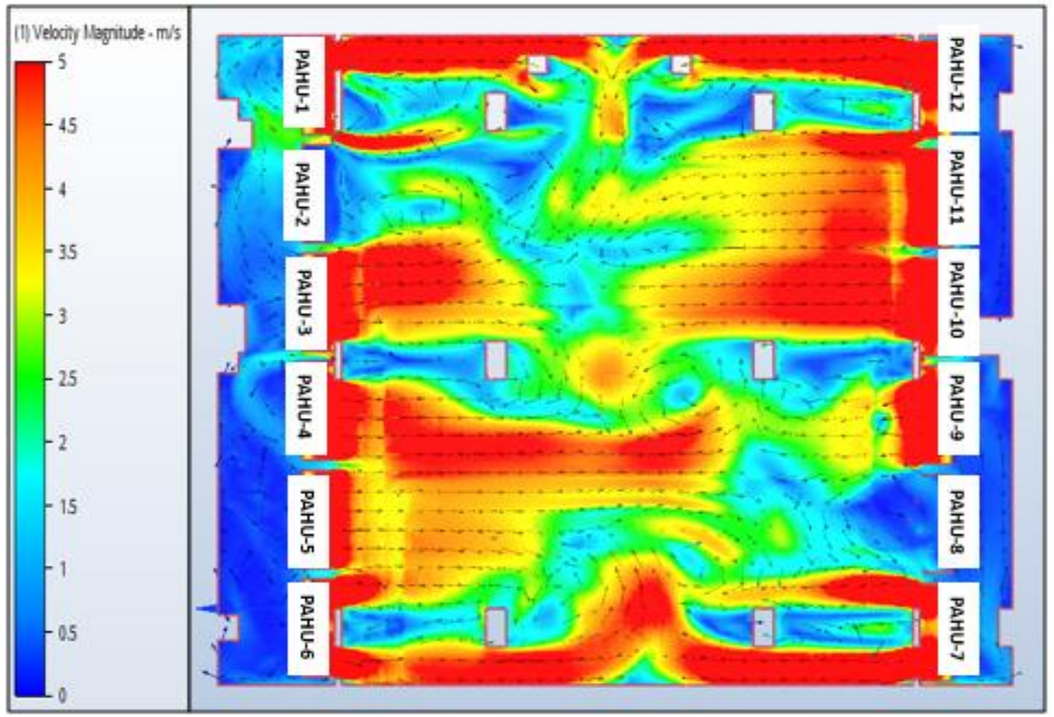
Results on Cut Planes are used to visualize temperature data on 3D model. Rack temperatures at different heights of server rack can be visualized.

Server hall temperature

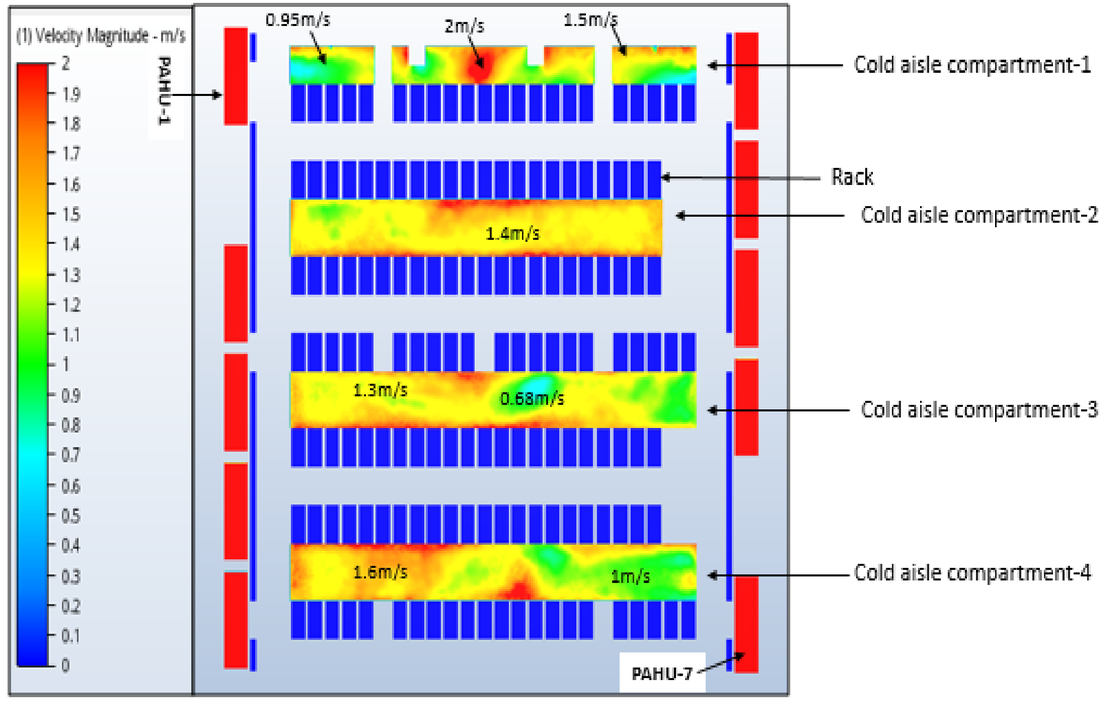


Data Center - Results- Temperature at 1.8 m level

Results using Cut Plane at 1.8m level from FFL can be used to evaluate Data Center Room temperature for personnel comfort. In this case , 32^0 C.



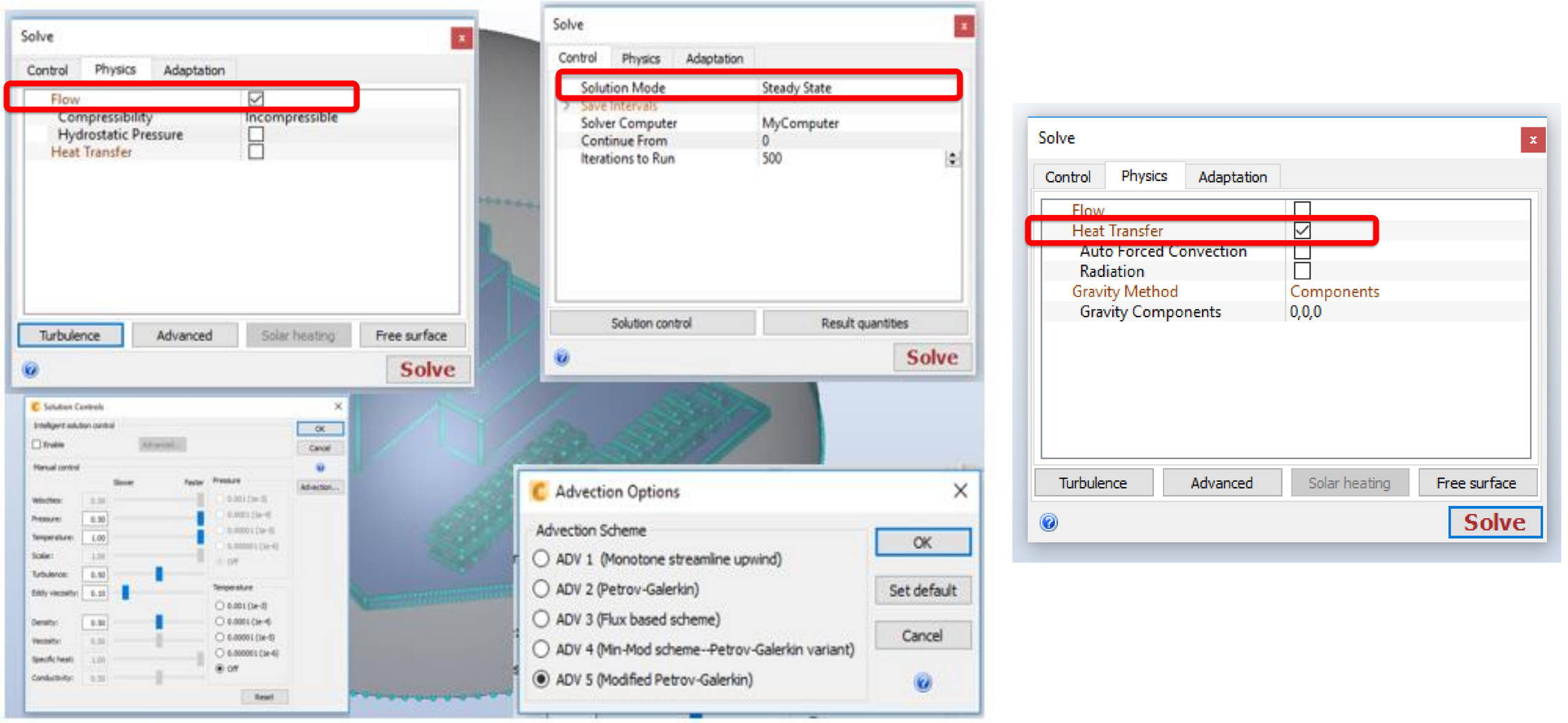
Supply air plenum



Supply air grills in cold aisle

Data Center - Results- Velocity contour plots

Cut Plane results of velocity are used to understand air flow distribution in the Data Center raised floor plenum in general and airflow distribution from the raised floor grills in the cold aisle

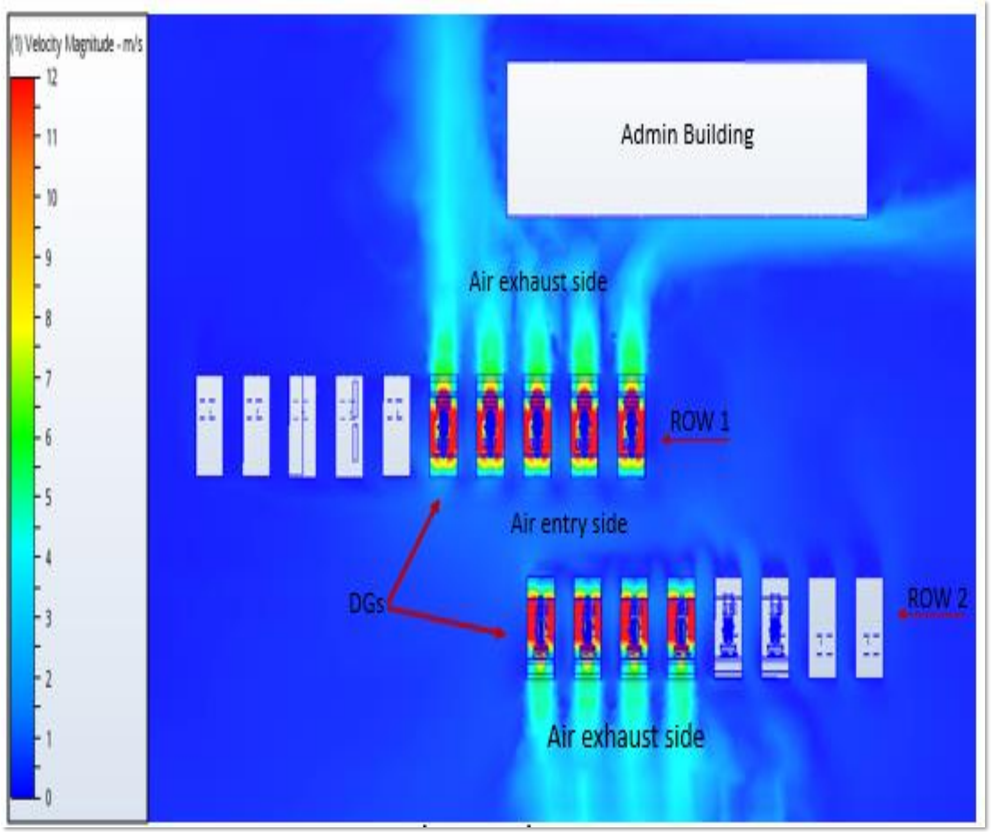


Backup Power Generator – Solver settings

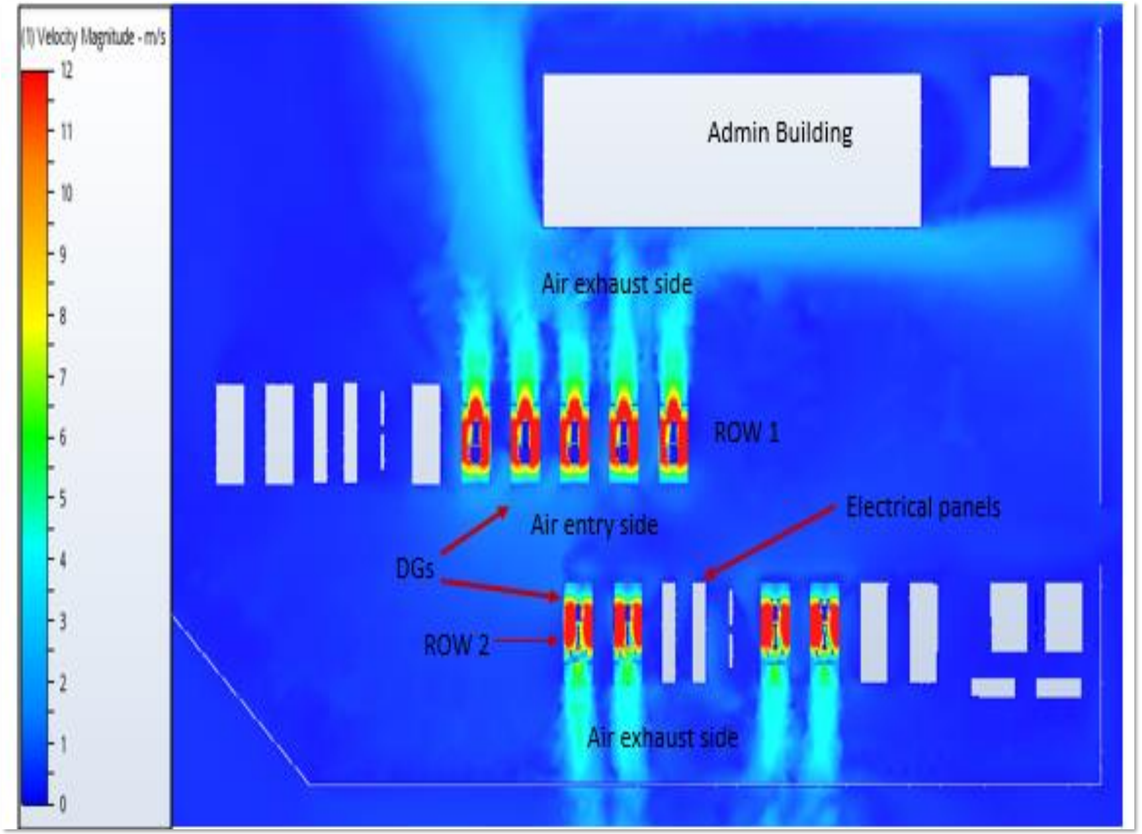
Steady state solution

#1 Flow ON with Intelligent Solution Control ON,

#2 Intelligent Solution Control OFF, Flow OFF and Heat Transfer ON, Forced Convection (Gravity method unselected)



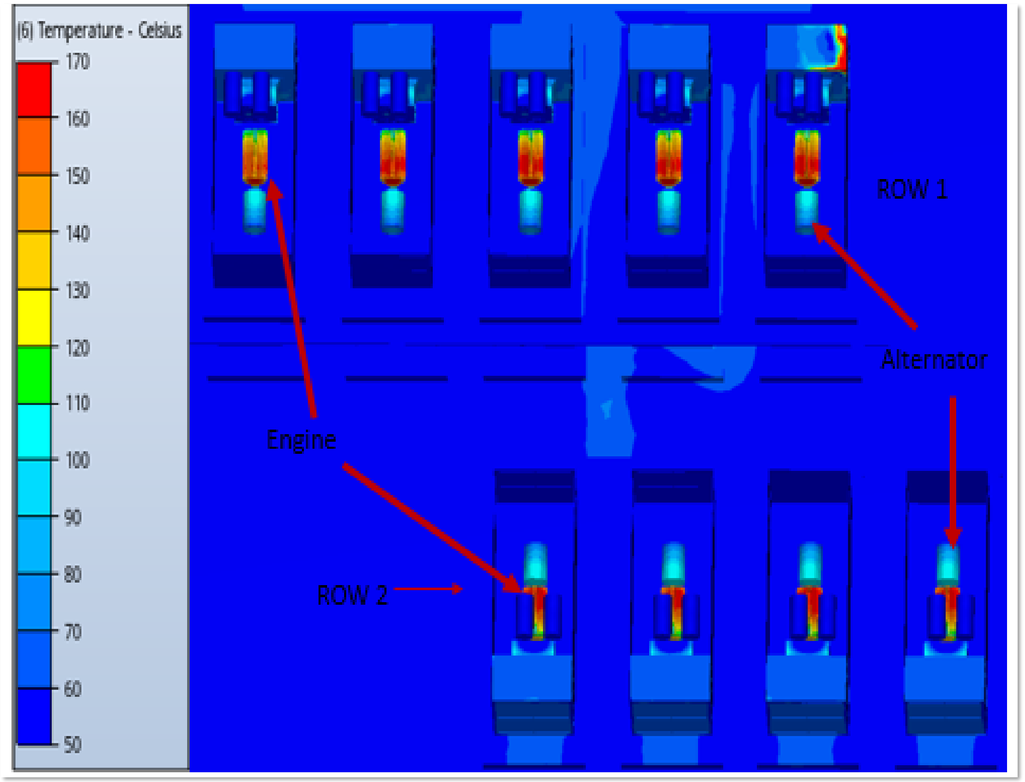
Air flow velocity pattern for upper level DGs



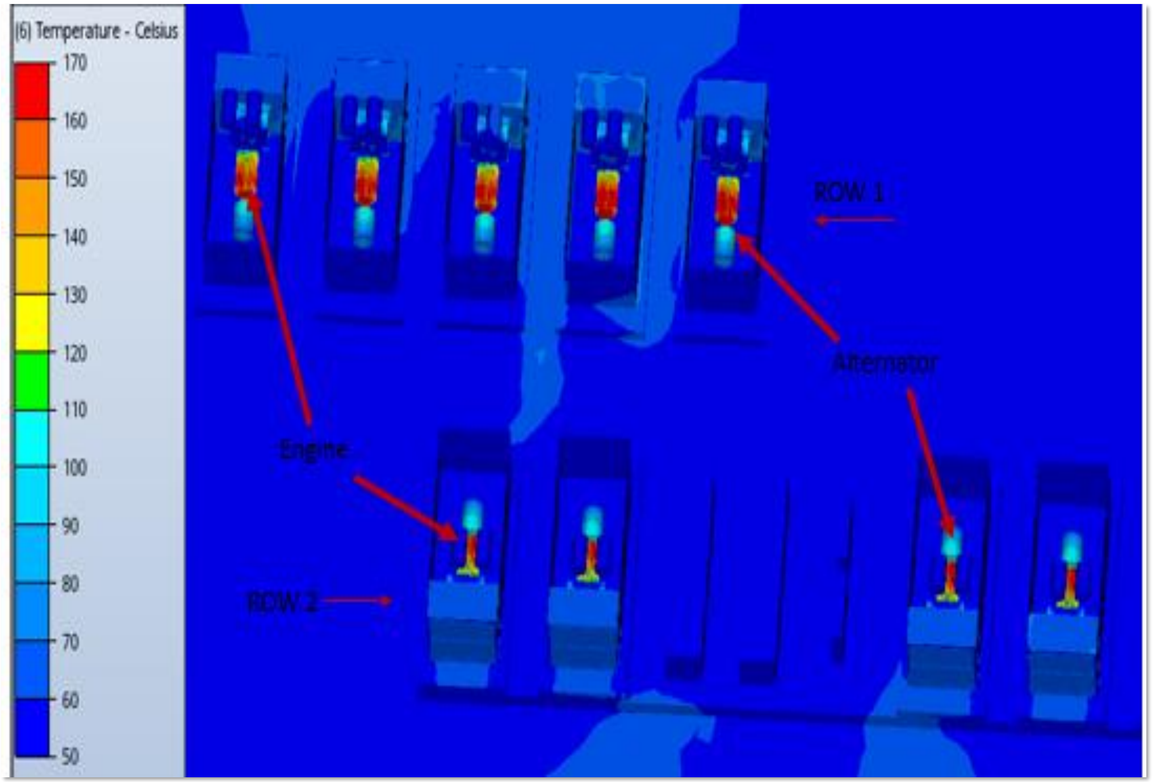
Air flow velocity pattern for lower level DGs

Backup Power Generator - Results- Airflow distribution

Cut Plane results of velocity are used to understand air flow distribution over back power generator set. Air flow velocity and flow distribution determine effectiveness of ventilation.



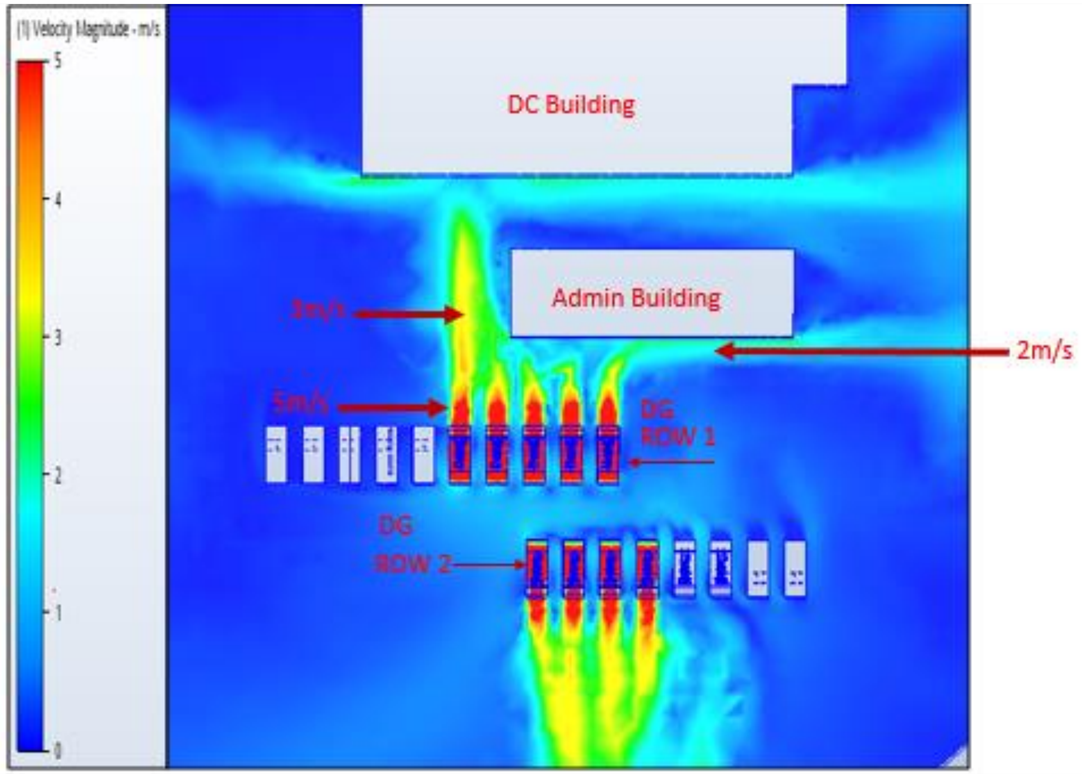
Engine and alternator surface temperature for upper level DGs



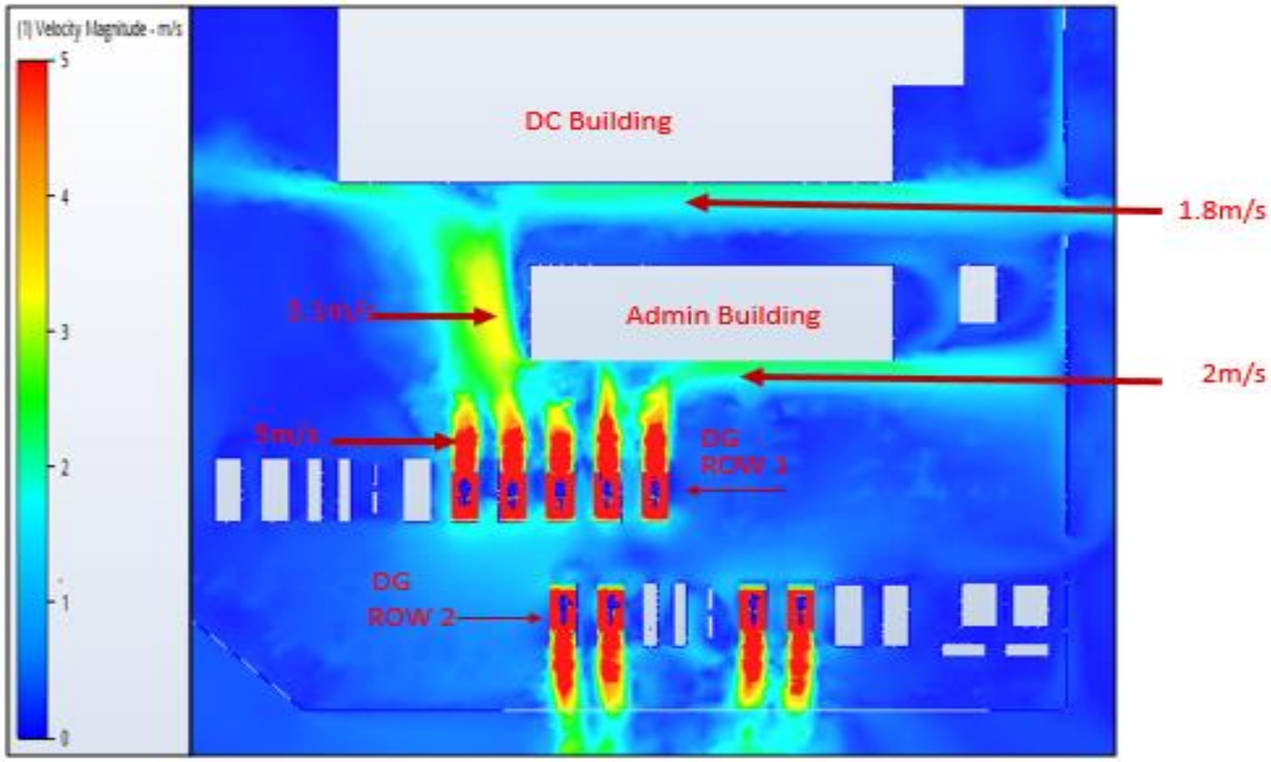
Engine and alternator surface temperature for lower level DGs

Backup Power Generator - Results- Temperature

Global results to display engine and alternator surface temperature throughout the model. Useful to evaluate adequacy of ventilation airflow for proper cooling of engine and alternator.



Air flow velocity distribution from upper level DGs



Air flow velocity distribution from upper level DGs

Backup Power Generator - Results- Velocity

Cut Plane results to display airflow velocity distribution from DGs. Useful to evaluate effect of exhaust air flow from DGs in people movement areas 9 (e.g. around admin building and Data Center (DC) building

Review results and evaluate design

Data Center Cooling

For Data Center cooling design, rack inlet temperatures decide performance of the server and return air temperature decides Data Center personnel thermal comfort.

Rack inlet temperature	21.5 to 22^0C
Average return air temperature	32 ^{0}C
Heat Removal	1584 kW

Based on CFD predicted server rack inlet temperatures and average return temperature, the server rack temperatures are within recommended limits as per ASHRAE TC 9. 9 (18 ^{0}C to 27^0C)

Backup Power Generator

For Backup Power generator, ventilation airflow distribution and resulting temperature field in and around the DG sets determine design performance of ventilation system. Based on CFD results, following can be concluded:

- DGs show engine surface temperature below 170 ^{0}C and alternator temperature below 110 ^{0}C, indicating adequate ventilation
- Alternator and engine temperature of all DGs are in acceptable range.
- Air velocity near the admin and DC building also in the acceptable range
- Ambient temperature around the DG plant is 45 ^{0}C.

Thank You….

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