MEP

MOST EFFICIENT PARTY

SUBJECT REPORT

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DTU

GROUP 10

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VISION

Our goal is to design a comfortable building, where the building installations supports the occupant's thermal and visual well being. We aim to hide the piping and ducts to avoid interfering with the minimalistic architectural design.

Bygningsreglementet.dk

Lavenergiklasse

	DGNB Platinum	DGNB Gold	DGNB Silver	DGNB Bronze*
Total performance index	80% and higher	65% and higher	50% and higher	35% and higher
Minimum performance index	65%	50%	35%	-- %

DESIGN CRITERIA

The main focus for this report has been to make an overall coherent MEP system that fulfills all the requirements, including the three main criteria; cost, time, and sustainability. Further, fulfilling the Danish Building Regulation from 2018 and Indoor Climate Category II (DS/EN 16798) has been a threshold, where the DGNB Platinum certification and the Low Energy Frame has been the final goals. To reach these goals we aim to score the maximum number of points in the relevant DGNB categories, for instance for the building envelope.

Additionally, the report has put extra focus on matters concerning comfort, ventilation, energy, and space optimization which are elaborated throughout the report.

Ventilation rates (l/s/m2)*	
Single office	1.4
Landscape office	1.4
Meeting room	4.2
Auditorium	10
Corridor	0.7
Toilet	10
Technical room and shaft	0.7
Kitchen	4.2

Ventilation duct dimensioning	
Maximum velocity	5 m/s
Ideal pressure loss	0.5 Pa/m
Maximum pressure loss	0.6 Pa/m

*Required ventilation rates to full fill Indoor Climate Category II for low polluting buildings

Building Envelope (W//m2*K)				
	BR18	DGNB (points)		
		2.5	7.5	10
Roof	0.20	0.20	0.15	0.10
Exterior walls	0.30	0.30	0.20	0.15
Floor towards ground	0.20	0.30	0.20	0.15
Windows	1.80	1.40	1.20	1.00

Energy	
BR18	41 kWH/m2/year
Low Energy Frame	33 kWh/m2/year Ug = 0.70 W/m2K, gg = 0.50, psi = 0.05 W/mK VAV max SFP = 1800 J/m3

Daylight	
Daylight Atonomy	50% of the relevant floor area must have more than 300 lux 50% of the time

Indoor Environment Quality – Category II (DS/EN 16798)	
Predicted mean vote	-0.5 < PMV < 0.5
Operative temperature	20 to 26 degC

BUILDING INFORMATION	
Building height	67.6 m
Floors above ground	17
Basement floors	5
Ground floor area	1.229 m2
Heated area	18.953 m2
Office height	3.146 mm
Office area	3.906 m2

BUILDING 313

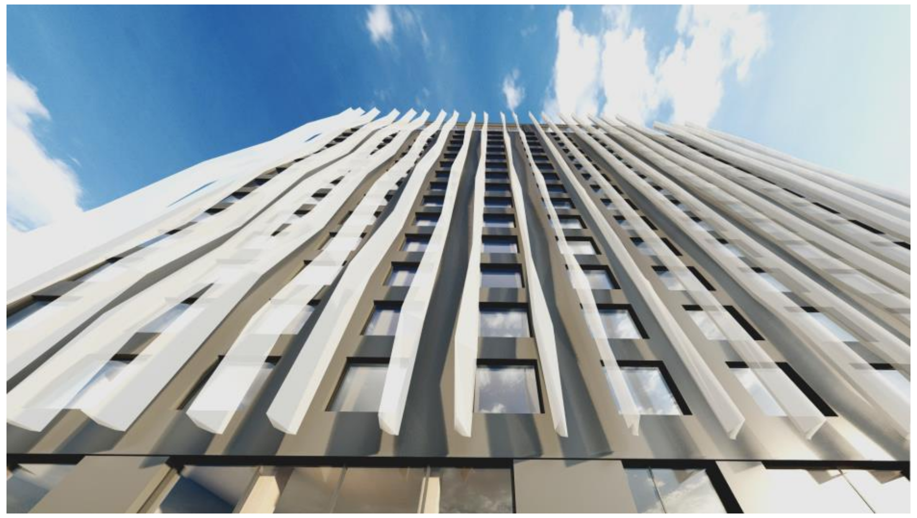
The building is divided into three main parts; the pedestal level at the bottom, the tower level in the middle, and the sky bar at the top. At the pedestal level the user is welcomed by an atrium. Further, this part of the building houses two auditoriums, a gym, shower and toilet facilities, cafeteria, common areas, and meeting rooms.

In the tower the offices are located. Each floor also has a common area, kitchenette, meeting rooms, and toilets.

The sky bar at the very top contains a restaurant and common areas.

The building's technical installations are mainly placed in two shafts – one in the northern part and one in the southern part.

The installations in the shaft are connected to service station in the technical rooms in the basement, on the 7th floor, and on the 16th floor.



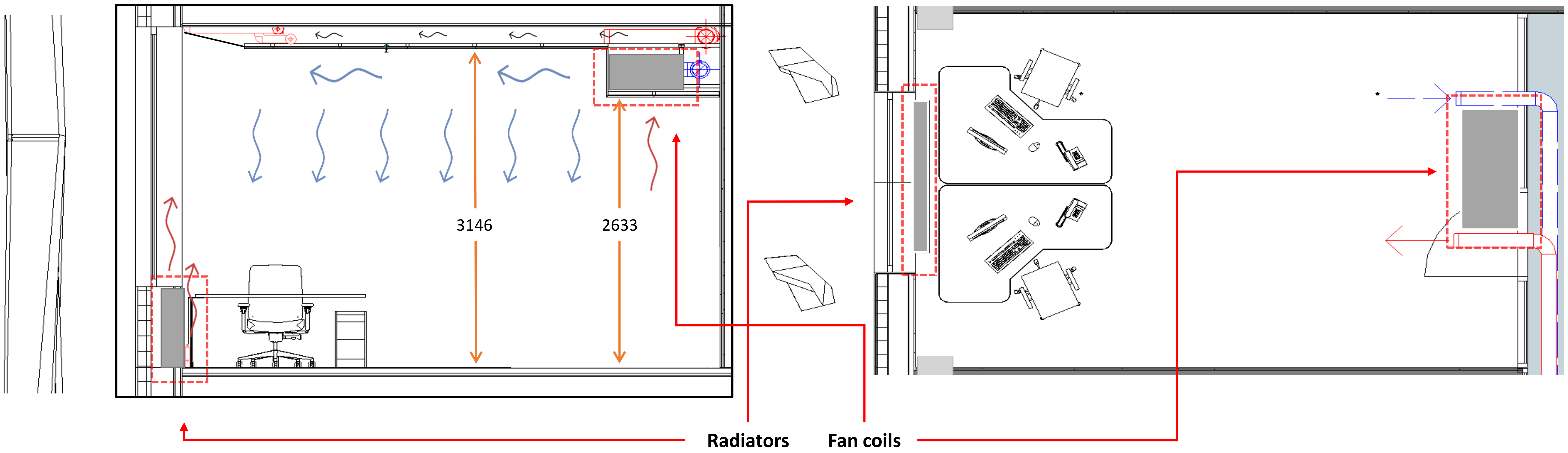


Figure 1: The building emissions and indoor pollutants is ventilated by the ventilation system, which supplies fresh air by diffuse ventilation. The heating in the building is regulated by radiators for heating and fan coil units for cooling.

VENTILATION PRINCIPLE

To ventilate the building from its building emission and indoor pollutions diffuse ventilation is used. Diffuse ventilation has several advantages compared to other ventilation solutions. The main reason for choosing diffuse ventilation is that it only requires 200 mm for the horizontal ducts to distribute the air, whereas regular ventilation, like displacement ventilation requires 500 mm. The extra 300 mm space increases the ceiling heigh and allows more daylight penetration in the room. Further, the distributed air is blown evenly down towards the office area, ensuring a low risk of draught, which allows the supply temperature to be 18C or even lower[2].

In the suspended ceiling the free height in the office area is 200 mm, whereas the free height in the hallway area and the beginning of the office area is 675 mm. The extra height within the suspended ceiling allows the ducts and pipes to cross each other and creates space for the fan coils in the offices. The amount of supplied air to each room is regulated through CO_2 sensors responding to the dampers for a sufficient flow rate, whereas the larger rooms uses a variable air volume (VAV) for a more precise air change and the smaller rooms uses constant air volume (CAV) as the components are smaller and cheaper. To save energy the heat from the return air are utilized in a rotary heat exchanger in the AHU.

HEATING AND COOLING PRINCIPLE

The rooms are heated by radiators as seen in figure 1. The supply temperature is only 45 C to score max point in DGBN criteria TEC 1.4 and due to the possibility for big radiator surface underneath the windows in the main part of the building. Return temperature is 35 C. Fan coil units are used for cooling of the rooms, and they are connected to a district cooling supply system with temperature set 7C/12C, this temperature set is based on datasheet number 2, in Appendix D.

CEILING PLAN

Figure 2 shows the ceiling in an office space. The ceiling has four light panels to ensure sufficient lighting. In the middle there is a CO_2 sensor to regulate the ventilation by the damper in the room. Next to the fan coil there an inspection hatch is placed to allow access to service the unit and to inspect and service the piping in the ceiling. The gray area to the right shows the lowered ceiling (675 mm) while the rest of the ceiling has suspended ceiling (free height of 200 mm) with metal panels of small perforated wholes to let the air through.

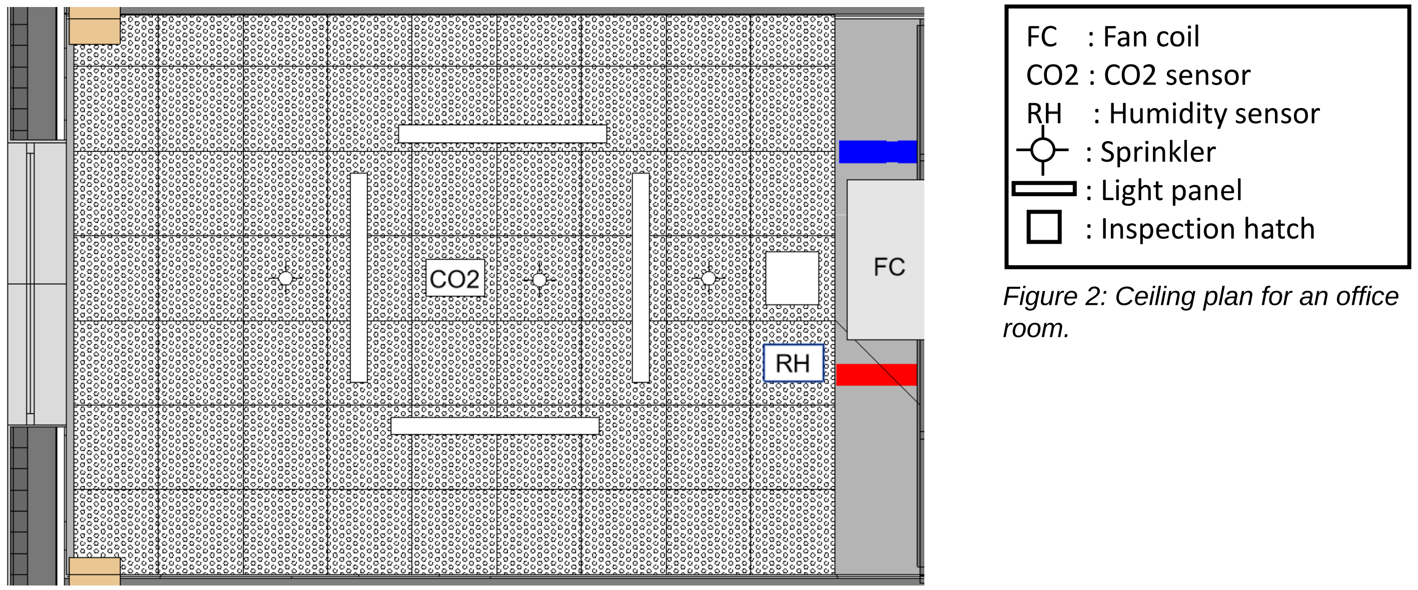


Figure 2: Ceiling plan for an office room.

VENTILATION DEMAND

As seen on figure 3 the building accommodates many different type of facilities and room types, which have different ventilation needs, since the building will be equipped with FCUs the ventilation only needs to cover the requirement for good atmospheric air quality for indoor climate category II according to DS/EN 16798. In Revit all rooms in the building have been assigned space types with corresponding ventilations rate, occupancy based on DS/EN 16798. The space types and their characteristics are listed in appendix A, table A.1 Extracting these characteristics of all spaces from Revit gave us the ability to get an overview of the areas of the different space types, the ventilation demand per floor and the occupancy per floor. This overview can be seen in appendix A. The building have space for six main air handling units (AHU) and two additional unit for the kitchen on level 16 and on ground level and level 3, based on the ventilation demand of each floor the building was split into three zones, each served by two of the main AHUs. These zone can be seen on figure 3.

CONCURRENCY FACTOR

DS/EN 16798 prescribes different occupancies for different space types, these were used to calculate an over all occupancy for the different floor types. To find a suitable concurrency factor for the ventilation system the occupancies, based on DS/EN 16798, was compared to the occupancies that the architects have used when designing the building, the comparison can be seen in table A.1 in appendix A. It turned out that architects have designed the building for much lower occupancies than DS/EN 16798 prescribes and an concurrency factor of 0.7 was used for almost every floor when calculating the size of the main shafts.

SIZING OF MAIN VERTICAL DUCTS

It is assumed that for every floor the ventilation demand can be equally divided between the ventilation units. The sum of the ventilation demand in each zone was used to find the size of the vertical ducts. To make the shaft space efficient the vertical shafts are rectangular. The ventilation demand is highest for zone 1, which requires 4740 l/s, to achieve a pressure loss on less that 0.5 Pa/m the required ducts size is 600 x 1200 mm, calculated trough a sizing tool provided by the ventilation supplier Øland. The supply duct needs 30 mm of insulation.

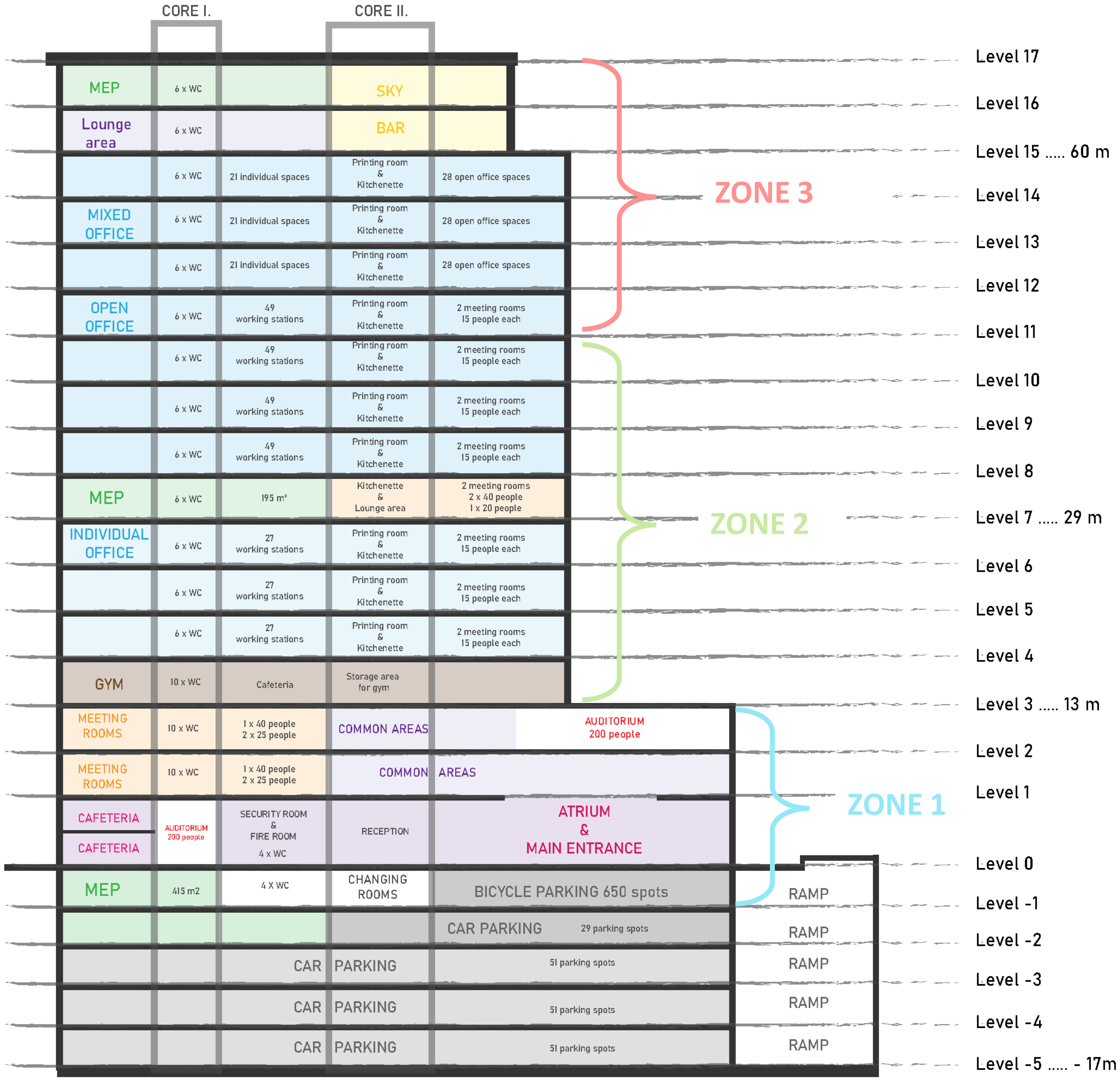


Figure 3: Schematic section of the building, where the distribution of different room types is seen, further the three different zones which the ventilation system is split up is marked

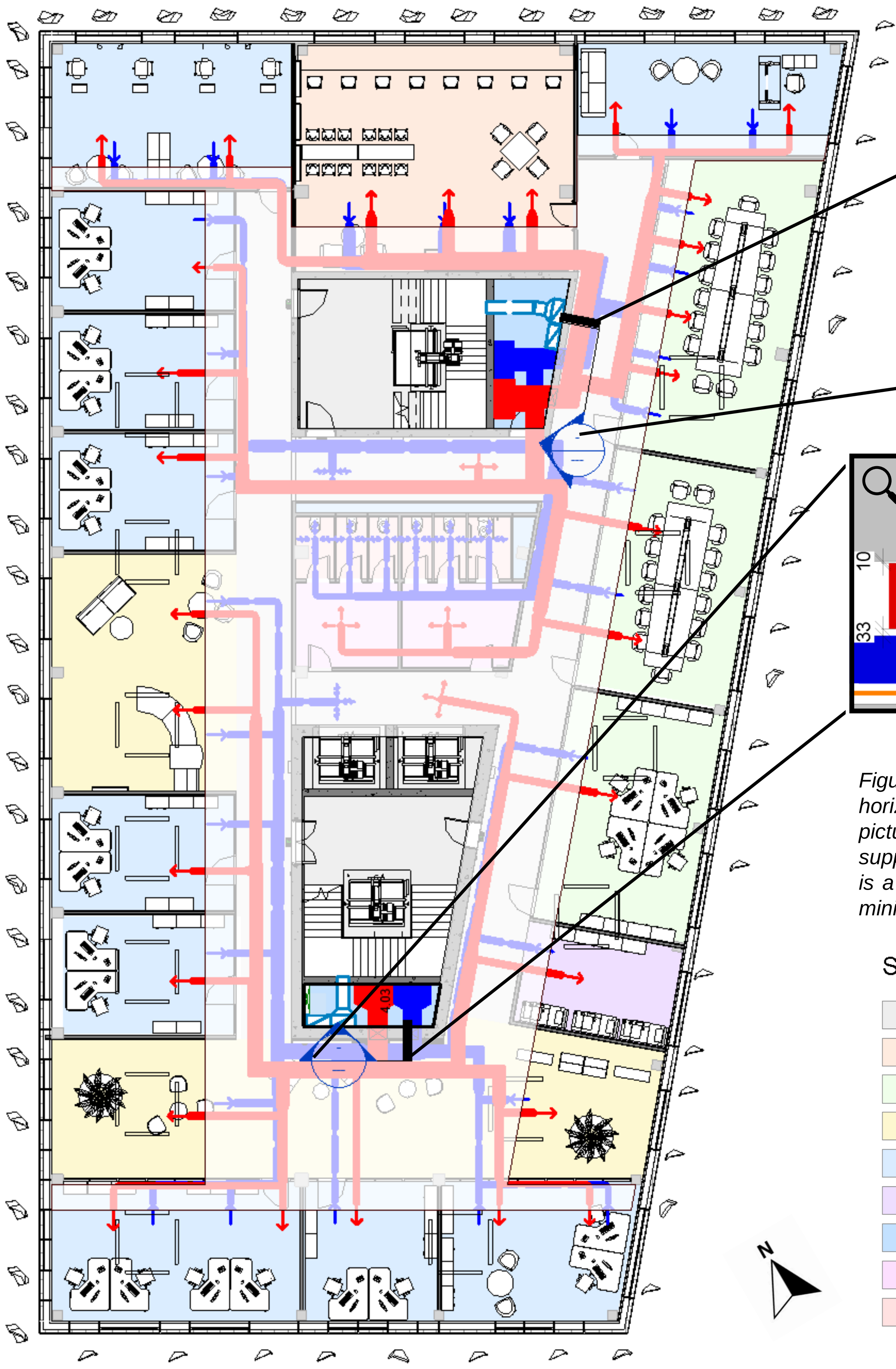


Figure 4: Drawing of the routing of the horizontal ducts between rooms on level 4. On all floors the air terminal must not be more than 25 m away from the main vertical duct to avoid a too high pressure loss in the system. The white coloured area indicates the part of the suspended ceiling which has a free height of 675 mm.

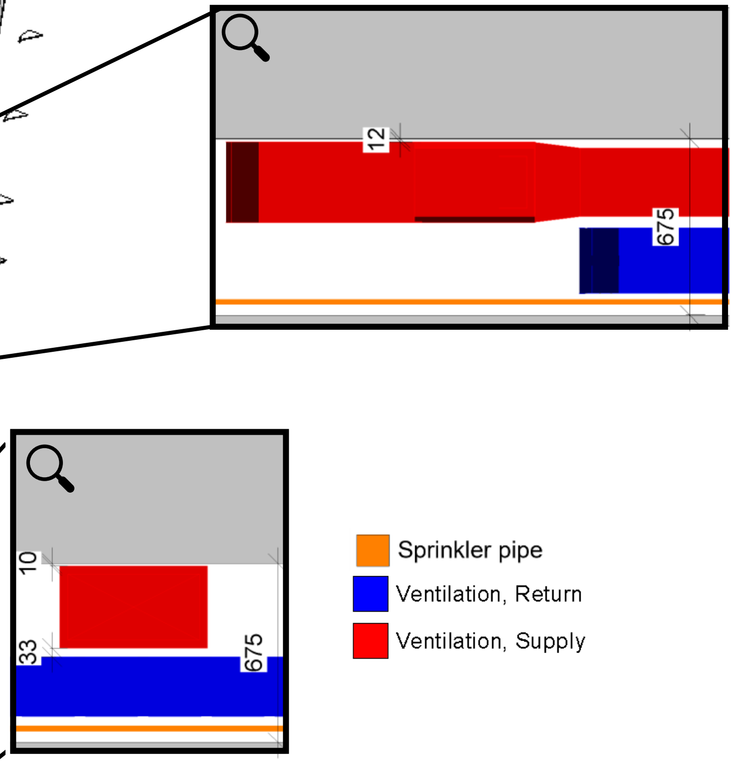


Figure 5: Cross section of the most critical parts of the horizontal routing of the ventilation ducts. As seen in the picture sprinklers runs below the ventilation ducts, and the supply and return ducts runs in two different heights. Which is a principle for the horizontal routing on the entire floor to minimize the numbers of elbows.

DISTIRUBTION OF AIR

The air is supplied from the air handling units (AHU) placed in the basement, 7th floor, and 16th floor. From the air handling unit, the ducts runs along the core in a vertical direction in the two main shafts. The air is then distributed on each floor along the corridors between the core and the rooms. The shafts are placed in the northern and southern end of the core to ensure that the vertical distance from the horizontal pipes to the air terminal furthest away are below 25 m. The concept of the routing are shown in the plane view of level 4 in figure 4.

The supply ducts are insulated with 30 mm insulation from the AHU to last branch in the system, to ensure a consistent supply air temperature. To avoid condensation a humidity sensor is placed in all rooms and the heat exchanger are controlled by these.

Since the shafts are within one fire zone and the floors are within another. Fire dampers are placed when the horizontal ducts leaves the shafts and silencers will be placed when needed where the horizontal ducts branch out to the rooms. The concept can be seen on the schematic drawing in appendix B.

CRITICAL SECTION

To make a space efficient building it have been a goal for both the structural team and the MEP team reduce the slab height and the height of the suspended ceiling. The structural team came op with a solutions for CLT slabs that where only 360 mm wide and without beams in the suspended ceiling. Rectangular ducts are used near the main shaft where the air flow is highest. This made it possible to decrease the suspended ceiling to 675 mm of free height in the corridors and 200 mm in the offices and residence areas, which is indicated with the white box in figure 4.

As seen in figure 5 the critical section are tight, but with squared ducts it is possible for them to cross one another at the most critical points, which is just outside the shafts.

HORIZONTAL VENTILATION ROUTES

The horizontal ventilation routes are modelled at level 4, and dimensioned to not exceed a pressure loss of 0.6 Pa/m and an air velocity of 5 m/s. As seen in figure 6 and 7 this is achieved. Further, the pressure loss at the air terminal are within the range of 0.4 Pa/m to 0.5 Pa/m, which makes it possible to increase the ventilation rate, in case the tenant wants to re-arrange and make some of the offices into meeting rooms.

AIR HANDLING UNITS

The air handling units are found through the ventilation rates and the pressure losses, which can be seen in appendix C. The units are divided into three zones as seen on figure 9. Within each zone two ventilation units are used to supply the northern and southern part of the building respectively. When aiming for the Low Energy Frame it is essential to have a low specific fan power and a high heat recovery rate. Therefore, SystemairCAD has been used to optimize the AHU in relation to these parameters. For the two upper zones the same AHU, Geniox 24, has been chosen, but due to the small difference in ventilation rates the zones' units differs slightly in relation to SFP and heat recovery, which can be seen in figure 8. In the lower zone, the AHUs are located in the basement in a room with double height, which allows the unit to be taller than the other unit types. Here the unit Geniox 27 is applied.

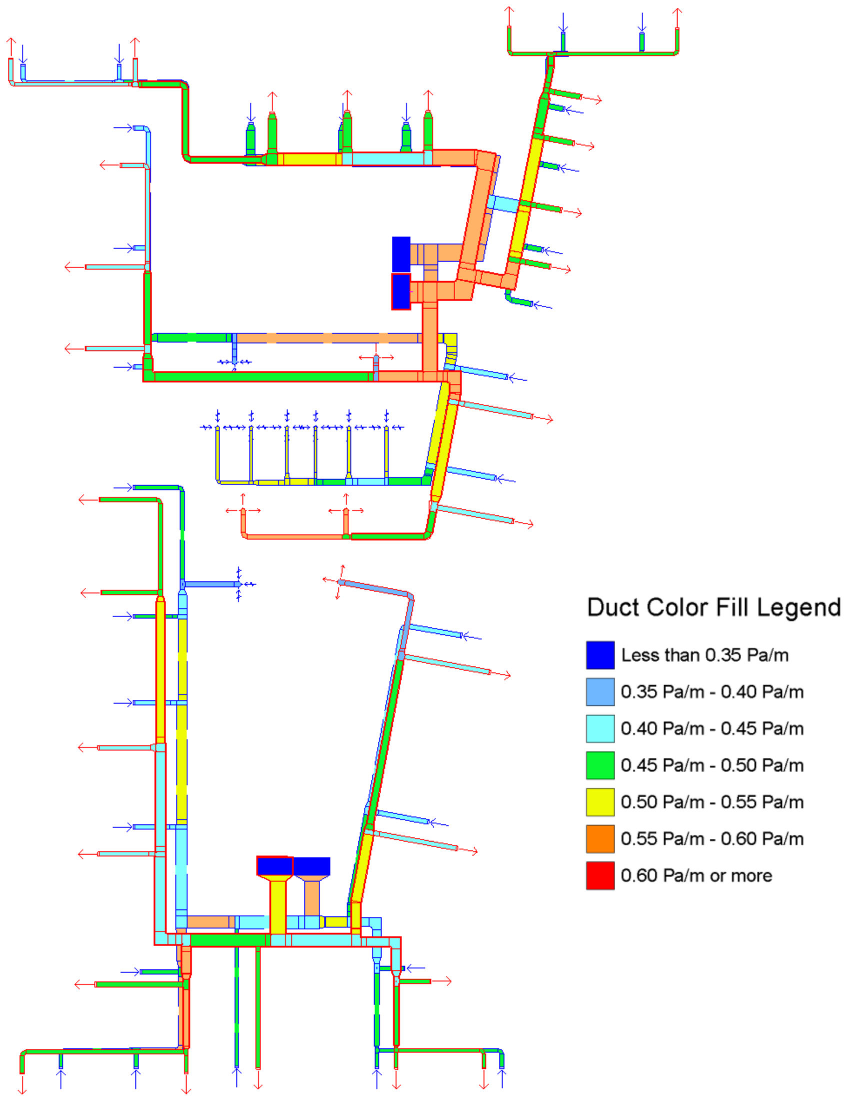


Figure 6: Illustrating the pressure loss for the horizontal ducts on level 4.

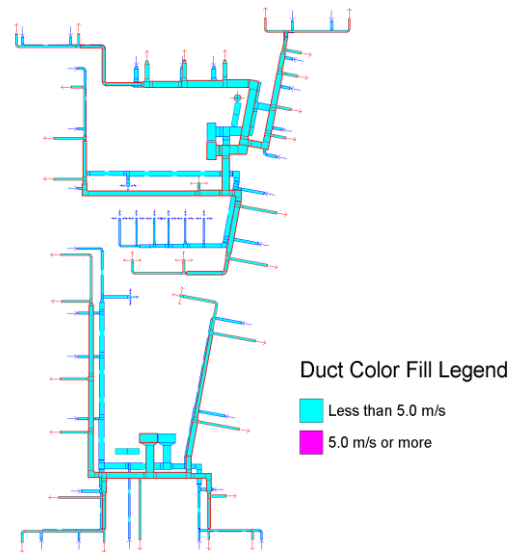


Figure 7: The air velocity in the horizontal ducts, does not exceed 5 m/s for level 4.

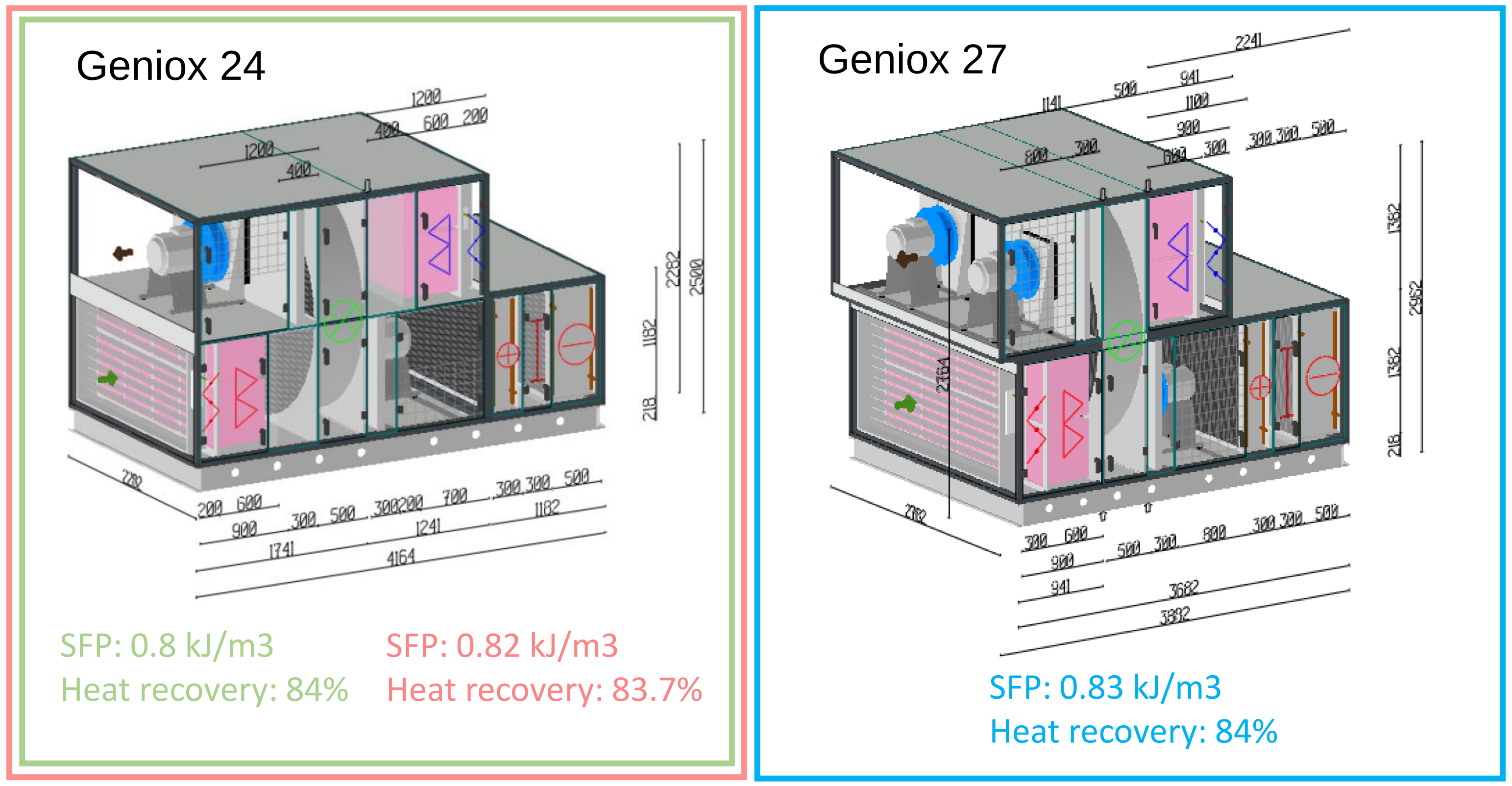


Figure 8: Illustration of the AHUs placed on the 7th floor and roof to the right and the AHUs in the basement to the left, including the different specific fan power values and heat recovery rates. The pitures are taken from SystemairCAD.

Figure 9: Showing the division of zone types for the AHUs indicated by colours. There are two AHUs within each zone. One unit's ventilation rate and pressure loss to the farthest air terminal is indicated to the right.

VENTILATION IN CARPARK

The ventilation in the carpark will be supported by jet fans that will lead the exhausted air outside through the opening of the carpark, fresh air will enter through a vertical duct to create circulation. The jet fans can be placed between the beams in the basement and no horizontal ducts are needed, which can be seen in figure 10. As a result the clear height of the basement can be increased compared to a ducted system. The height of the jet fan is approximately 500 mm, see appendix D, datasheet number 4, and the beams in the basement is 400 mm, allowing the jet fans to be placed in between the beams and thereby only lowering the free height by 100 mm. The free total height is 2.6 m from the floor to the jet fan.

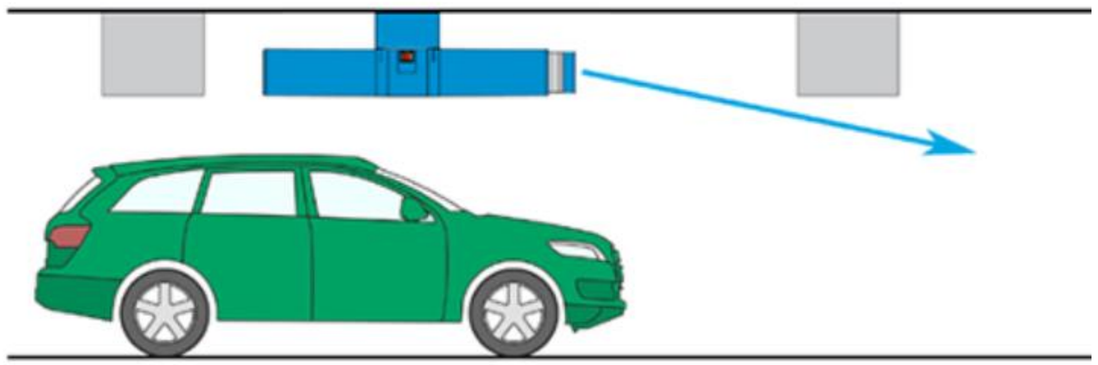


Figure 10: Principle drawing of the Jet fans, made by Novenco.

FIRE VENTILATION

The allocated fire ventilation contain a set of two ducts (400x800 mm) and are placed in each shaft as seen on figure 11 and 12. The fire ventilation will ensure that in case of fire the staircases, anteroom and elevator will be pressurized with an overpressure of minimum 50 Pa. The staircases and the fire ventilation ducts in the shafts are connected by horizontal ducts on every floor. The staircase surrounds the elevator and a grill is letting air flow between the staircases and the elevator shaft. The air release in case of fire will further ensure a minimum air velocity of 2.0 m/s through an open door to the staircase in any effected zone in the entire building. The air-release will further be applicable for the floor below the fire-affected floor and when all other doors and elevators are closed. Both anterooms, staircases, elevators, and southern and northern shafts are placed within a fire section marked by the thick walls. The division of fire zones can be seen in the report from subject 5. Space in the basement and on level 16 have been allocated for fire ventilation.

Lastly, the anterooms must be between 5 to 20 m2 and the minimum width of the staircase may not be less than 1.2 m. This is all obtained as seen in the figures 11 and 12.

Pressurized staircase (50 Pa)
Pressurized anteroom (50Pa)
Pressurized elevator (50Pa)
Air release in case of fire
Air speed min. 2 m/s
Fire ventilation

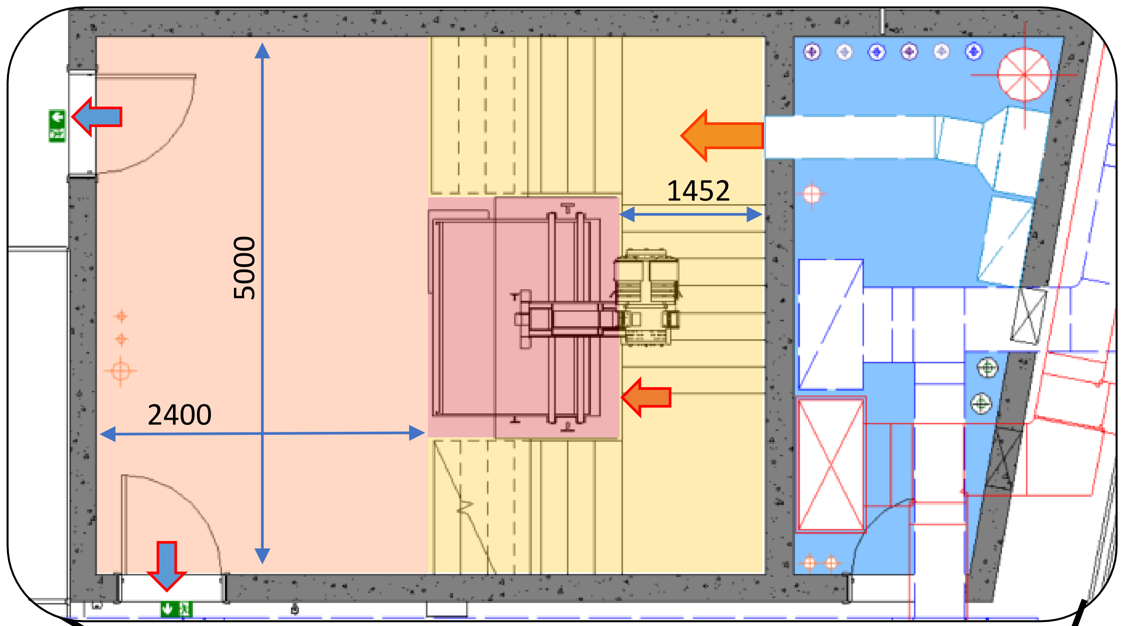


Figure 11: Illustrating the fire ventilation zoning in the northern anteroom and shaft.

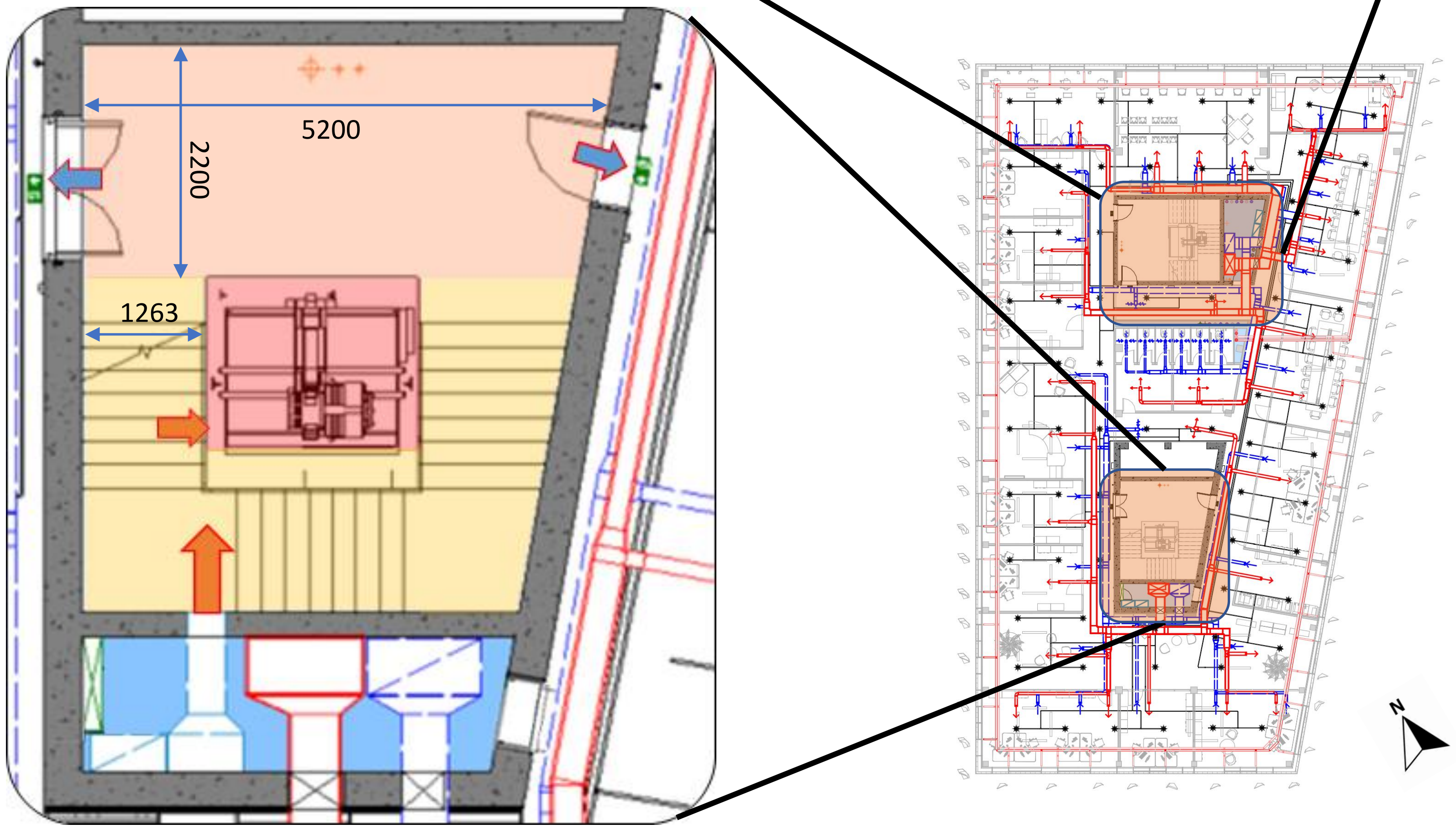
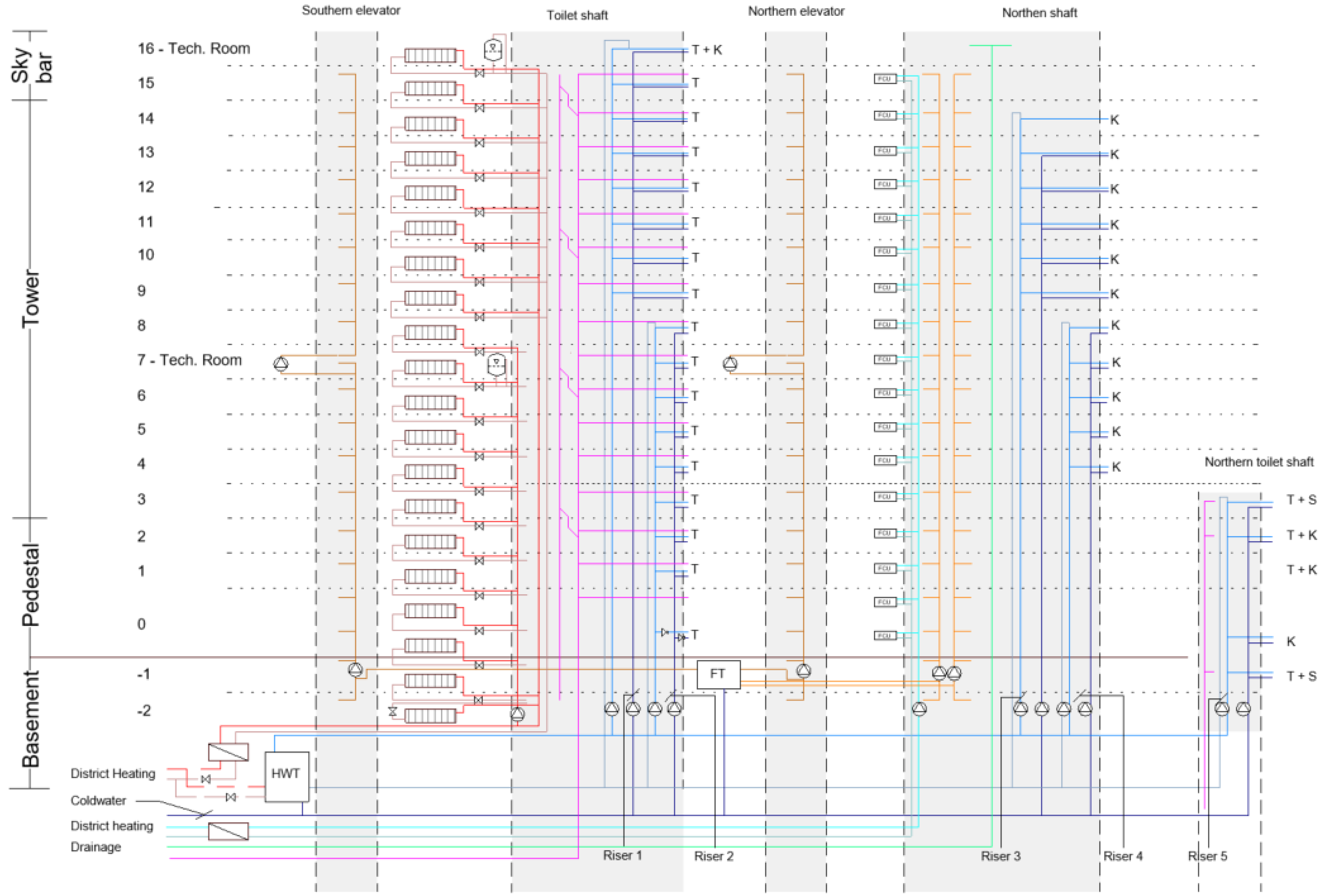


Figure 12: Illustrating the fire ventilation zoning in the southern anteroom and shaft.



Signature

T	Toilet
K	Kitchen
S	Shower
HWT	Hot water tank
FT	Fire tank
FCU	FCU loop

Radiator loop
Booster pump
Valve
Pressure reducing valve
Expansion tank

Hot water
Cold water
Circulation
Heating Supply
Heating Return

Cooling Supply
Cooling Return
Sprinkler
Wet riser
Roof Drainage
Sanitary Drainage

Figure 13: Principle digram showing the hydronic installations and drainage.

Figure 14: Highligthing the placement of the five domestic water risers.

PRINCIPLE OF THE HYDRONIC INSTALLATIONS

The hydronic installations in the building are shown on the schematic diagram on figure 13 and includes water for heating, domestic water, sprinkling, wet riser, roof drainage and sanitary drainage. All installations are connected to the basement where service station for all types of technical services are placed, but on the seventh floor additional technical installations like booster pumps for the hydronic fire installations and an expansion vessel for the heating system is placed. On all levels toilets are placed close to the toilet shaft where riser 1 and 2 are located, riser 3 and 4 serves kitchenettes placed close to the northern shaft on all office floors which is from floor 4 to 14. On level -1 to 3 shower room, kitchens and toilets are placed in the northern end of the building, away from the shafts. Together with a need of dividing the system into pressure zones creates the need of water risers in another location that the northern shaft. To secure hot water within 10 seconds hot water tanks are placed in the basement and within each domestic hot water riser, the water is circulating.
The pumps have to be placed at the service stations in basement, outside of the shafts, even though they are drawn in the shaft at this principle drawing.

DOMESTIC WATER

Different system for distribution of domestic water are applicable for high rise buildings [15]. Some of these systems are shown in table 1 together with an evaluation of the systems. From the table zone divided systems and series connected systems are shown to be attractive. These systems have a low risk of bacterial growth and a relatively low cost. Though, they both require more space for installations compared to some of the other systems. The zone divided system takes up more space in the basement with booster pumps placed at the bottom of each zone. The series connected system require space for booster pumps at several floors. Further, the series connected systems are more vulnerable in relation to pump failure as if one of the pumps fail, the entire building would be without water. For the zone divided system only the zone in which the pump failure occurred would be without water. Due to the space requirements and the consequences of a pump failure, we have chosen to distribute the domestic water with a zone divided system. All the pipes are insulated to avoid high thermal losses and condensation.

	System diagram	Risk of bacterial growth	Initial cost	Energy cost	Required space
Roof tank		high	high	high	low
Single booster system		low	high	high	low
Zone divided system		low	low	medium	medium
Series connected system		low	medium	low	medium
Pressure zones with break units and top tank		high	high	low	high

Table 1: Different domestic water distribution systems and their score; high, medium, and low, relative to each other.

PRESSURE ZONES

The number of zones depends on the statical pressure, which is determined from the building height. The total pressure at the tap should be between 250 to 550 kPa, which results in a statical pressure difference of 300 kPa. If the statical pressure exceeds 300 kPa pressure reducing valves are needed [8].

In table E1 in appendix E the statical pressure for the five risers are shown. Ideally riser 2 should be split to avoid the pressure reducing valve, but this have not been prioritized due to space constraints. Further, only one pressure reducing valve is needed.

ROOF DRAINAGE

The rainwater is collected in two main siphonic roof drainage that are connected to one main pipe running in the northern shaft. The siphonic roof drainage is great for larger rainfalls as the flowrate generally is higher, since there are less air in the pipes and would drain the roof faster [16].

COOLING

District cooling is provided to the building by chillers at DTU and transported in an internal system on the campus. As seen on figure 13 on the last page the cooling are supplied to the rooms by one vertical riser and then distributed horizontally at each floor. The supply and return pipes for the fan coil units will be running in the suspended ceiling and the FCUs will be placed according the cooling demand in each room. The piping for cooling is insulated to avoid thermal losses and condensation.

HEATING

The building is indirectly connected to the district heating provided by *Vestforbrænding* and the radiators in the building are serviced by two sets of supply and return pipes, who are insulated. The heat distribution are split into two to avoid too high pressure in the system and expansion vessels are placed in top of the two systems where the pressure is lowest, and spaces are allocated for them in the technical rooms on these floors. Due to low U-values one floor can be seen as one radiator loop, since the volume of water only will be around 1000 kg/h, and there is room for pipes with a nominal diameter of 50 mm. An estimation of the water mass running in the pipes and sufficient size for the pipes can be seen in appendix E in table E2. Other solutions like radiant ceiling and thermal slabs could have been chosen for heating. Radiators was chosen due to possibility for high flexibility, every radiator has its own thermostat, which mean that bigger rooms easily can be changed to smaller which all can be individually controlled.

FIRE INSTALLATIONS

The building has an extensive sprinkler system on every floor, the sprinkling system are designed by the fire team to full fill that each sprinkler head covers maximum 12 m2. The routing of the sprinkling can be seen in figure 17. Fire risers are needed due to the building height being above 30 m, thus booster pumps are also necessary. The wet riser and hose wheel pipes are placed in the anteroom in front of the fire elevators in the two staircase rooms as seen on figure 18. Booster pumps are placed in the technical room on level 7.

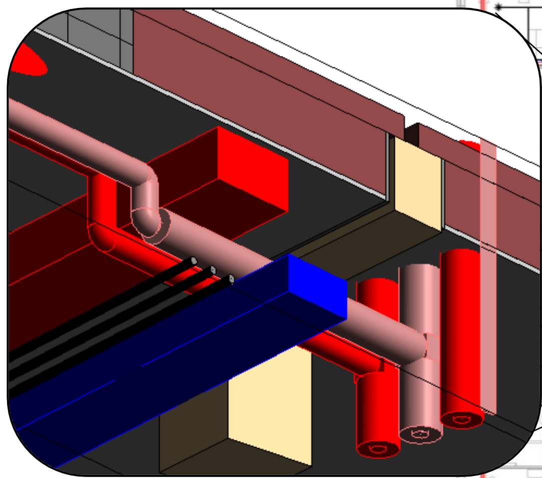


Figure 15: The routing of the pipes from the vertical pipes in the toilet shaft to the horizontal pipes serving the floor. Ass seen the pipes can branch out between the ventilation ducts (red and blue) and sprinkling pipes (black).

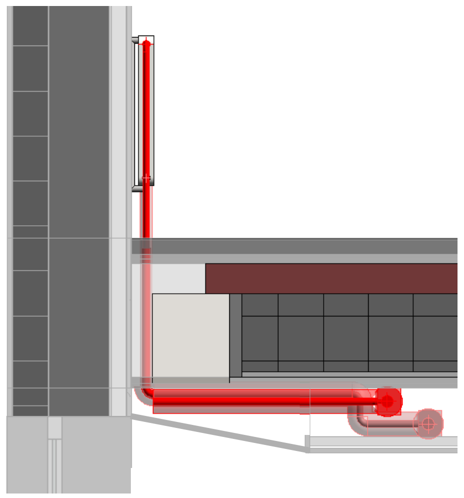


Figure 16 The horizontal piping for the radiators runs in the suspended ceiling approximately 80 cm from the façade and serves the level above where they are running. The columns along the facade are wider than the beams, which gives a gap of 5 cm between the façade and the slab, the pipes are running in this gap, which will be fire insulated.

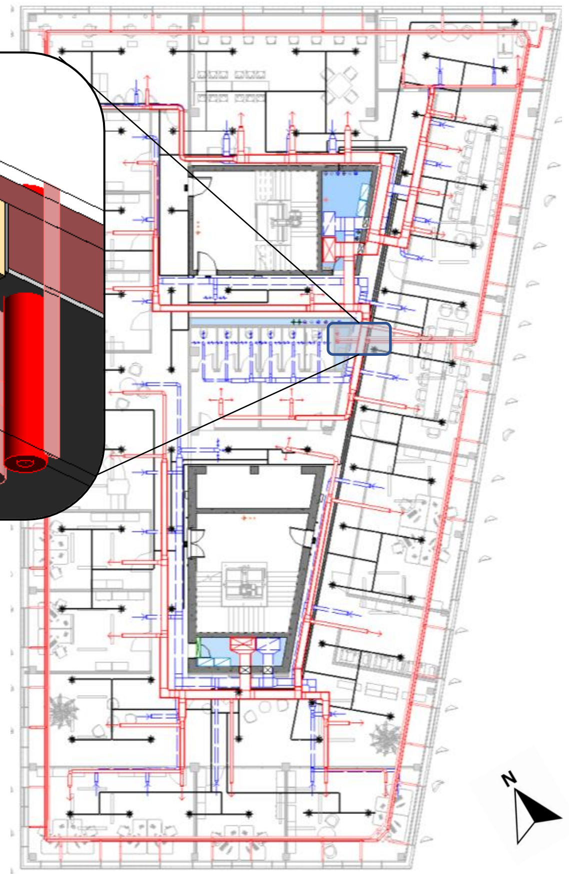


Figure 17: Horizontal pipes for heating and sprinkling, together with ventilation system. The pipes for heating runs along the façade and the sprinklers are the black pipes, running in H-shapes.

NOTHERN SHAFT

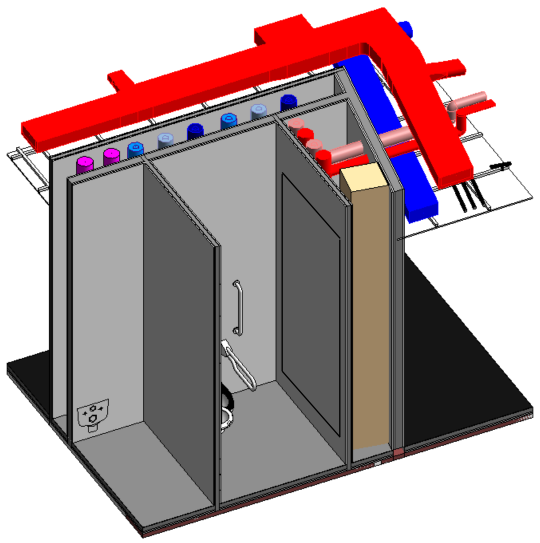
The northern shafts seen on figure 18, contains comfort ventilation (blue and red squares), fire ventilation (turkish blue squares), two set of domestic water risers including cold water, hot water, and circulation, cooling supply and return, solid waste which is collected in a container in the basement, roof drainage and a set of sprinkler risers. Each installation are installed with space for inspection and service.

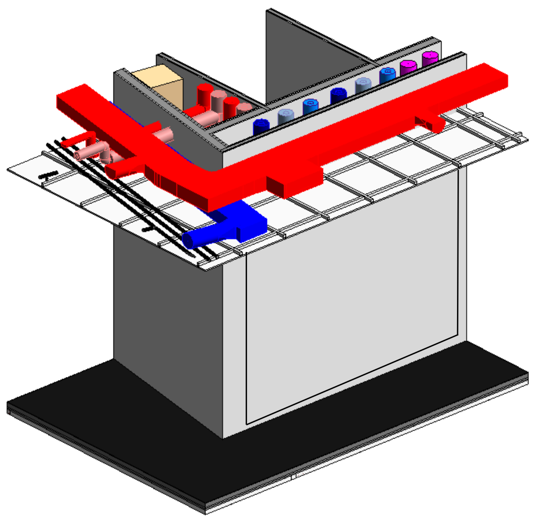
TOILET SHAFT

The northern toilet shaft, contains two sets of domestic water rises (cold, circulation and hot domestic water) and a set of sanitary drainage with double stack waste pipes to avoid pressure fluctuations. Further, the heat distribution pipes (supply and return) are placed near the handicap toilet with easy access to the rest of the floor and almost in the center of the building to decrease the horizontal distances in the piping to the radiators. The shaft has room for manifolds to distribute the heat to the radiators on the respective floors. Both shafts facing the toilets are designed with a thin wall, which easily can be taken off to assess the installations. This has been illustrated in the 3D-model below.

SOUTHERN SHAFT

The southern shaft accommodate comfort ventilation distribution, fire ventilation, and electronics. The electronics are placed here, so it is kept away from the wet risers in case of leaches. The dimensions given on the comfort ventilation ducts are the maximum sizes to make sure the ducts will fit into the shaft.





Pipe signature

Solid waste	Hose reel pipe
Dom. cold water	Sprinkler riser
Dom. circ. water	Sanitary drainage
Dom. hot water	Roof drainage
Heat – Supply	Cooling - Supply
Heat – Return	Cooling - Return
Wet riser	

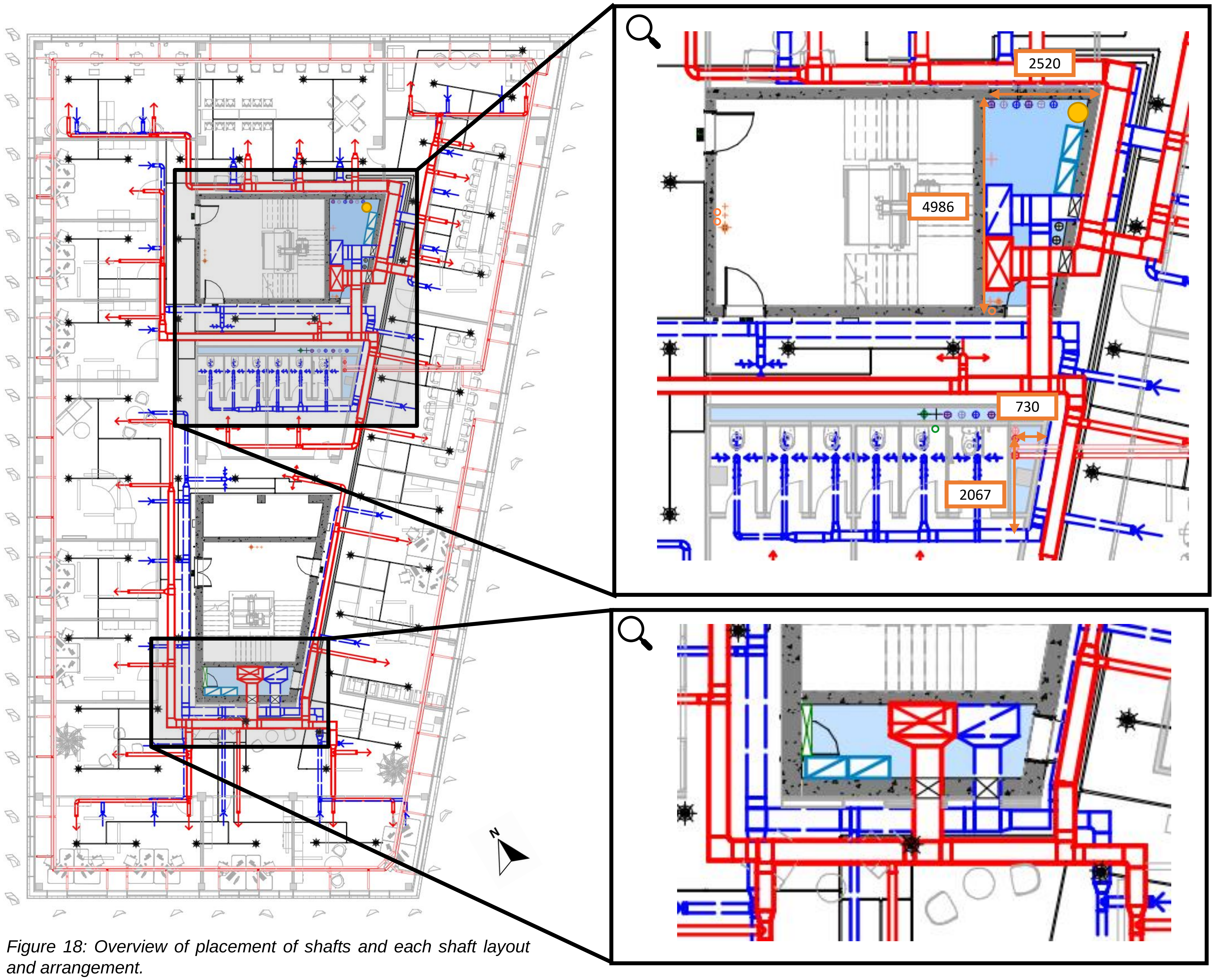


Figure 18: Overview of placement of shafts and each shaft layout and arrangement.

ARRANGEMENT

The building have 1205 m2 of technical room which are divided up in 4 different technical floors, two in the basement, one on the 7th floor and on one the 16th floor. By choosing this layout it have been possible to divide the ventilation up in six different zones and in this way reduce the vertical ventilation ducts. Furthermore, this division gives more space to fire installations throughout the building. An overview of the sizes of the different technical rooms can be seen in table 2. The technical floors in the basement account for 66% of the total area for technical rooms. The technical rooms on the 16th and 7th floor have space for two AHUs each, fire installations, expansions vessels and other equipment, floor plans can be seen in appendix F. The technical rooms in the basement accommodates all different type of technical installation that exist in the building and have partly double height.

AREA ALLOCATION

The areas for different service station are mainly based on the BSRIA handbook [12] and recommendations from the lectures [13]. An overview of the areas and how those are calculated can be seen in appendix G. The main pipes and ducts between the shafts and the service stations was modelled in Revit to ensure that the technical floors had sufficient space for those.

Location in Building	Area (m2)	Detailed location	Detailed Area (m2)
Basement	800	Level-1	250
		Level -2 (single height)	420
		Level -2 (double height)	130
Level 7	210	Level 7 - north	110
		Level 7 - South	100
Level 16	195	-	-
Area of all technical floor	1205		

Table 2: Overview of the areas for the technical rooms.

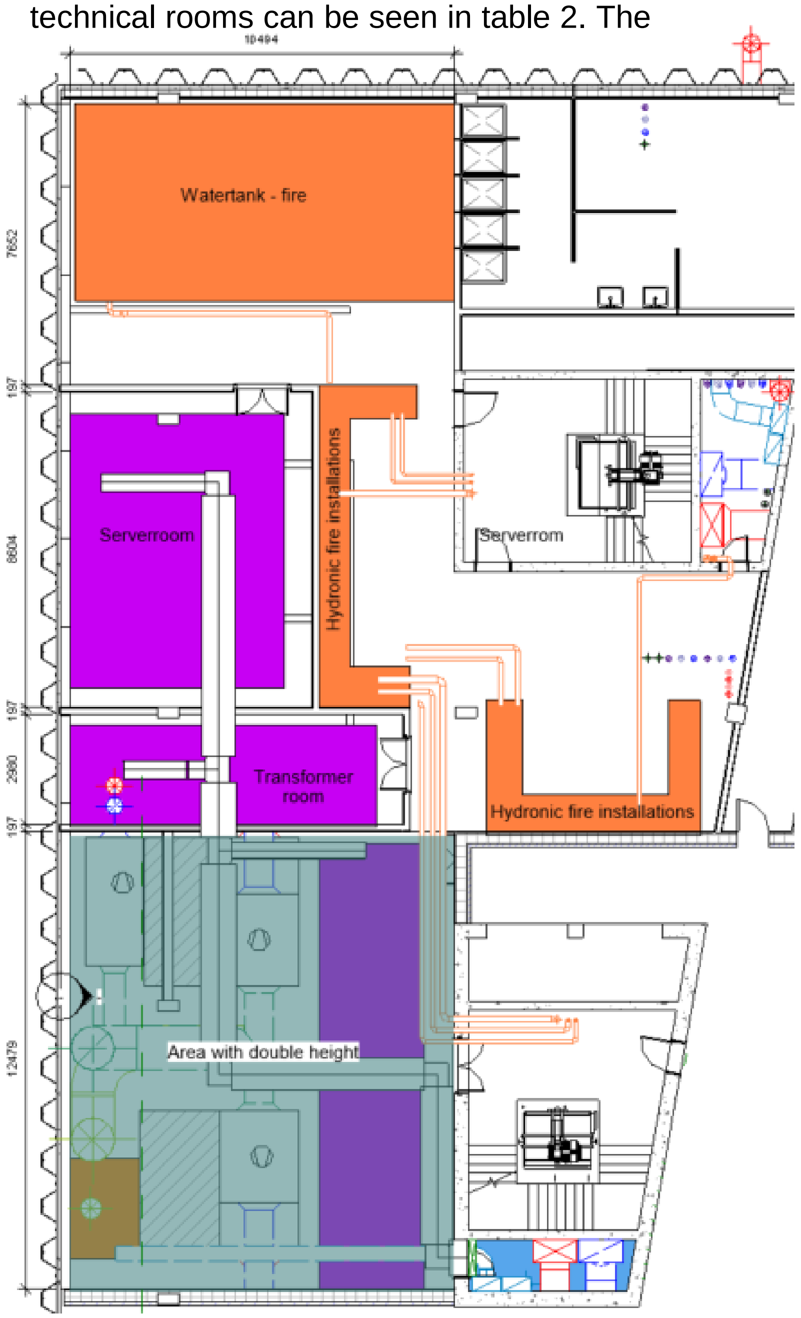


Figure 19: Floorplan over the technical room at level -1

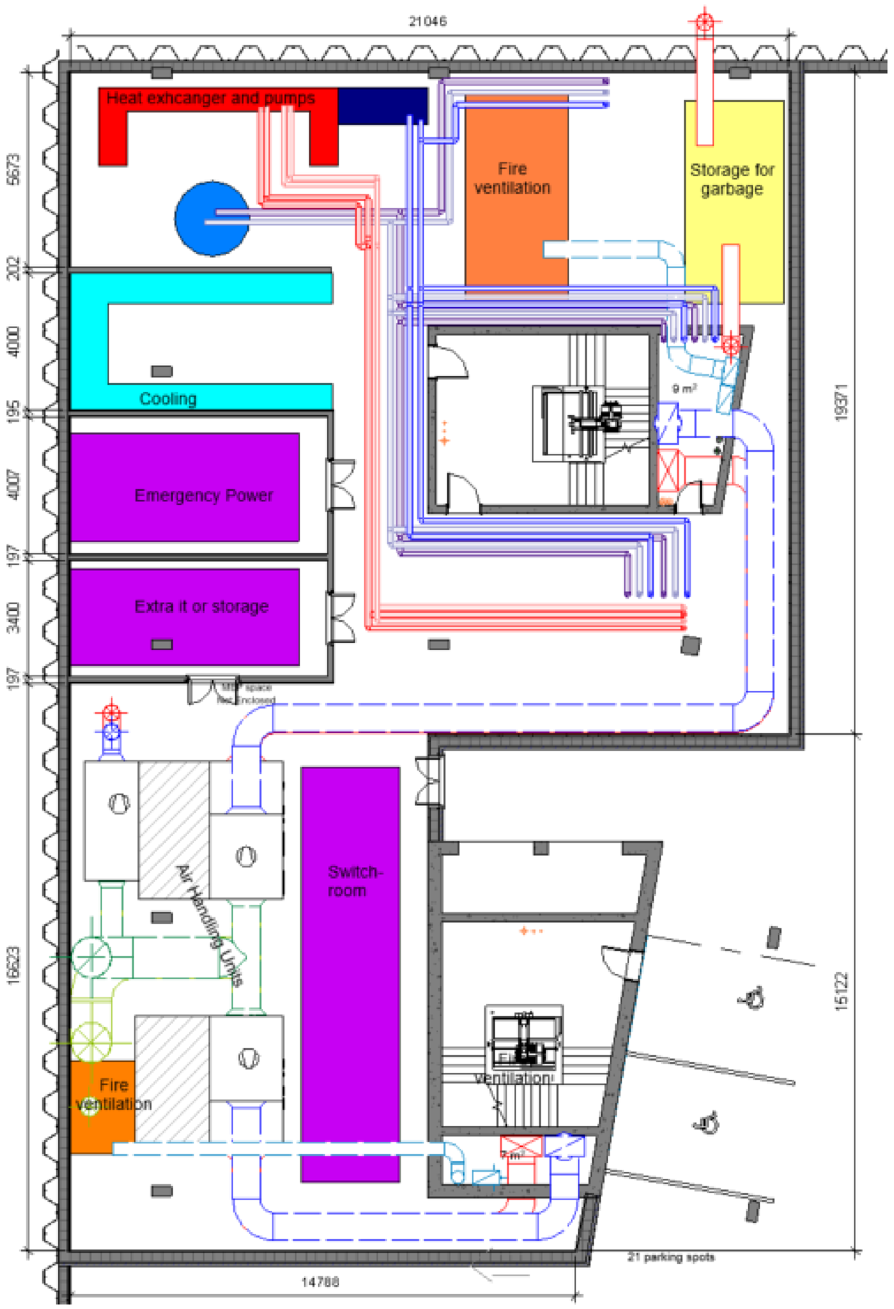
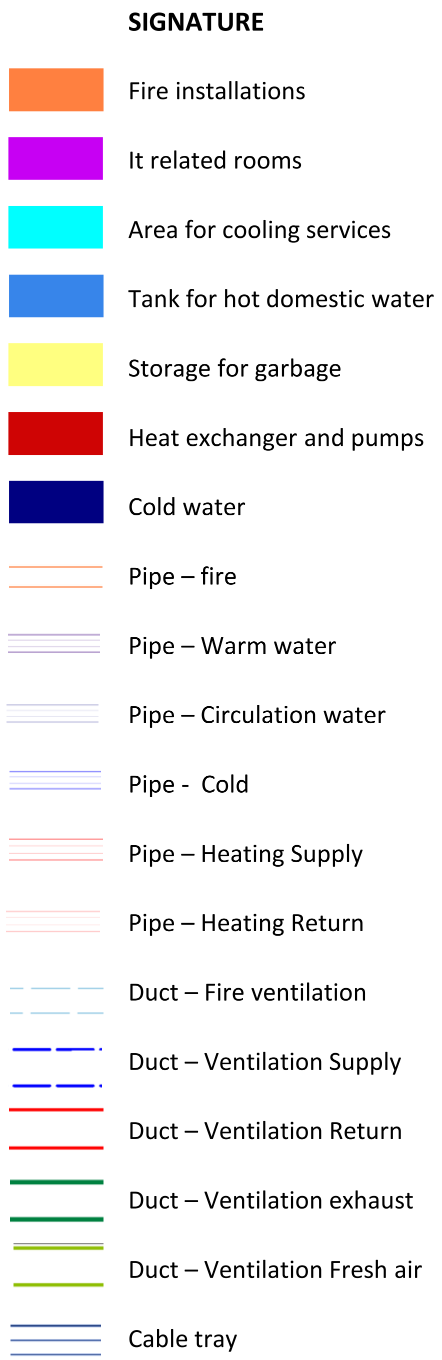


Figure 20: Floorplan over the technical room at level -2



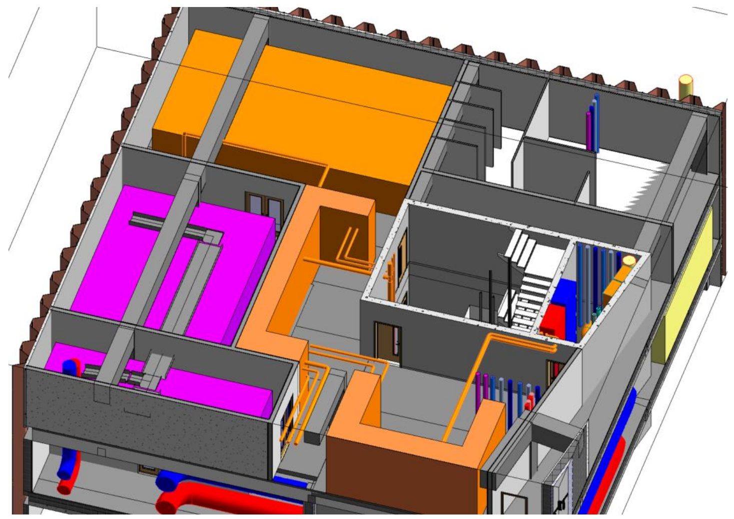


Figure 21: 3D view of the technical room in level -1. Main Pipes for hydronic fire installations and cable trays is drawn.

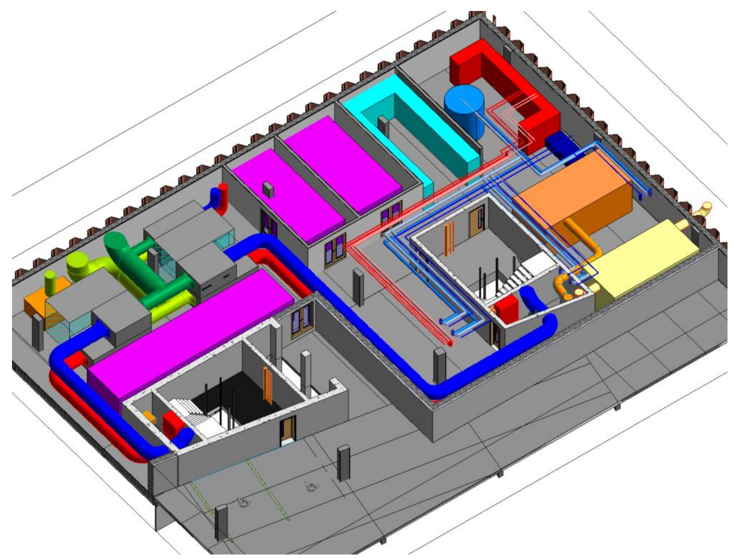


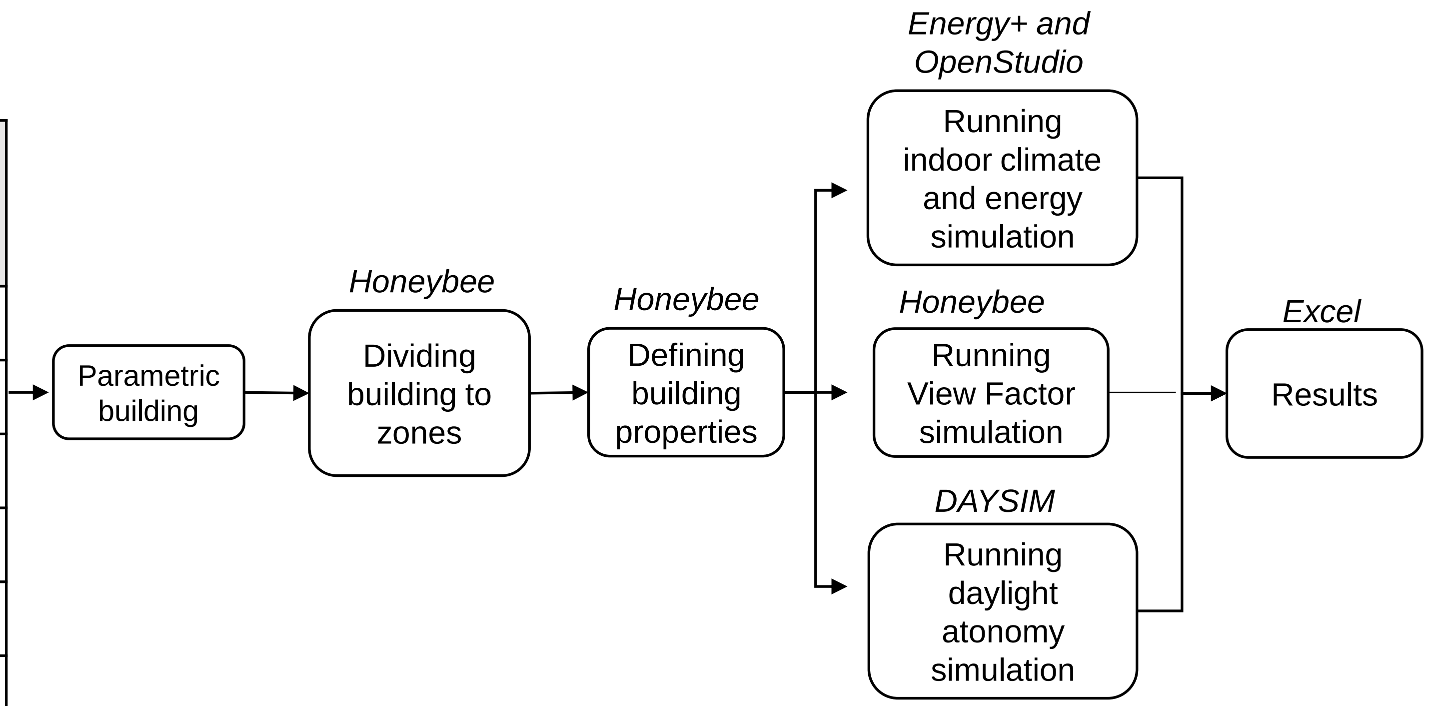
Figure 22: 3D view of the technical room on level -1, ducts for ventilation and main pipes for hydronic installations is drawn.

PARAMETERS OF THE SENSITIVITY ANALYSIS

The location, size and type of windows and shading have a big impact on the daylight levels in the building, view and overheating. It is important to choose the correct combination to achieve a satisfactory balance. To find the optimal combination a sensitivity study is carried out iterating through numerous different parameters to achieve an optimal design.

SIMULATION INPUTS

Simulation number	Glazing (%)	Shading overhang (cm)
1	30	1
2	30	2
	…	
4	30	None
	…	
20	60	None



Glazing Ratio $= \frac{\boldsymbol{Area_{window}}}{\boldsymbol{Area_{wall}}}$

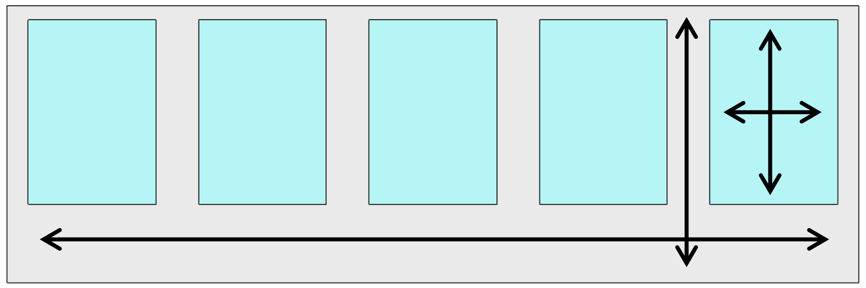


Figure 23: The glazing ration described the window and exterior wall relationship.

Distance between shadings

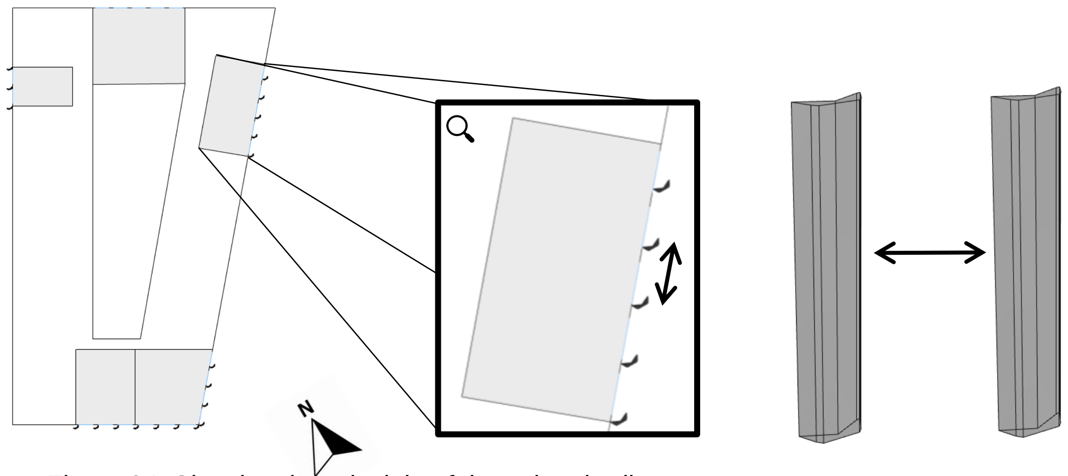


Figure 24: Showing the principle of the solar shadings.

SENSITIVITY ANALYSIS

The focus of the sensitivity analysis is to optimize the daylight, temperatures above 25, 26 and 27 C and the view factor. To regulate and optimize these factors a set of parameters are chosen which are the glazing percentage (figure 23) and the spacing between the vertical shades (figure 24) except on the north facade. The glazing percentages ranges from 20% to 60% with 10% step and for the spacing between the shades ranges from 1 to 4 m and 'no shading' with 1 m step, adding up to 20 simulations in total.

The simulation is run without surrounding building context as most of the office floors are not impacted by these in terms of daylight and energy. The lower floors which are impacted by the surroundings will be taken into account later in the report. Further, simulation input details can be seen in appendix H.

The tool used for the analysis is Grasshopper as it excels in running many simulations with multiple parameters but can also quickly become complex. The Grasshopper script is attached in the digital appendix. The flow chart to the left shows an overview of the script workflow. First of all, a parametric model of an office floor is modelled for quick adjustments geometry. The floor is then divided into critical zones, to minimize the amount of area to simulate, these can be seen on the next page on figure 25. Next, the properties of the building is defined. This step is very important as few assumptions can have big impact on the results. The model is then divided into thermal, daylight and view, where further properties are defined, and the simulation can take place. After each simulation, the results are stored in Excel, ready to be analyzed.

ANALYSIS AND RESULTS

All of the results of the sensitivity analysis are visualized in table 4 and the final optimized parameters are highlighted with green. The optimized values are generally chosen due to the design criteria of having 300 lux on 50% of the relevant floor area in 50% use time and the criteria of minimizing hours above 26 and 27. However, the daylight showed out to be the decisive factor in all zones, since a low DLA also resulted in less overheating. The view factor is included to extended the simulation and to make sure the shading was not taking too much of the view outside but did not end up playing a role in any of the designs.

The simulated zones are shown on the right, including, canteen, single office, open office and meeting room for an easy overview of the representative zones and their type and orientation. The final optimized parameters from table 4 (green) are collected in table 3.

Facade	Glazing [%]	Shade spacing [m]
North	50	No shades needed
East	30	2
South	40	4
West	50	2

Table 3: Final glazing values and shading distances on the office floor

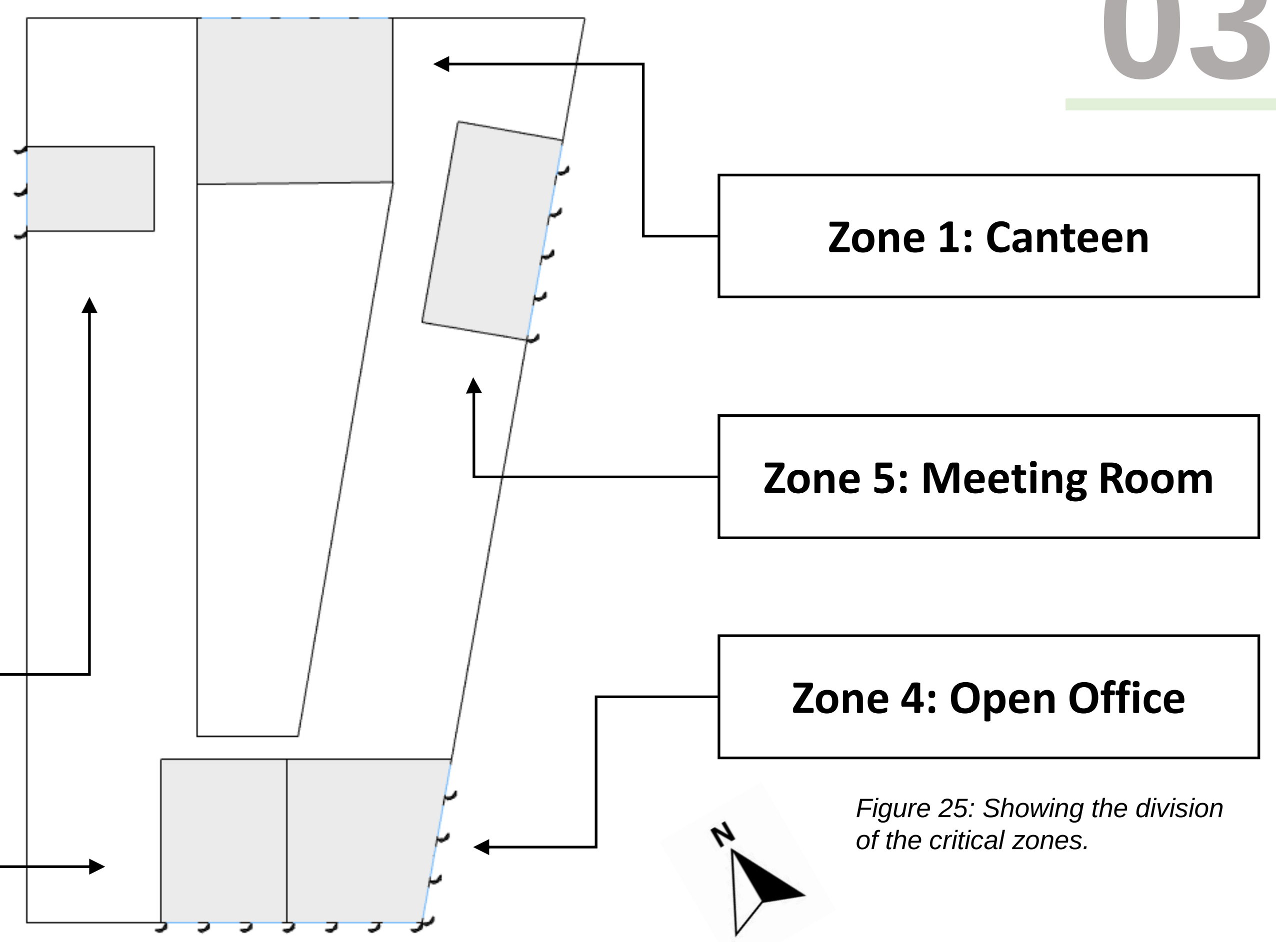


Figure 25: Showing the division of the critical zones.

Parameters		Daylight					Overheating															View				
		DLA					Temp > 27 [hours]					Temp > 26 [hours]					Temp > 25 [hours]					Average View Factor				
Glazing	Shade Spacing	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.3	1	✗ 31	✗ 17	✓ 62	✗ 29	✗ 31	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 0	✓ 4	✓ 0	✓ 0	✓ 0	91	38	0	65	154	60.71	65.03	60.9	61.92	63.78
0.3	2	✗ 31	✗ 40	✗ 33	✓ **88**	✓ **67**	✓ 0	✓ 3	✓ 0	✓ **0**	✓ **0**	✓ 0	✓ 16	✓ 0	✓ **2**	✓ **18**	91	194	104	**831**	**829**	60.71	65.55	61.71	**63.51**	**64.85**
0.3	3	✗ 31	✗ 33	✗ 33	✓ 82	✓ 58	✓ 0	✓ 1	✓ 0	✓ 0	✓ 0	✓ 0	✓ 11	✓ 0	✓ 1	✓ 1	91	112	64	715	829	60.71	65.51	61.7	63.41	64.81
0.3	4	✗ 31	✗ 40	✗ 33	✓ 91	✓ 71	✓ 0	✓ 3	✓ 0	✓ 0	✓ 0	✓ 0	✓ 17	✓ 0	✓ 3	✓ 21	91	215	147	957	889	60.71	65.67	61.89	63.93	65.15
0.3	No Shade	✗ 31	✗ 40	✗ 33	✓ 91	✓ 67	✓ 0	✓ 4	✓ 0	✓ 0	✓ 0	✓ 0	✓ 17	✓ 0	✓ 5	✓ 29	91	227	184	1024	994	60.71	60.82	62.01	64.18	65.47
0.4	1	✗ 38	✗ 33	✗ 29	✓ 79	✓ 58	✓ 0	✓ 2	✓ 0	✓ 0	✓ 0	✓ 0	✓ 12	✓ 0	✓ 0	✓ 1	220	158	1	444	504	61.18	65.21	61.13	62.5	64.09
0.4	2	✗ 38	✗ 40	✗ 46	✓ 97	✓ 96	✓ 0	✓ 10	✓ 0	✓ 0	✓ 0	✓ 0	✓ 35	✓ 0	✗ 125	✗ 132	220	355	303	1226	1138	61.18	65.74	62.04	64.15	65.21
0.4	3	✗ 35	✗ 40	✗ 42	✓ 91	✓ 87	✓ 0	✓ 8	✓ 0	✓ 0	✓ 0	✓ 0	✓ 28	✓ 0	✓ 75	✓ 81	220	299	308	1176	1049	61.18	65.74	62.09	64.15	65.22
0.4	4	✗ 38	✗ 40	✓ **50**	✓ 97	✓ 92	✓ 0	✓ 10	✓ **0**	✓ 0	✓ 0	✓ 0	✓ 40	✓ **0**	✗ 218	✗ 166	219	395	**398**	1397	1232	61.18	65.87	**62.3**	64.68	65.57
0.4	No Shade	✗ 35	✗ 40	✓ 50	✓ 100	✓ 96	✓ 0	✓ 13	✓ 0	✓ 0	✓ 0	✓ 0	✓ 43	✓ 0	✗ 269	✗ 203	219	417	488	1468	1348	61.18	66.06	62.45	64.96	65.94
0.5	1	✓ 50	✗ 40	✗ 33	✓ 91	✓ 75	✓ 0	✓ 7	✓ 0	✓ 0	✓ 0	✓ 0	✓ 28	✓ 0	✓ 1	✓ 34	353	273	69	766	786	61.67	65.48	61.39	62.93	64.33
0.5	2	✓ 50	✓ **53**	✓ 50	✓ 100	✓ 100	✓ 0	✓ **19**	✓ 0	✓ 0	✓ 1	✓ 0	✓ **67**	✓ 0	✗ 358	✗ 263	352	**476**	499	1463	1349	61.67	**66.03**	62.33	64.6	65.47
0.5	3	✓ 50	✓ 53	✓ 50	✓ 100	✓ 100	✓ 0	✓ 19	✓ 0	✓ 0	✓ 0	✓ 0	✓ 67	✓ 1	✗ 387	✗ 249	353	476	596	1508	1345	61.67	66.2	62.49	64.8	65.6
0.5	4	✓ 50	✓ 60	✓ 50	✓ 100	✓ 100	✓ 0	✓ 23	✓ 0	✓ 2	✓ 15	✓ 0	✓ 86	✓ 2	✗ 541	✗ 335	352	543	643	1668	1497	61.67	66.25	62.65	65.3	65.92
0.5	No Shade	✓ **50**	✓ 60	✓ 50	✓ 100	✓ 100	✓ **0**	✗ 27	✓ 0	✓ 4	✗ 36	✓ **0**	✗ 104	✓ 13	✗ 642	✗ 413	**352**	575	788	1800	1653	**61.67**	66.53	62.88	65.7	66.4
0.6	1	✓ 50	✗ 40	✗ 46	✓ 97	✓ 87	✓ 0	✓ 9	✓ 0	✓ 0	✓ 0	✓ 0	✓ 40	✓ 0	✓ 11	✗ 113	506	318	199	929	986	62.14	65.59	61.62	63.24	64.64
0.6	2	✓ 50	✓ 60	✓ 50	✓ 100	✓ 100	✓ 0	✗ 28	✓ 0	✓ 1	✗ 35	✓ 0	✗ 117	✓ 8	✗ 439	✗ 385	507	571	681	1538	1546	62.14	66.13	62.56	64.93	65.79
0.6	3	✓ 50	✓ 60	✓ 58	✓ 100	✓ 100	✓ 0	✗ 29	✓ 0	✓ 5	✗ 51	✓ 0	✗ 118	✓ 56	✗ 663	✗ 421	507	563	891	1762	1604	62.14	66.39	62.9	65.38	66.05
0.6	4	✓ 50	✓ 60	✓ 58	✓ 100	✓ 100	✓ 0	✗ 29	✓ 0	✗ 38	✗ 77	✓ 0	✗ 152	✓ 30	✗ 808	✗ 505	506	658	828	1936	1718	62.14	66.52	62.97	65.83	66.32
0.6	No Shade	✓ 50	✓ 60	✓ 67	✓ 100	✓ 100	✓ 0	✗ 35	✓ 0	✗ 141	✗ 148	✓ 0	✗ 180	✗ 117	✗ 946	✗ 643	506	724	1052	2086	1894	62.14	66.72	63.3	66.37	66.9

Table 4: Sensivity analysis results for the 5 zones during a year measured upon DLA, overheating and view. Settings not complying with the design criteria are marked with a red cross and if complying marked with a green check. The chosen settings are marked with green.

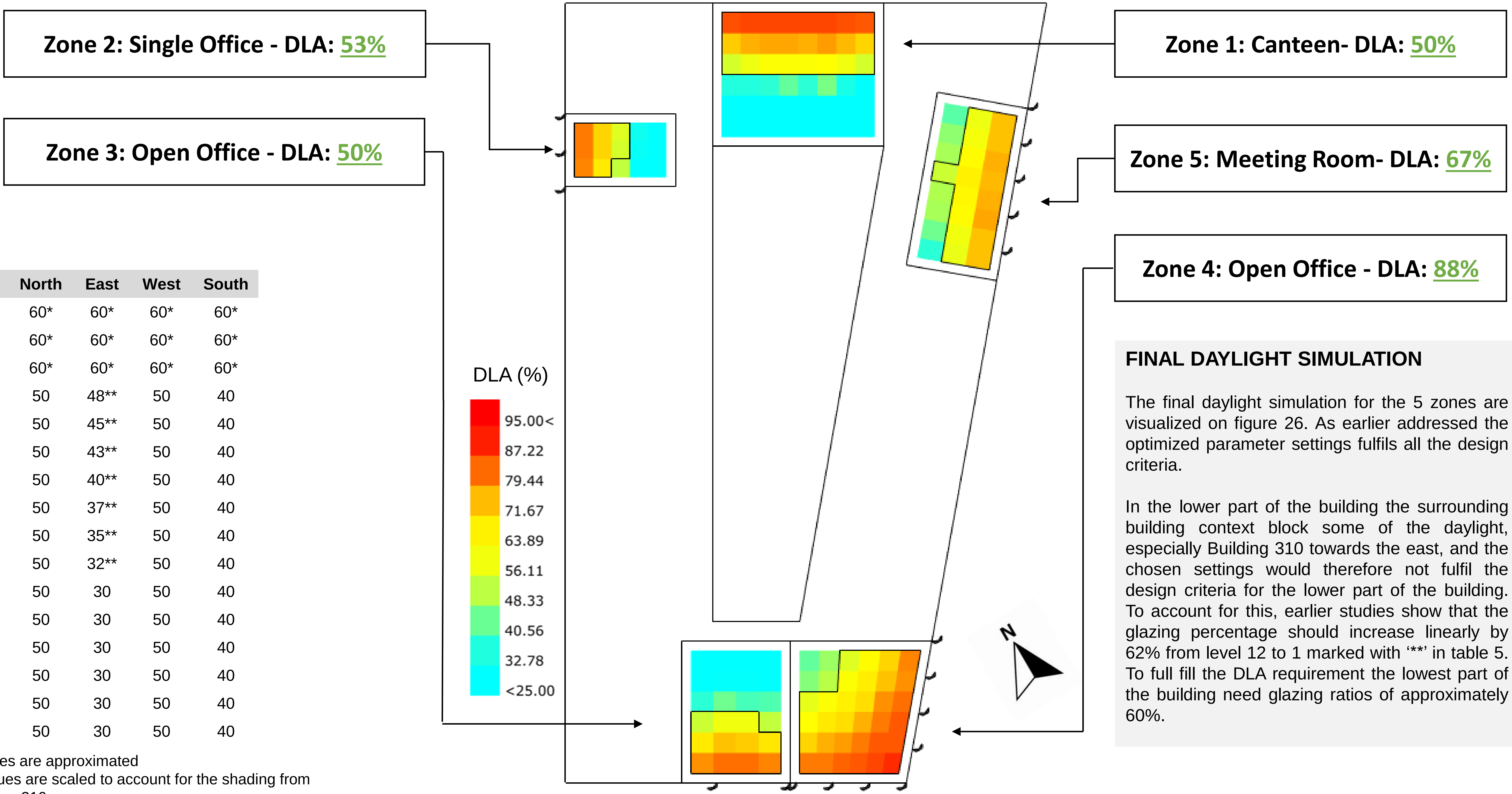


Figure 26: The final simulation for the five zones. The black line shows the boundary on where the 300 lux are present 50% of the time.

Floor	North	East	West	South
1	60*	60*	60*	60*
2	60*	60*	60*	60*
3	60*	60*	60*	60*
4	50	48**	50	40
5	50	45**	50	40
6	50	43**	50	40
7	50	40**	50	40
8	50	37**	50	40
9	50	35**	50	40
10	50	32**	50	40
11	50	30	50	40
12	50	30	50	40
13	50	30	50	40
14	50	30	50	40
15	50	30	50	40
16	50	30	50	40

*Values are approximated
**Values are scaled to account for the shading from Building 310

Table 5: Glazing percentages for the different levels in the building varying with llevel and orientation.

FINAL DAYLIGHT SIMULATION

The final daylight simulation for the 5 zones are visualized on figure 26. As earlier addressed the optimized parameter settings fulfils all the design criteria.

In the lower part of the building the surrounding building context block some of the daylight, especially Building 310 towards the east, and the chosen settings would therefore not fulfil the design criteria for the lower part of the building. To account for this, earlier studies show that the glazing percentage should increase linearly by 62% from level 12 to 1 marked with '**' in table 5. To full fill the DLA requirement the lowest part of the building need glazing ratios of approximately 60%.

Window specification for Schüco Nordic Alu-inside

g-value	U-value [W/m2*K]	Light Transmittance
0.37	0.70	0.70

For further information see appendix D, datasheet number 3.

ENERGY AND OPERATIVE TEMPERATURE

Figure 27 shows the cooling and heating in the five zones during a year. The fan coils are set to turn on in May to September to avoid running heating and cooling at the same time. The heating demand is high during the winter and the cooling demand relatively lower during the summer, which may be due to the shading, as it will minimize the radiation during the summer or that the glazing is too large, which may increase the heat loss.

The operative temperature during the year is optimized to comply with BR18 and have less than 100 hours above 26 (orange dotted line) and less than 50 hours above 27 (red dotted line), which can be seen in figure 28.

The most critical day regarding overheating is showed in figure 29, where Zone 1 is the only room where the temperature exceed 27 C.

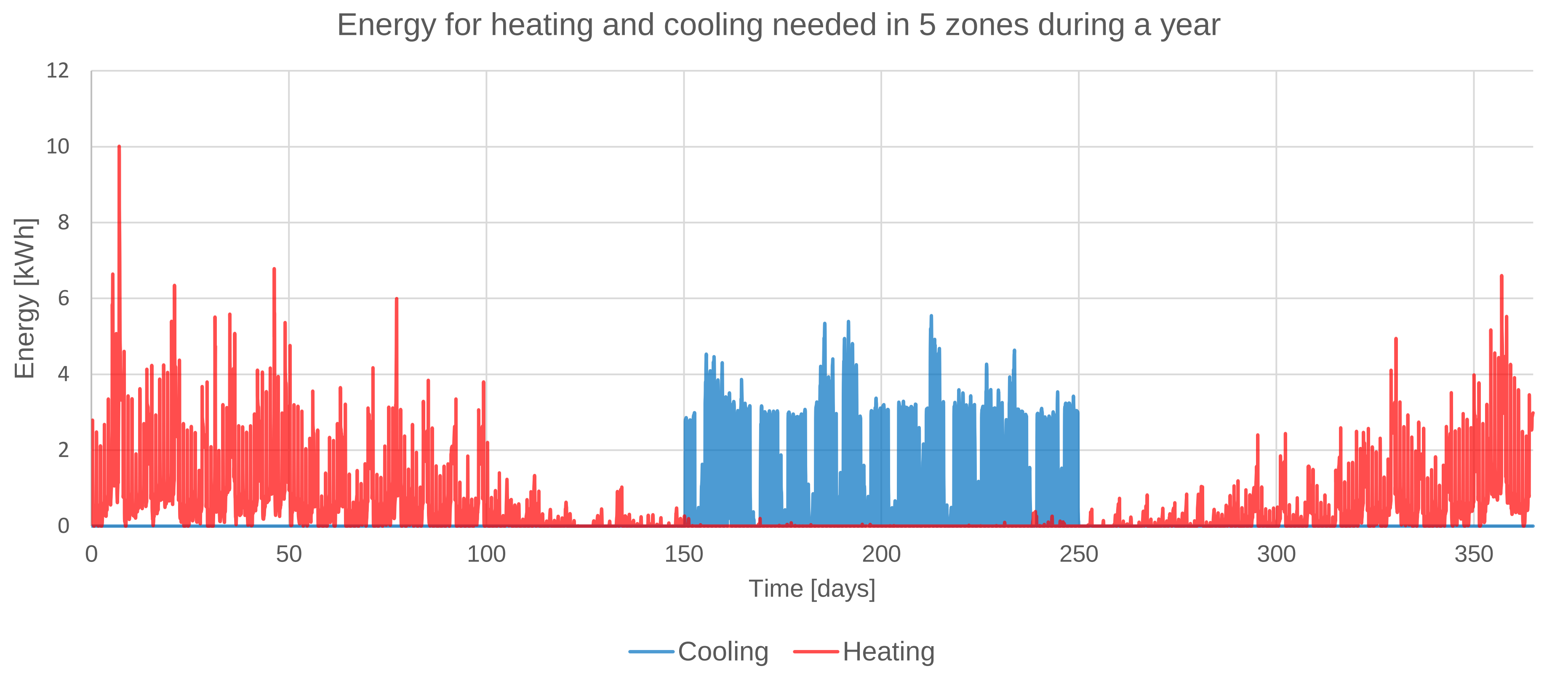


Figure 27: The final energy simulation showing the energy for cooling and heating during a year.

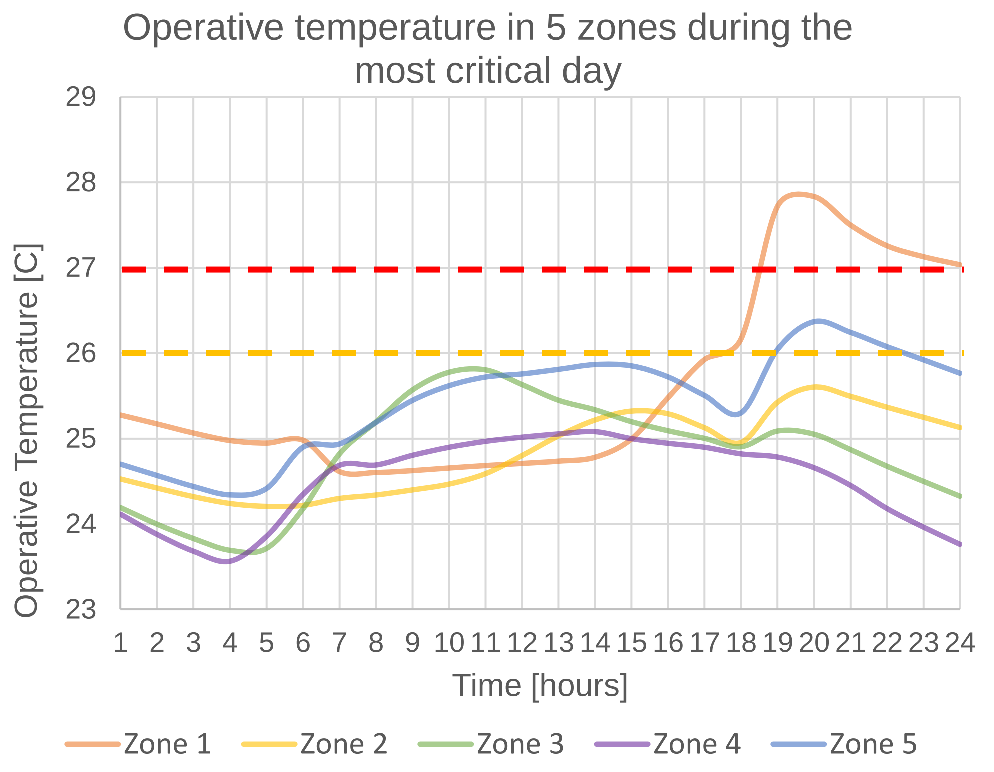


Figure 29: The final thermal simulation showing the operative temperature during a day for the 5 zones.

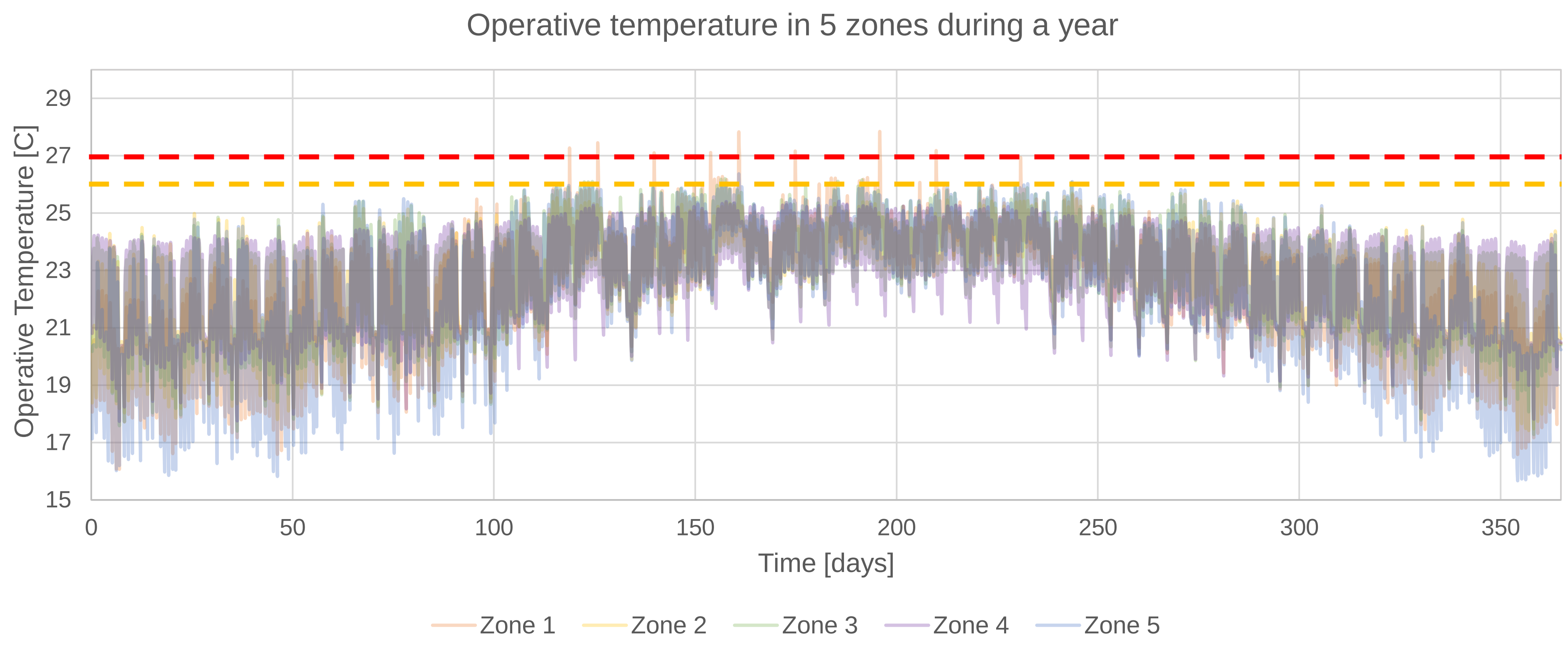


Figure 28: The final thermal simulation showing the operative temperature during the year for the 5 zones.

CHOICES AND ASSUMPTIONS

For the Be18 energy frame calculation several assumptions and choices has been made. These assumptions are stated in appendix I, and further supporting calculations can be seen in the following appendices. The glass ratios are found through the sensitivity analysis to fit the different levels of the building, and the glazing areas can be seen in appendix J.

As seen in figure 30 the Low Energy Frame is met with a total energy requirement of exactly 33.0 kW/m2/year. This goal is reached by having low U-values for the building envelope and low g-values for the windows to shut out the solar heating and thus avoid a too high use of mechanical cooling. Further, optimization of the air handling units' SFP-values and heat recovery rates has been an important factor to bring down the energy use for ventilators. Zones where daylight is controlled by the daylight sensor in the room, showed out to bring down the electricity requirements for lightning as well. Additionally, the solar shading panels has had a smaller positive impact too.

This goal has been reached without using solar panels. If solar panels are wanted, they can still be added, and they would decrease the required energy consumption even further.

The specific input and the complete key value documents can be found in appendix N.

In figure 31 the energy frame is calculated using a correction factor of 100% instead of 50% when calculating the building envelope U-values. This assumption is crucial in relation to being within the Low Energy Frame. Though, if the higher U-values are used, the building have an energy use lower than 41.1 kWh/m2/year, which is the threshold for the BR 2018 Energy Frame.

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	0,0	33,0
Total energy requirement		34,1

Figure 31: Screenshot of the key numbers in kWh/m2 year for the energy frame calculation when using a correction factor of 100% for the different building envelope U-values calculated in appendix L.

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
95,1	0,0	95,1
Total energy requirement		33,0

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
71,4	0,0	71,4
Total energy requirement		33,0

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
41,1	0,0	41,1
Total energy requirement		33,0

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	0,0	33,0
Total energy requirement		33,0

Contribution to energy requirement

Heat	15,4
El. for operation of bulding	10,5
Excessive in rooms	0,0

Net requirement

Room heating	8,9
Domestic hot water	6,5
Cooling	1,9

Selected electricity requirements

Lighting	5,7
Heating of rooms	0,0
Heating of DHW	0,4
Heat pump	0,0
Ventilators	3,5
Pumps	0,5
Cooling	0,7
Total el. consumption	23,9

Heat loss from installations

Room heating	0,0
Domestic hot water	1,2

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Figure 30: Screenshot of the key numbers in kWh/m2 year for the energy frame calculation made in Be18.

REFLECTION OF METHODS

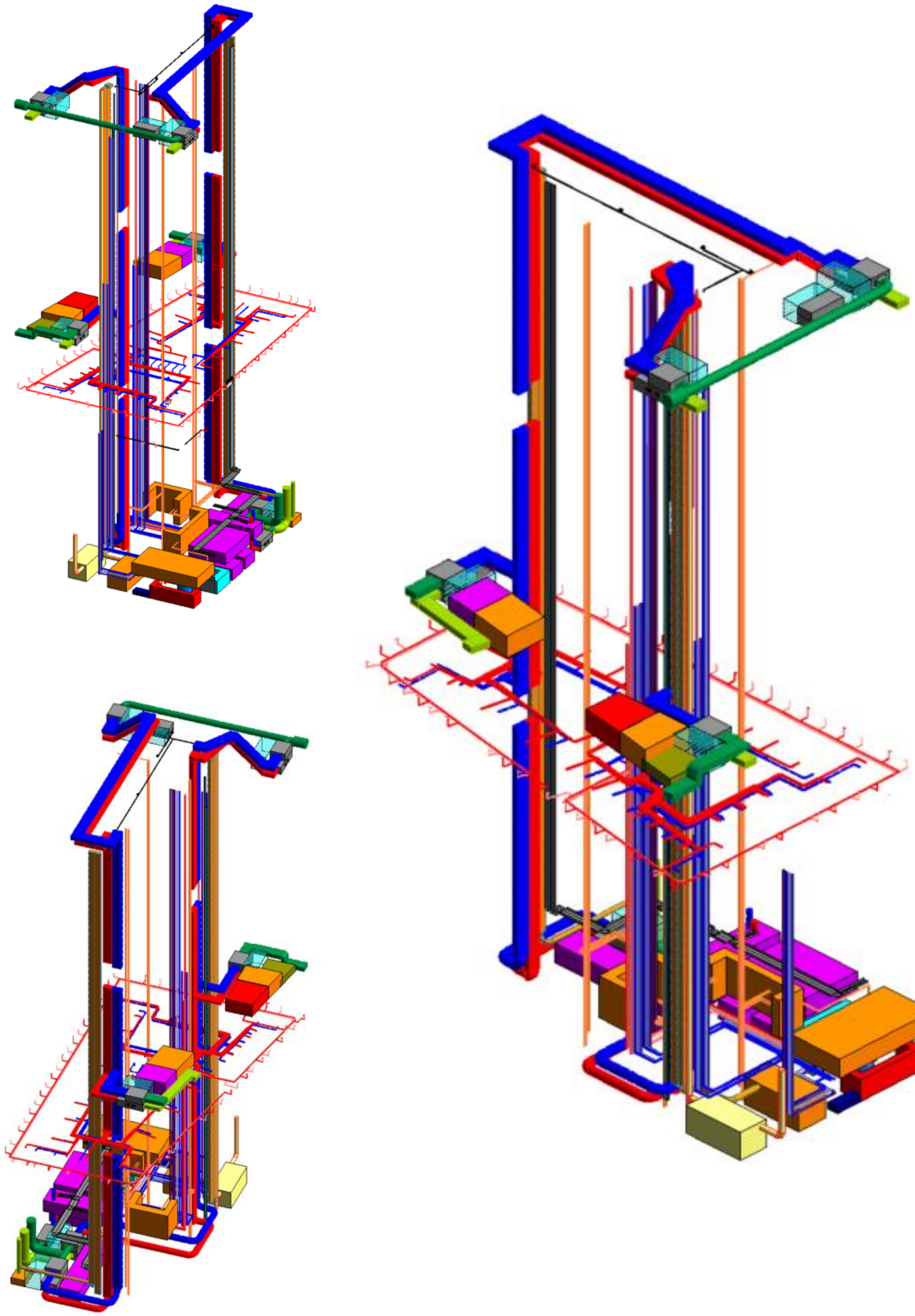
The design phase of building 313 has involved thorough communication with the entire team and challenging decisions. Many of the decisions impact each other which makes it a complex task to fulfill all the requirements for each subject. A major learning has been to realize the importance of decisions in the early design stage as those can be difficult to change later on. A great tool for us has been Rhino/Grasshopper, as the parametric models are very effective once they are constructed, however it has mainly been used by our subject, and if the rest of the subjects could have utilized the parametric model in Rhino and integrated their analysis tools this could have benefitted the design process in many aspects.

FINAL SOLUTION

All our solution has been focusing primarily on a creating a coherent MEP system that fulfills all the requirements, including the three main criteria; cost, time, and sustainability. Some particular solutions have been to use fan coils for cooling as they are cheaper than a regular cooled ceiling, rather effective to regulate the temperature, flexible if one is defect to replace. On the other hand, they can emit noise to the environment, they must be serviced regularly to remove excess condensation water and takes up space from the suspended ceiling. Which show that not all solutions are perfect and choosing a solution requires prioritizing. Still, there remain unsolved details which must be further concretized in the next steps of the design phase.

CONCLUSION

Our main goal of making an overall coherent MEP system that fulfills all the requirements, including the three main criteria; cost, time, and sustainability as well as fulfilling the Danish Building Regulation from 2018 and Indoor Climate Category II (DS/EN 16798), has been accomplished in close collaboration with the remaining subjects 1, 2, and 5. The complete MEP system is shown to the right and is successfully integrated in the building model.



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Level	Zone	Ventilation demand [l/s] (EN/DS 16798-1)	People load (EN/DS 16798-1)	People load according to arc/fire plans	%-difference	Concurrency factor used for dimensioning	Ventilation demand with concurrency factor [l/s]	Ventilation demand in zone
Level 0	Zone 3	3071	291	200	0.69	0.7	2149.84	
Level 1		2534	211	170	0.81	0.85	2153.815	
Level 2		5362	612	340	0.56	0.6	3217.02	
Level 3		2795	91	60	0.66	0.7	1956.78	9477.455
Level 4	Zone 2	1449	104	47	0.45	0.7	1014.51	
Level 5		1449	104	47	0.45		1014.51	
Level 6		1449	104	47	0.45		1014.51	
Level 7		2059	193	95	0.49		1441.51	
Level 8		1477	108	60	0.56		1034.18	
Level 9		1477	108	60	0.56		1034.18	
Level 10		1477	108	60	0.56		1034.18	7587.58
Level 11	Zone 1	1477	108	60	0.56	0.7	1034.18	
Level 12		1477	108	60	0.56		1034.18	
Level 13		1477	108	60	0.56		1034.18	
Level 14		1477	108	60	0.56		1034.18	
Level 15 Sky Bar		2978	331	80	0.24		2084.53	
Level 16 Sky Bar		2423	252	35	0.14		1696.31	7917.56
SUM		35912	3048	1541	0.51		24983	

Table A1: Overview of the ventilation of different level according to DS/EN 16798, occupancy loads and concurrency factors.

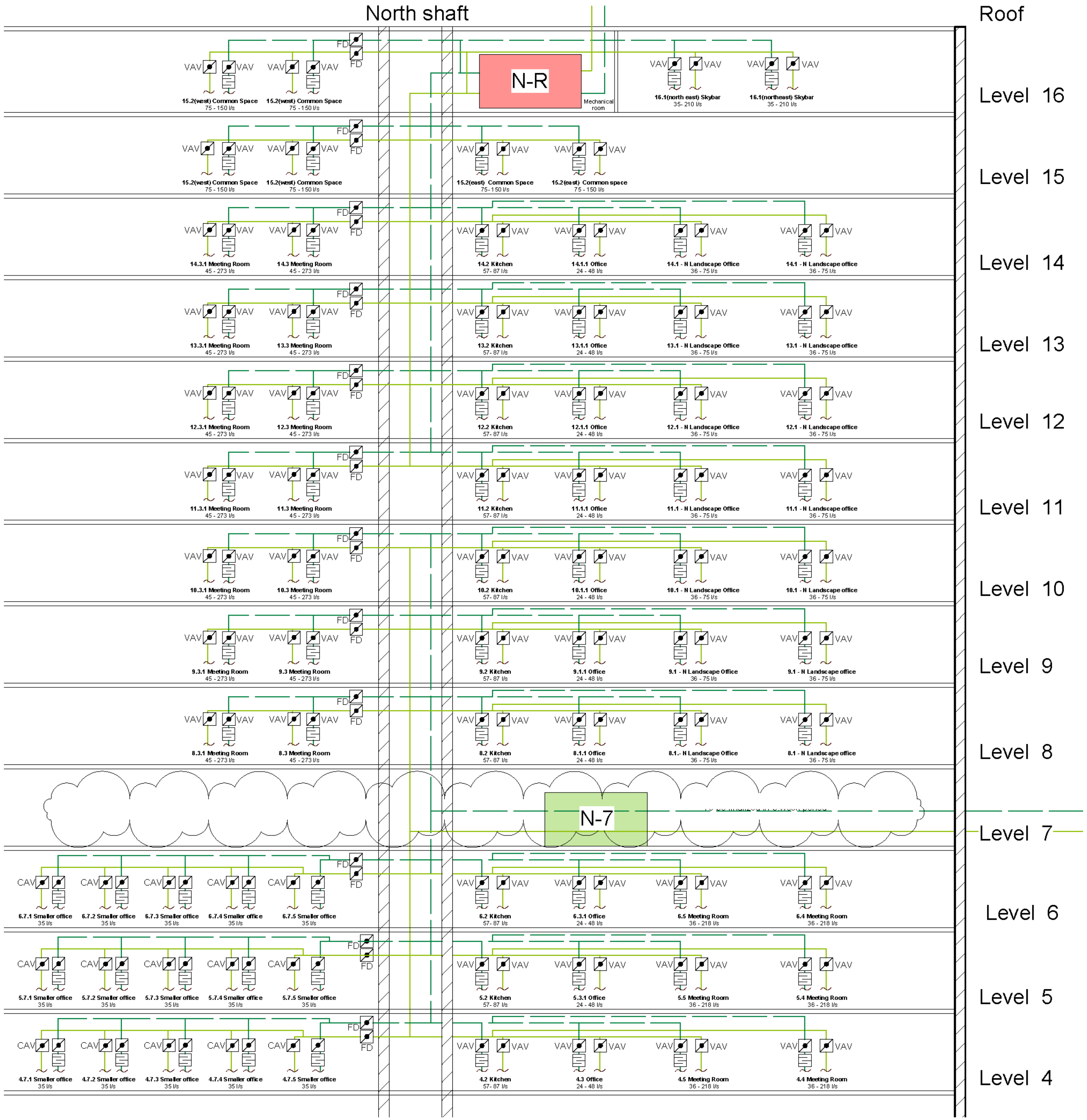
Space type	Ventilation rate	Person/area	Note	Area
Corridors	0.7 $l/(s \cdot m^2)$	-	Table B.6 - EN/DS 16798-2	3576
Office rooms	1.4 $l/(s \cdot m^2)$	10 m^2/person	Table B.6 - EN/DS 16798-2	5089
Mixed area	1.2 $l/(s \cdot m^2)$	15 m^2/person	Table B.6 - EN/DS 16798-2	3550
Meeting rooms and printer room	4.2 $l/(s \cdot m^2)$	2 m^2/person	Table B.6 - EN/DS 16798-2 And assumption	1915
Gym	5 $l/(s \cdot m^2)$	5 m^2/person	Assumption, based on other room types	352
Restaurant	5.4 $l/(s \cdot m^2)$	1.5 m^2/person	Table B.6 - EN/DS 16798-2	1064
Kitchen	4.2 $l/(s \cdot m^2)$	-	Assumption, based on other room types	103
Toilet	10 $l/(s \cdot toilet)$	0 m^2/person	From table B.13 in EN/DS 16798-1	204
Auditoriums	10 $l/(s \cdot m^2)$	0.75 m^2/person	Table B.6 - EN/DS 16798-2	517
Technical rooms & shaft	0.7 $l/(s \cdot m^2)$	-	Table B.6 - EN/DS 16798-2	1439
Shower room	5 $l/(s \cdot m^2)$	-	From table B.13 in EN/DS 16798-1 and assumtion	73

Table A2: Overview of different space assigned to different spaces on all unique floors in Revit. The unique floors are the ground floor, level 1-4, level 7, level 8, level 15 and level 16. Level 4-6 have the one layout and level 8-14 have another layout, that are the same for those floors.

Appendix B – Schematic ventilation drawing

Table B1: The figure shows the principle of the distribution of air from the AHU's placed on the level 16 and 7 respectively. It is seen that for all meeting rooms and landscape offices CAV ventilation are used, where for bigger landscape offices VAV are used to accommodate different occupancies. Fire dampers are placed at all horizontal shaft that goes in or out of the shafts. Silencers are placed where the ducts runs from the corridors to the rooms.

The AHUs at the level 7 and 16 have intake and discharge through the façade, where the AHUs in the basement have intake and discharge through light shafts in the terrain.



Signature

- Ventilation duct - return
- Ventilation duct - supply
- CAV – Constant Air Volume Damper
- VAV – Variable Air Volume Damper
- FD – Fire Damper
- Silencer

Northern system		
Horizontal ducts		
	0.30	
	1.62	
	0.65	
	1.09	
	1.18	Pa
	0.94	
	1.10	
	0.84	
	1.88	
	0.35	
Total	*9.95Pa*	
Vertical ducts		
Length	11.6m	
Friction	0.6Pa/m	
Total	*7.0Pa*	
Pressure drop from one AHU		
Totalt pressure loss for the system	**16.9Pa**	
With 25% correction for elbows and branches	**21.1 ≈ 21Pa**	

Southern system		
Horizontal ducts		
	0.90	
	1.38	
	2.39	
	1.34	Pa
	1.12	
	0.12	
	1.22	
	0.98	
Total	*9.45Pa*	
Vertical ducts		
Length	11.60m	
Friction	0.50Pa/m	
Total	*7.0Pa*	
Pressure drop from one AHU		
Totalt pressure loss for the system	**16.4Pa**	
With 25% correction for elbows and branches	**20.5 ≈ 21Pa**	

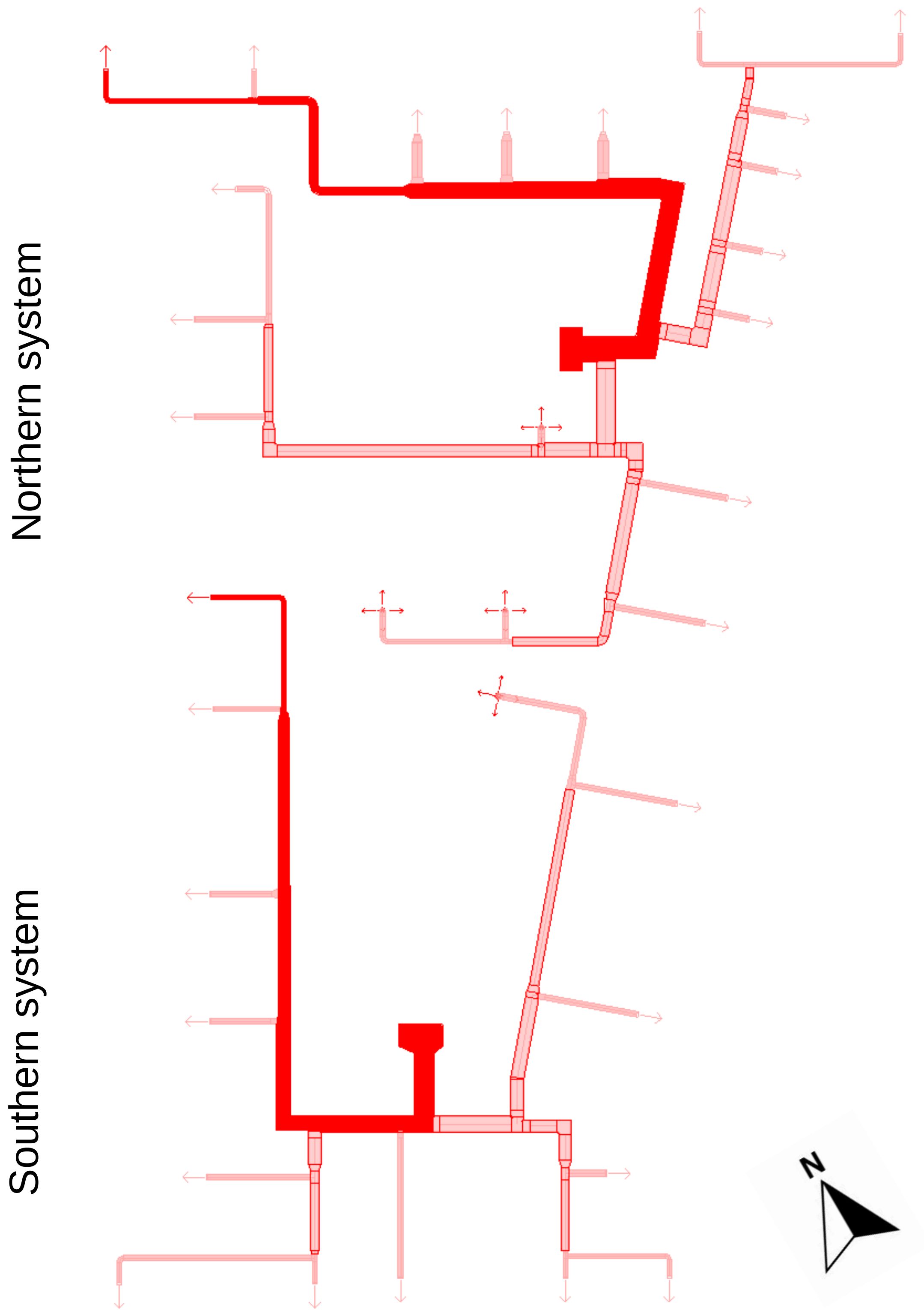


Figure C1: Highlighting the routes to the farthest air terminal for both the northern and southern system.

Appendix D – Links to datasheets

Datasheet number	Element	Link	Note
1	AHU	https://shop.systemair.com/upload/assets/GENIOX_CATALOGUE_GLOBAL_2020_E2602.PDF	On page 14 approximately sizes is noted for a Geniox AHU form systemair. In the project 4 size 24 is used and 2 size 27. The exact sizes of the units is calculated with systemair .
2	Fan Coil Unit	https://shop.systemair.com/upload/assets/54624_IOM_SYSCOIL2_01-N-3GB.PDF	
3	Windows	https://energivinduer.dk/wp-content/uploads/sites/3/536-1.pdf	
4	Jet fans	https://www.novenco-building.com/media/1331/jet-fans-cat-gb-mu16102-0621.pdf	

	Level	Alti- tude [m]	Static pressure [kPa]				
			Riser 1	Riser 2	Riser 3	Riser 4	Riser 5
Sky bar	16	64	0				
	15	60	40				
Tower	14	56	80		0		
	13	52	120		40		
	12	48	160		80		
	11	44	200		120		
	10	40	240		160		
	9	37	270		190		
	8	33		0		0	
	7	29		40		40	
	6	25		80		80	
	5	21		120		110	
	4	17		160		150	
	3	14		190			0
Pedestal	2	10		230			40
	1	6		270			80
	0	0		330			110
Basement	-1	-4					150

Table E1: Statical Pressure of the five vertical risers, calculated under the assumptions that the static pressure riser 10 kPa/m.

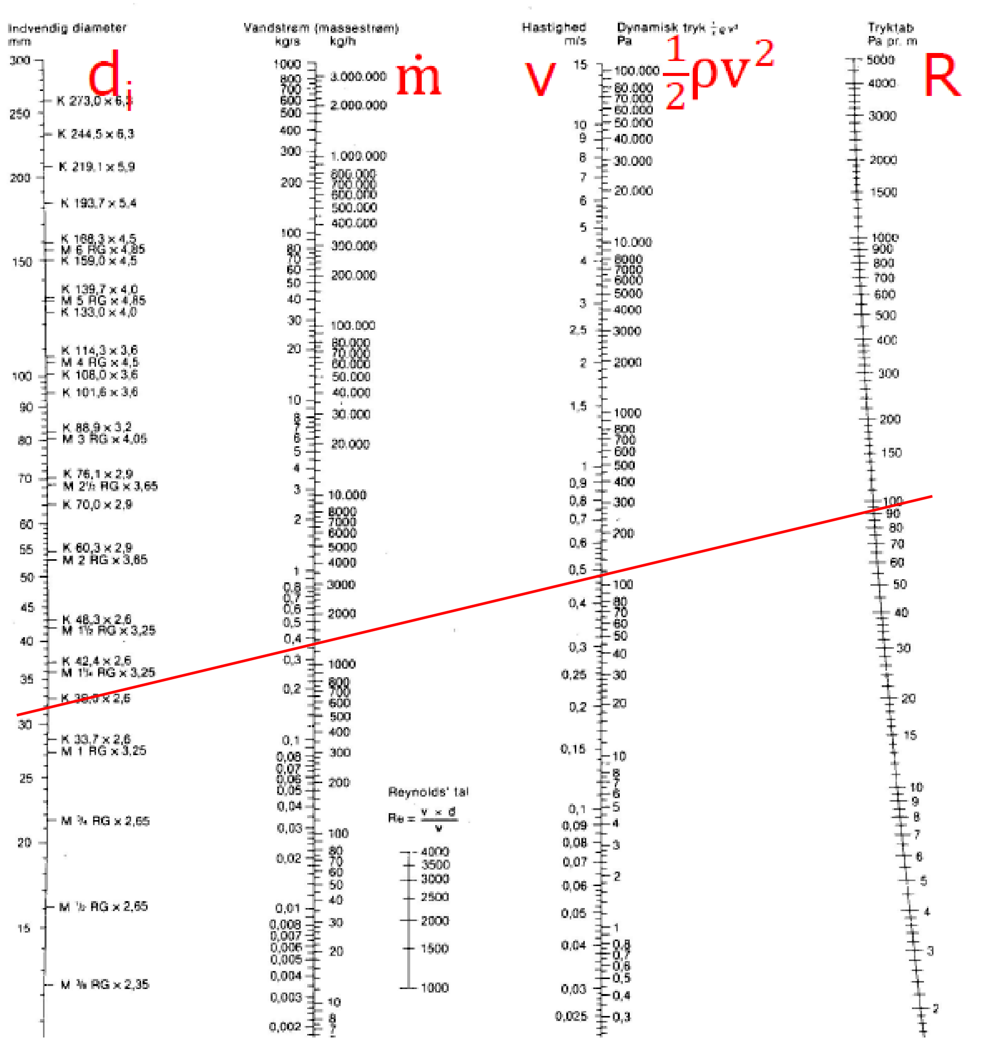


Figure E1: The mass flow(1320 kg/h) found in table H2 is used estimate a diameter of the horizontal main pipes on level 4. Since the water is running in steel pipes, the pressure loss, needs to be under 100 Pa/m which results in a pipe with an internal diameter of 38 mm. The monogram is from SBI-anvisning 175, p 164. [

Heat loss calculation for level 4									
Construction Element	Numbers / percentage	Length [m]	Height [m]	Areal [m2]	Areal fradag [m2]	Effective area [m2]	U-value [W/m2K]	Temp difference [C]	Heat loss [W]
Exterior wall	1	134.6	3.86	520	215.0792	304	0.15	32	1478
Window (W)	0.5	43.5	3.86	84	0	84	0.9	32	2418
Window (E)	0.3	44.2	3.86	51	0	51	0.9	32	1474
Window (S)	0.4	27.4	3.86	42	0	42	0.9	32	1218
Window (N)	0.5	19.5	3.86	38	0	38	0.9	32	1084
Heat loss:					**7672**				
With SF (2)					**15344**				
Mass flow (kg/h)					**1320**				
Volume flow (l/s)					**0.37**				

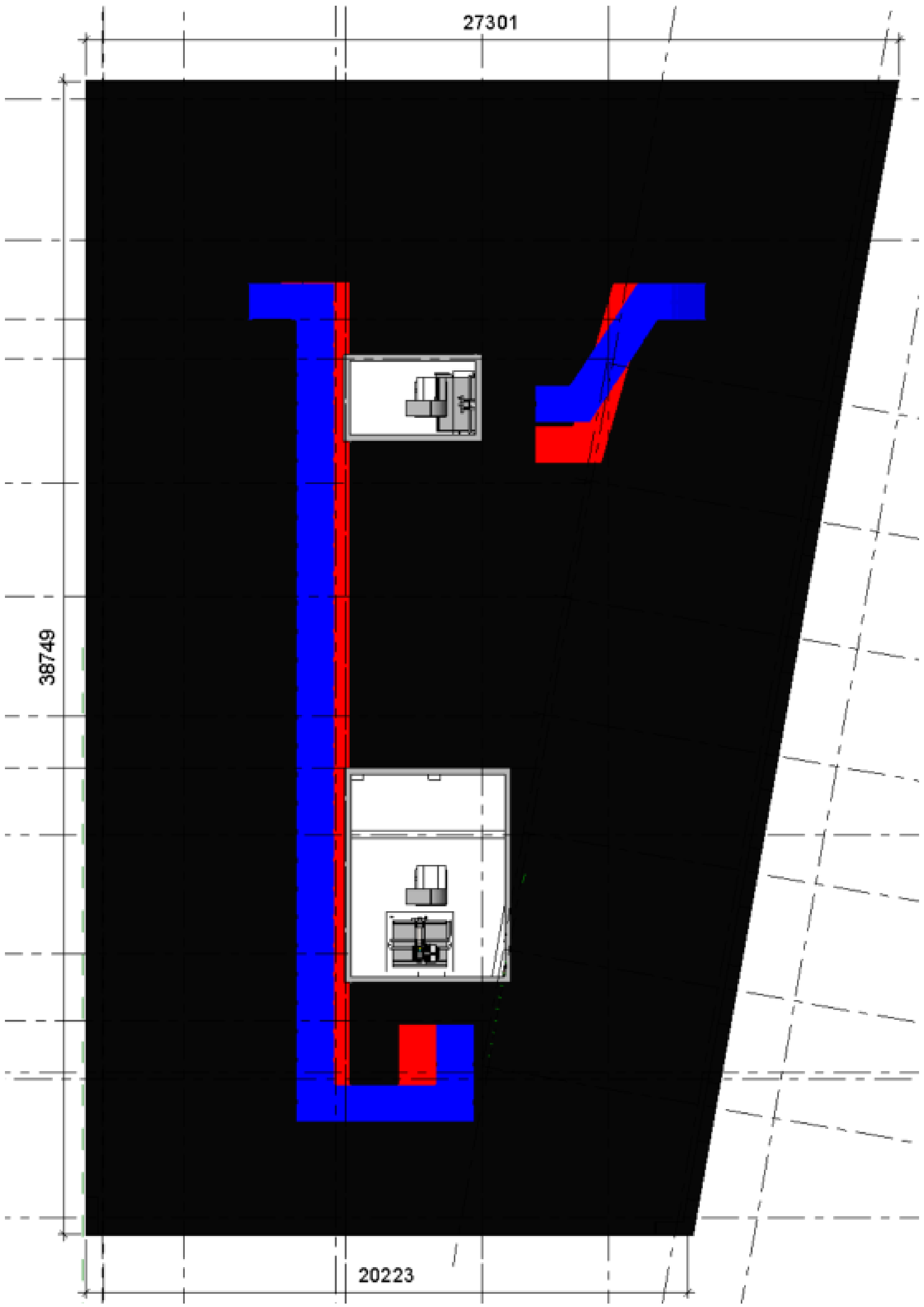
Table E2: Heat loss calculation of level 4. A security factor of 2 is used due to very simplified calculation without infiltration loss, line loss and ventilations loss.

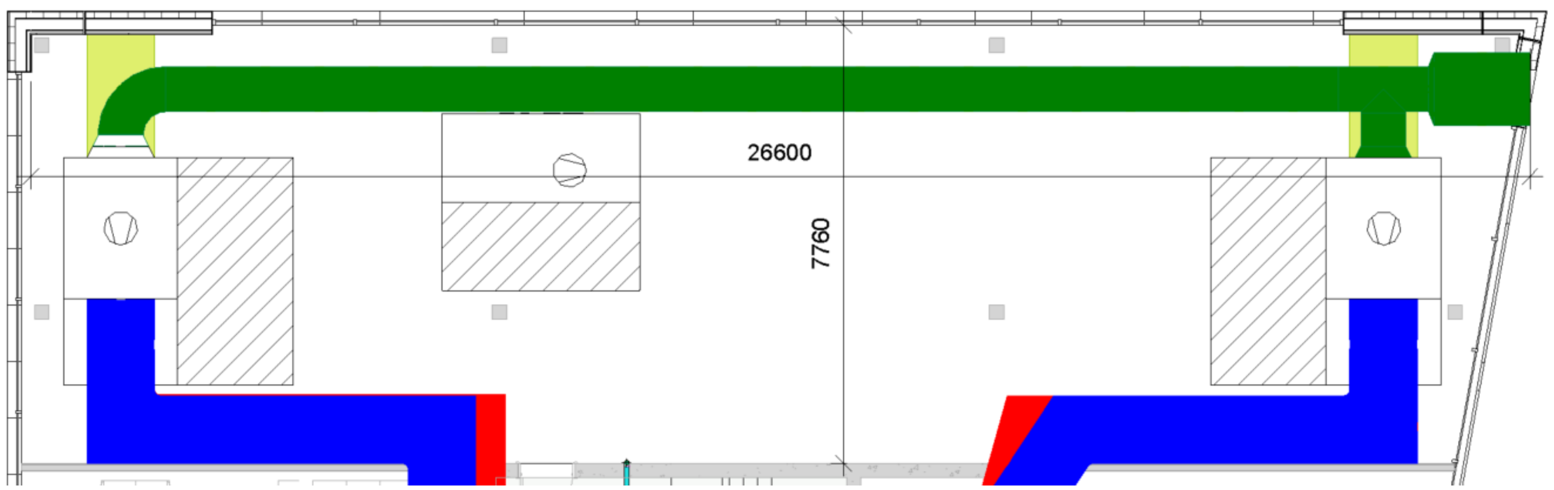
Appendix F – Floor plans of the technical floors

SIGNATURE

- Fire installations
- It related rooms
- Expansion vessel and other heat related instalaltions
- Duct – Ventilation Supply
- Duct – Ventilation Return
- Duct – Ventilation exhaust
- Duct – Ventilation Fresh air

Figure F1: Plan of level 7 where the technical room is located´. Since the two shafts are placed in the northern and southern end of the building and the architects would like to avoid dead ends around the core, the technical rooms was split into to. Beside space for the ventilation units, the technical rooms have space for booster pumps for the fire installations, expansion vessels for the heating system and space for it related installations





SIGNATURE

- Duct – Ventilation Supply
- Duct – Ventilation Return
- Duct – Ventilation exhaust
- Duct – Ventilation Fresh air

Figure F2: Plan view of the technical room on level 16. The exhaust pipes goes out of the eastern end of building because the primary wind direction is west. The technical room have space for two amin AHUs that can serve level 10 to 16 and a smaller AHU that can serve the kitchen on level 16. Further the room have plenty of space for fire ventilation and expansion vessel connected to the heating system.

Figure F3: Plan view of the roof and the routing of the ducts along the roof from the technical room to the shafts. The supply duct will be insulated to secure a steady temperature of the air from the air handling unit to the air terminals. The ducts runs over the roof to spare space in the suspended ceiling on level 16 and to meet the wishes of the architects for at terrasse towards the south connected with the restaurant.

Appendix G – Area calculations and assumptions for the technical floors

Type of technical service	Area (m2) Basement	Area (m2) Level 7	Area (m2) Level 16	Note
Hydronic installations for fire	122	36	35	Divided in to three areas in the basement: Two have space for pumps and other equipment, and the last have space for a water tank with a volume of 110m2. The area are based on the rule of thumb from the powerpoint slides (kilde) .
Fire ventilation	50			The area of the fire ventilation in the basement are based on the smaller units that are needed to ventilate the auditoriums and covers an area of 50 m2. An area of 18 m2 in both technical rooms on level 7 are also left for fire installations if needed. On level 16 45 m2 are dedicated to fire ventilations installations for pressurization of the staircases and elevators
Ventilation	200	107	135	The air handling units and the ducts are modelled in revit to figure out the routing and the space that they take up. Overall an area of 100 m2 with double height are used for the ventilation unit and 100 m2 for ducting in the basement. On level 7 the twon AHU's are placed in two different technical rooms, taking up 60m2 and 47 m2 respectively. On Level 16 all AHU's are placed in the same room, the two main AHUs and routing requires 105 m2, addtionally 30 m2 are dedicated to at smaller unit, that can serve the kicthen.
Heating	40	18	15	The area of both heating installations and the water tank in the basement are based on figure 11 from the BSRIA handbook. To avoid to high pressure on the expansion tank this one is placed at level 16 and 7.
Water tank, hot water	Volume: 9m3	-	-	According to engineeringtoolbook [11] the size of the water tank needs to be 5l /occupant in offices. According to the architects the building is designed for 1540 occupants, thus the tank has to have a volume of 7.7 m3, to ensure enough hot water even if the use of the building change with a volumen of 9 m3 is drawn in Revit and used in the BE18 calculatins.
Coldwater	7	-	-	A smaller space for the intake of cold water from the city grid are placed next to the hotwater tank, se secure easy routing and space for expansin tank and pumps.
Cooling	30	-	-	From the Grasshopper thermal simulations, the peak cooling loads is known to be 11.3 kW. The simulated area only covers approximately 50% of the cooled floor area thus 50% is added and the the number are then multiplied by the numbers of floors in the building (16). This give an estimated peak cooling load of 271 kW, which according to figure 15 in the BSRIA Handbook[12] needs service station for cooled chillers of 35 m2. DTU have district cooling which requires less space than water wooled chillers and in is assumed that 30 m2 is sufficienT.
Electricity	-	16	-	According to the BRASIA Handbook[12] an office building normally uses 62W/m2, which give a collected use of 1178 kW for the building (the heated area is 19000 m2). The southern technical room on level 7 have 18 m2 of space for technical installations.
Serverroom	55	-	-	The use of IT will grow in the future, thus a big serverroom are assigned 55 m2.
Transformer room	30	-	-	Figure 37 in the BSRIA Handbook[12] show that for at electricity use of 1178 kW the transformer room needs to be 15 m2 and a height of 3.1 m. The building don't fulfill the height requirements, thus a room of 30 m2 is assigned
Emergency Power	30	-	-	According to figure 25 in the BSRIA Handbook[12] the room for an emergency generator need 25 m2 and a height of 3.1 m, thus a slightly larger room is assigned
It & switchroom	35	-	-	According to figure 35 in the BSRIA Handbook[12] the room for a switches and distribution needs to be 30 m2 and has a height of 4m, thus a part of the double height basement is assigned.
Extra room for it /storage	25	-	-	Due to uncertainties about the size of the IT-room and other service station are room is left for unforseen service station or storage.
Waste	20			Space for a container and a waste suction to the road.
Corridors / space for routing	156	33	10	
Sum of areas	**800**	**210**	**195**	

Time [hours]	Occ. Load [%] General
8-11	80
11-13	25
13-16	50
16-17	25

Time [hours]	Occ. Load [%] Meeting Rooms
8-12	100
12-13	0
13-15	100
15-17	50

Table 1	m^2 pr. person	Watt/per-son	Equipment Watt /person	Lighting W/m^2	Other equipment W/m^2	Notes
Landscape office	10	90	90	5	3	Note 3,5
Single office	12	90	90	7	3	
Print and copying room				10	100	
Reception	20			8	3	
Canteen	1.5	90		5	3	Note 1
Kitchen incl. secondary spaces					3	Note 2
Meeting rooms	2	90	25	8	20	Note 4

Note 1: Area calculated excluding buffet area.

Note 2: Heat gain determined after kitchen design.

Note 5: The area includes the whole floor area including corridors, walking areas, break-out spaces etc. In practice the occupancy load in the landscape office is probably 6-7 m2/person.

Reference: http://agilex.io/F21/DX/11080/MEP/reqs

Appendix I – Be18 Choices and Assumptions

Front page	Value	Unit	Comment	Source
Heated foor area	18953	m2	Extracted from the revit model by the architects see appendix J table J2	
Heated basement	1953	m2	Extracted from the revit model	
Developed area	1229	m2	Extracted from the revit model	
Heat capacity	62	Wh/K m2	Se table appendix J table J3	
Mechanical cooling - Share of floor area	0.73	-	Non-cooled areas: Walls, shower room, toilets, shafts, and technical rooms	
Building envelope	**Value**	**Unit**	**Comment**	**Source**
Areas	See appendix K	m2	Outer walls are divided into orientations	
U-value	Exterior wall: 0.15 Roof: 0.1 Basement floor: 0.15 Basement wall: 0.19	W/m2K	The building envelope scores 10 points regarding the DGNB criteria for building envelope for both the roof, exterior wall, and basement floor, and scores 7.5 point for the basement walls. Se appendix L for the calculations of the U-values.	[1]
Line losses	**Value**	**Unit**	**Comment**	**Source**
Length	Windows: 12889 Roof: 173 Pedestal: 166 Foundation: 171 Walls towards cold basement: 304	m	Line loss length are found through the revit model for the roof, pedestal level, and the foundation. For line losses form the windows see appendix K table K4	
Line loss	DGNB ETC 1.3	W/mK	The line losses are found from the DGNB TEC 1.3 criteria and are assumed to obtain the maximum amount of points. Windows: 0.03, others: 0.3.	[1]
Windows	**Value**	**Unit**	**Comment**	**Source**
Orientation	N: 15 E: 120 S: 195 W: 285	degree	The entire east facade is assumed to have the same orientation, even though some of the facede is faceing 105 degrees.	
Area	See appendix K	m2	The facades varries in glazing areas in relation to the floor height and their orientation found though. The glazing ratios and area calculation can be seen in table K3.	
U-value	0.7	W/m2K	Low energy windows - Schüco Nordic Alu-inside	[10]
Frame fraction (Ff)	0.7	-	Low energy windows - Schüco Nordic Alu-inside	[10]
g-value	0.37	-	Low energy windows - Schüco Nordic Alu-inside	[10]
Shadow	See below	-	Shadow values are set to the defalut value for all orientations.	
Shading	**Value**	**Unit**	**Comment**	**Source**
Left	North: 0 South: 17 East and west: 32	degree	Shadow angels from the sun shading panels are found in appendix M	
Right	North: 0 South: 17 East and west: 32	degree	Shadow angels from the sun shading panels are found in appendix M	
Ventilation	**Value**	**Unit**	**Comment**	**Source**
The relative operation time (Fo)		-	The relative operation time is set to 1 for most room types. Though, for the meeting rooms in use, it is set to 0.8 (and 0.2 for meeting rooms not in use), for the auditorium it is set to 0.7 when in use, and for the sky bar the value in use is set to 0.8.	
Mech. Vent. (qm)	Corridors: 0.8 Mixed: 1.167 Tech: 0.7 Others: 1.2	l/s m2	The cut-off value of 1.2 is valid for most of the room types. The minimum ventilation rate is set for the technical rooms, which is ventilated with 0.7 l/s m2 to secure the ventilation of building emissions for a low polluted building. The mixed areas are assumed to have 15 m2 pr. person, and the vantilation rate is set to fit this need.	[3]
Heat recovery (n vgv)	0.84	-	The heat recovery value is found through optimizations from SystemairCAD, which can be seen in appendix X and are for all units rounded to be 0.84.	
Nat. vent. winter (qn)	0.082	l/s m2	There is no natural ventilation in the building, so the value here is valid for the infiltration instead. The value is set to follow the infiltration for a low energy building according to BR18 when the building is occupied.	[5]
Nat. vent. - night (qi,n)	0.042	l/s m2	Infiltration for a low energy building according to BR18 during the time of no occupancy.	[5]
Specific fan power (SFP)	Pedestal: 0.83 Level 4-10: 0.8 Level 11-16: 0.82	kJ/m3	The SFP-values are found through optimizations made in SystemairCAD. The specific zone type's SFP-value are found as a mean of the units used for the zone types, fx are the offices only placed in the tower region. Therefore the offices SFP is found as a mean between 0.8 and 0.82.	
Max mech. vent. (qm,s)	Corridors: 0.8 Mixed: 1.167 Tech: 0.7 Others: 1.2	l/s m2	The maximum mechanical ventilation is set to be the same as the normal ventilation rate, due to the fan coils installed where cooling is needed. Fan coils will be regulating the thermal indoor climate instead of the ventilation.	
Nat. vent. summer (qn,s)	0.082	l/s m2	Infiltration for a low energy building during the day	[5]
Mech. vent. night (qm,n)	0.7	l/s m2	This value follows the minimum ventilation rate to ventilate the building emissions for a low polluted building.	[3]
Nat. vent. night (qn,n)	0.042	l/s m2	Infiltration for a low energy building during the night.	[5]

Lighting	Value	Unit	Comment	Source
Power when lighting is off	0.2	W/m2	Assuming the light still uses a small amount of power even though it is off.	
Power when lighting is on		W/m2	To be able to calculate the power need for the lighting it is assumed that the entire building is lit-up by LED lamps except for the sky bar, which is lit-up by tungsten.	
Required lux level		lux	The required lux level is found according to EN 12464, but a cut-off value of 300 lux is applied for the rooms with higher lux level (meeting rooms, auditoriums, and kitchen in the sky bar).	[7]
Daylight factor	0-2	%	The daylight is varying throughout the building.	
Control	Zones with daylight: K Auditorium: U Others: U		In zones with daylight the lighting is contorled by the daylight censor in the room. In the auditorium and the other room types the light is controlled manually.	
Operation time	Meeting room: 0.8 Auditorium: 0.7 Sky bar: 0.8 Others: 1		Assuming the light is not on the entire operation time for the meeting room, auditorium, and sky bar.	
Power due to task lighting	1	W/m2	The power due to task lighting is set to 1 W/m2 in the office zones. Assuming one desk lamp (10 W) per person and each person having 10 m2.	
Stand-by	0.2	W/m2	Assuming the light still uses a small amount of power even though it is off.	
Mechanical cooling	**Value**	**Unit**	**Comment**	**Source**
El-demand (1/cop)	0.25	kWh-el/kWh-cool	The cop value is set to 3 to follow a standard value.	
Heat distribution plant	**Value**	**Unit**	**Comment**	**Source**
Supply pipe temperature	45	℃	To obtain the maximum amount of points for the DGNB demand TEC 1.4 for heating system and heating distribution	[1]
Hot water tanks	**Value**	**Unit**	**Comment**	**Source**
Number of tanks	1	-	Two pressure zones are needed - see the hydronic installation section.	
Tank volume	1000	L	Asumption	
Heat loss from hot-water tank	1.8	W/K	Assumption made based on the Be18 examples, which lies between 1.5 and 1.8 W/K	
Circulation pipes	**Value**	**Unit**	**Comment**	**Source**
Pipes for hot water	396	l (m)	Height of risers: 1: 68 m, 2: 37 m, 3: 60 m, 4: 4 m, 5: 29 m	
Pipes for hot water		Loss (W/mK)		
District heat exchanger	**Value**	**Unit**	**Comment**	**Source**
Nominal effect	360	kW	The nominal effect is set to overcome the ventilation loss with HRV (in winter), which is shown on the front page of the Be18 sheet (357.5 kW)	
Solar cells	**Value**	**Unit**	**Comment**	**Source**
			No solar cells are installed on the building .	

Table I1: Comments for the different input parameters to Be18. When it is not mentioned in the table a default value has been used instead.

Building area above ground	Area (m2)
common meeting rooms	1130
rented office area	7339
Open Offices	6379
Single/ Double Offices	960
rented gym/restaurant/cafeteria	2234
Sky Bar	898
Gym	911
Cafeteria	425
Public common areas	3171
public facilities (excl. Cafeteria)	817
Auditoriums	504
Bathrooms, Kitchens, Changing	313
MEP (outside core)	421
Core + fire	1811
Building Management	60
Total	16982

Table J1: Architects area distribution above ground.

Building area		
	%	Area (m2)
Offices	23	3906
Corridors	20	3396
Toilets	4	679
Meeting room	11	1863
Auditorium	3	504
Sky bar	4	679
Gym	5	911
Mixed	15	2547
Cores & shaft	13	2208
Shower room	1	136
Kitchen (sky bar)	1	153
Total area above ground		16982
Heated basement		1953
Total heated building area		18935

Table J2: Area distribution for ventilation and lightning based on table J1 and figure J2.

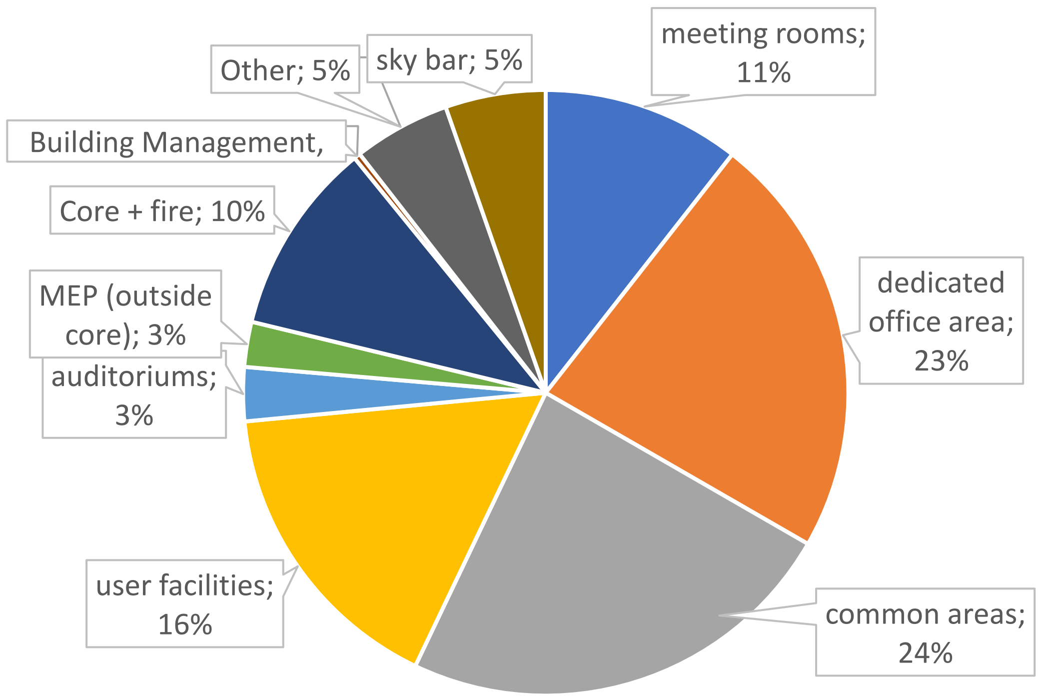


Figure J2: Building floor area usage by type (above ground).

Heat capacity calculation

Ydervægsareal eks. vinduer og døre	11200	Det totale ydervægsareal **Indtastning kun i de gule felter**
Etageareal	17000	Det totale areal for hele bygningen
Bygningens kompakthed	0.66	
Rumstørrelser 1= små (boliger), 2= mellem, 3= store (storrumskontorer og klasseværelser)	3	

Indvendige overflader		Varmekapacitet Wh/K m²			Areal for konstruktion (Hvis det er en enkel bygning, kan tallet 1 indsættes i stedet for areal i de gule felter herunder):
Loft				samlet:	1
Gips (ét lag)		3		-	
Nedhængt loft		3		3.0	1
Klinkebeton (1.800 kg/m³)		45		-	
Beton (2.400 kg/m³)		60		-	
Gulv				samlet:	1
Trægulv på isolering		4		-	
Trægulv på strøer på beton		10		10.0	1
Hævet gulv over beton		10		-	
Trægulv med dug på beton		17		-	
Tæppe på beton		30		-	
Klinkebeton evt. med klinker (1.800 kg/m³)		45		-	
Linoleum på beton		53		-	
Beton evt. med klinker (2.400 kg/m³)		60		-	
	Bygningens kompakthed				
Ydervægge	Lille >0,65	Mellem 0,65-0,25	Stor <0,25	samlet:	1
Gipsplader (to lag)	4	3	2	-	
Porebeton (535 kg/m³)	10	7	4	5.0	0.5
Tegl (1.500 kg/m³)	25	17	9	-	
Klinkebeton (1.800 kg/m³)	33	23	13	-	
Beton (2.400 kg/m³) (stål)	43	30	17	21.5	0.5
	Rumstørrelser				
Skillevægge	Små (boliger)	Mellem	Store (storrumskontorer og klasseværelser)	samlet:	1
Gipsplader (to lag)	13	7	4	2.0	0.5
Porebeton (535 kg/m³)	15	7	4	-	
Tegl (1.500 kg/m³)	38	19	11	-	
Klinkebeton (1.800 kg/m³)	50	25	15	-	
Beton (2.400 kg/m³)	67	33	20	10.0	0.5
Inventar		10		10	
Resultat				**62**	

Table J3: Calculations for the building's heat capacity.

Appendix K – Building Envelope and Line Loss

Basement walls			
	Perimeter (m)	Height (m)	Wall area (m2)
Level - 1	142	4	530
Level -2	125	3	420
		Total	950,8

Table K1: The area of the basement walls found from figure K1 and K2.

Building wall (including wndows)					
	North	West	South	Southeast	East
Pedestal (floor 1 to 3)	415	786	330	524	284
Tower (per floor)	105	167	76	152	-
Skybar (floor 15 and 16)	211	299	156	304	-

Table K2: The total area of the building envelope for the different levels found from figure K3 and K4.

		Glazing ratio (%)					Glazing area (m2)					Wall area (m2)				
	Floor	North	Southeast	West	South	East	North	Southeast	West	South	East	North	Southeast	West	South	East
Pedestal	1 to 3	60	60	60	60	0	249	171	472	198	0	166	114	314	132	284
Tower	4	50	48	50	40	-	53	73	84	30	-	53	79	84	45	-
	5	50	45	50	40	-	53	69	84	30	-	53	84	84	45	-
	6	50	43	50	40	-	53	66	84	30	-	53	87	84	45	-
	7	50	40	50	40	-	53	61	84	30	-	53	91	84	45	-
	8	50	37	50	40	-	53	56	84	30	-	53	96	84	45	-
	9	50	35	50	40	-	53	53	84	30	-	53	99	84	45	-
	10	50	32	50	40	-	53	49	84	30	-	53	104	84	45	-
	11	50	30	50	40	-	53	46	84	30	-	53	107	84	45	-
	12	50	30	50	40	-	53	46	84	30	-	53	107	84	45	-
	13	50	30	50	40	-	53	46	84	30	-	53	107	84	45	-
	14	50	30	50	40	-	53	46	84	30	-	53	107	84	45	-
Sky bar	15 and 16	50	30	50	40	-	105	91	149	63	-	105	213	149	94	-
						Total area	*934*	*872*	*1540*	*594*	*0*	*851*	*1394*	*1383*	*725*	*284*

Table K3: The calculation to support the areas for the building envelope is based on glass ratio and orientation of the building. The glass ratios are found through the sensitivity analysis.

Line loss due to windows [m]	
Total window area [m2]	4348
Assumed window height [m]	1,48
Assumed window width [m]	1,24
Assumed area of each window [m2]	1,84
Number of windows [-]	2369
Window circumference [m]	5,44
Line loss due to windows [m]	**12889**

Table K4: The line losses from windows are based on the assumption that each window has a dimension of 1.48x1.84 m, which is the standard dimension of the applied window type [10].

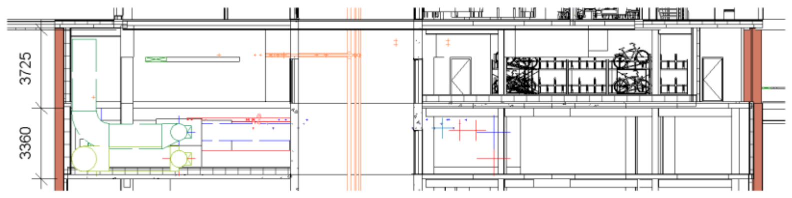


Figure K1: Section of level –1 and –2 to show levels' heights.

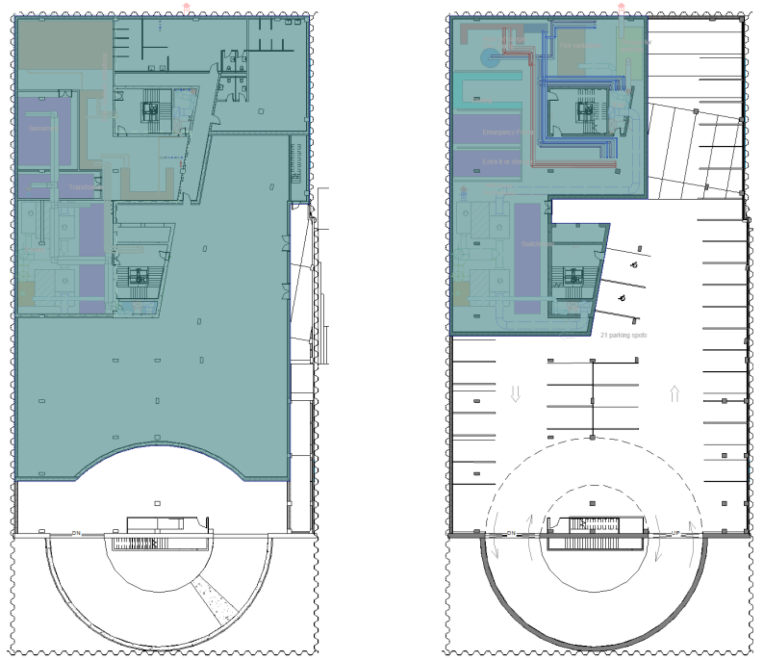


Figure K2: Plan view of level –1 and –2, where the heated area is highlighted with green.

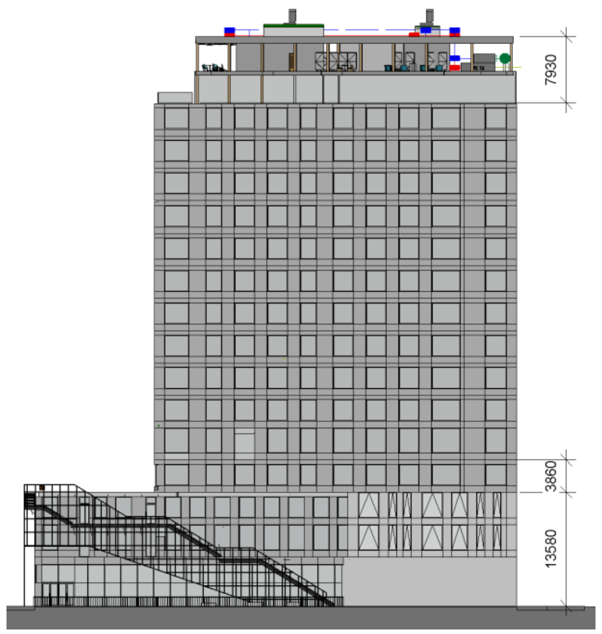


Figure K3: Elevation of the building from the eastern side to show the height of the pedestal, a floor in the tower section and the sky bar.

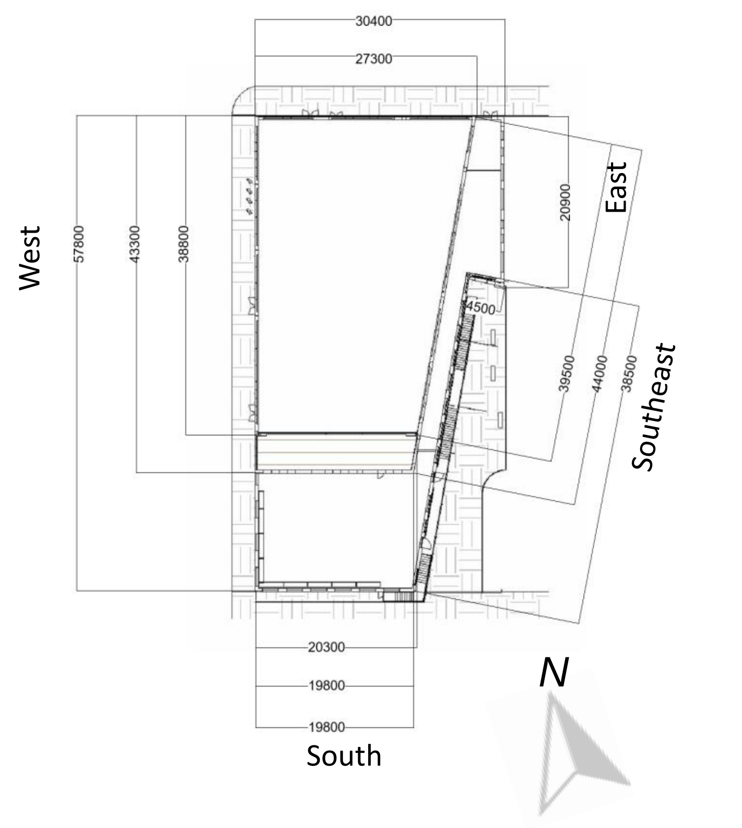
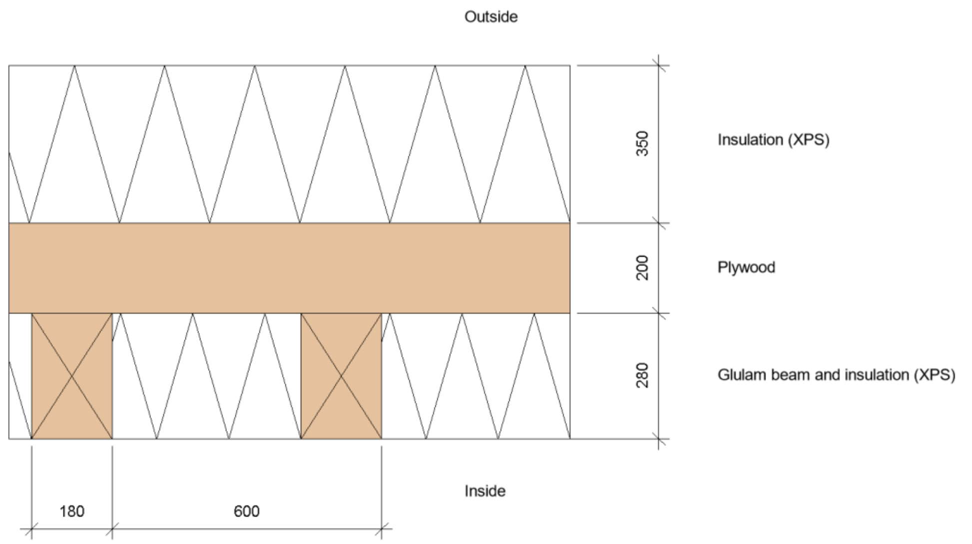


Figure K4: Building seen from the top to show the building envelope's dimensions.

Appendix C – U-values and illustration of thermal layers

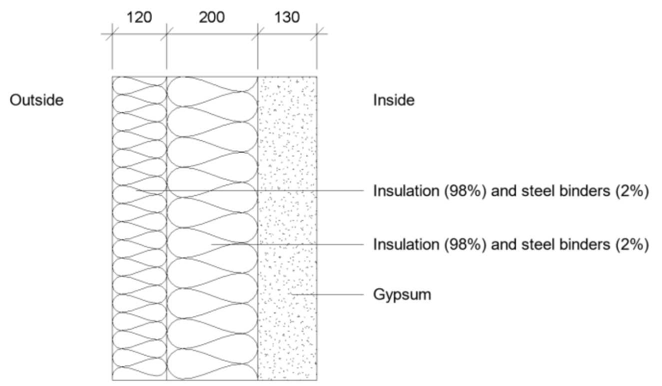
Roof



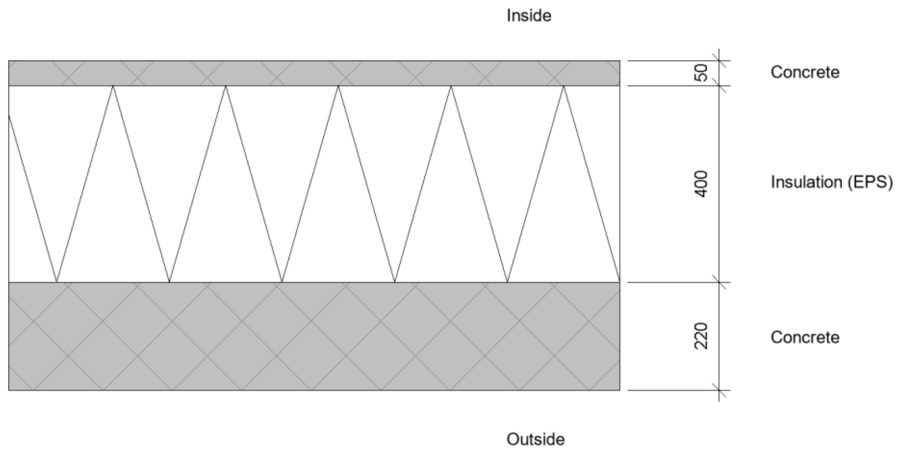
Roof			
Layer	Thickness	Thermal conductivity	Isolation property
	d	λ	R
	[m]	[W/mK]	[m²K/W]
Outside surface	-	-	0.04
Insulation (XPS)	0.350	0.038	9.21
LVL	0.100	0.140	0.71
Glulam beam	0.112	0.110	1.02
Insulation (XPS)	0.148	0.038	3.90
Gypsum	0.050	0.520	0.10
Inside surface	-	-	0.10
		∑R (m²K/W) =	*15.08*
		Simple U-value (W/m²K) =	***0.07***
		Corrected (50%) U-value (W/m²K) =	***0.10***
		Corrected (100%) U-value (W/m²K) =	***0.20***

Exterior wall			
Layer	Thickness	Thermal conductivity	Isolation property
	d	λ	R
	[m]	[W/mK]	[m²K/W]
Outside surface	-	-	0.04
Insulation cl. 34	0.118	0.034	3.459
Steel	0.002	35.00	0.000
Insulation cl. 34	0.196	0.034	5.765
Steel	0.004	35.00	0.000
Gypsum	0.130	0.520	0.250
Inside surface	-	-	0.130
		∑R (m²K/W) =	*9.6*
		Simple U-value (W/m²K) =	***0.10***
		Corrected (50%) U-value (W/m²K) =	***0.15***
		Corrected (100%) U-value (W/m²K) =	***0.20***

Exterior wall



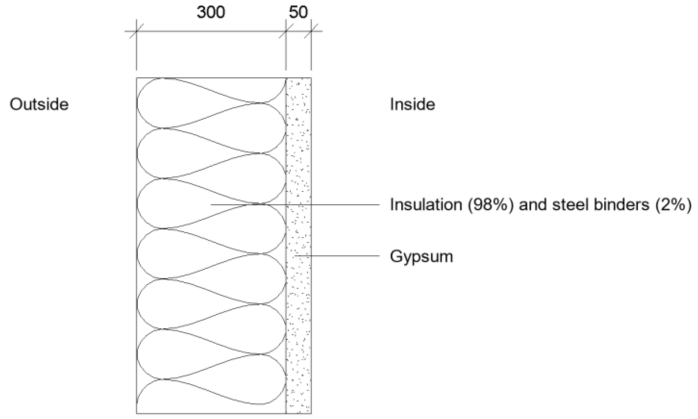
Basement floor



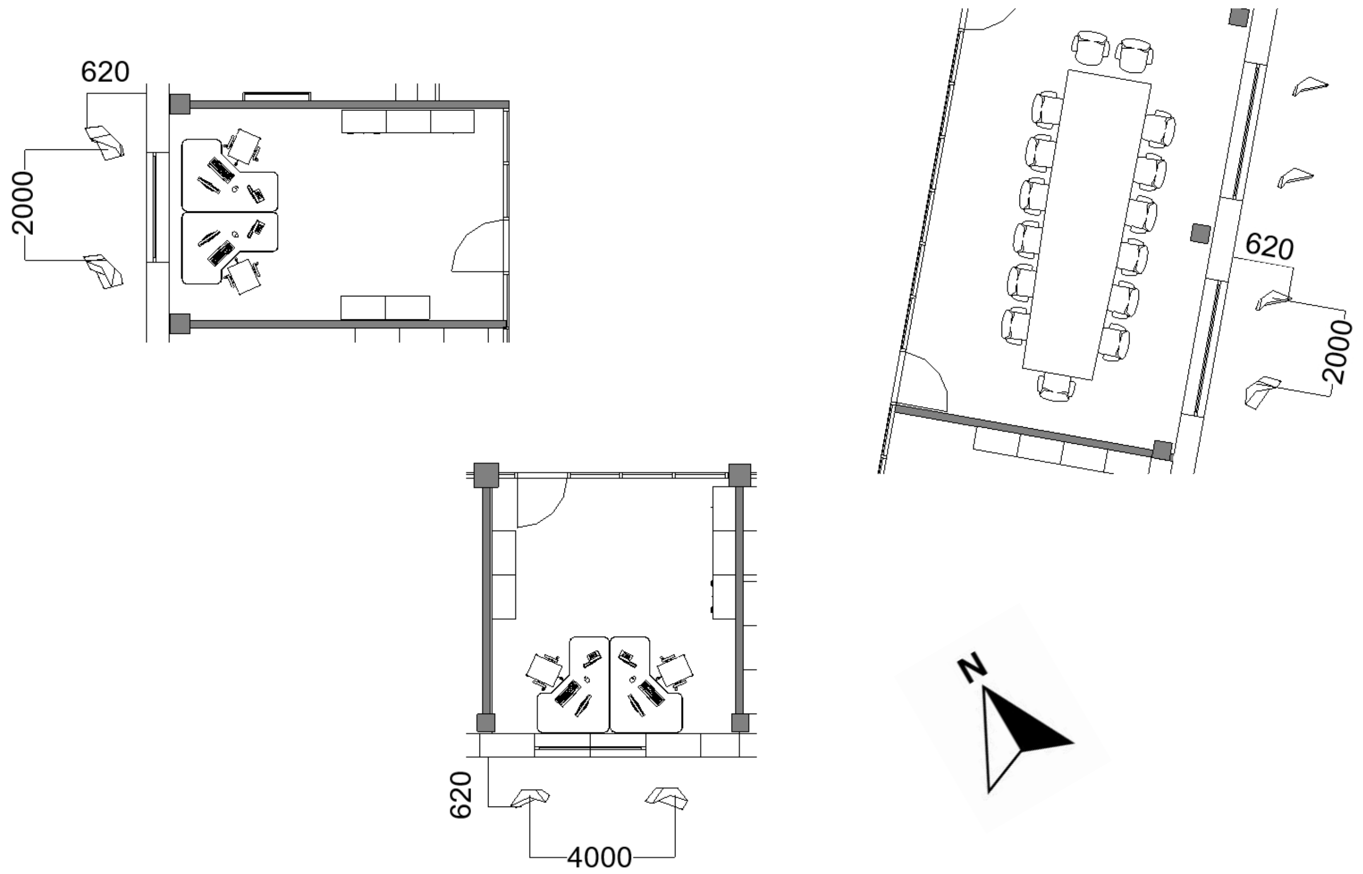
Floor between heated and non-heated basement			
Layer	Thickness	Thermal conductivity	Isolation property
	d	λ	R
	[m]	[W/mK]	[m²K/W]
Inside surface	-	-	0.170
Concrete	0.05	1900	0.026
Insulation (EPS)	0.400	0.038	10.526
Concrete	0.220	1900	0.116
Outside (cold basement) surface	-	-	0.170
		∑R (m²K/W) =	*11.01*
		Simple U-value (W/m²K) =	***0.09***
		Corrected (50%) U-value (W/m²K) =	***0.14***
		Corrected (100%) U-value (W/m²K) =	***0.18***

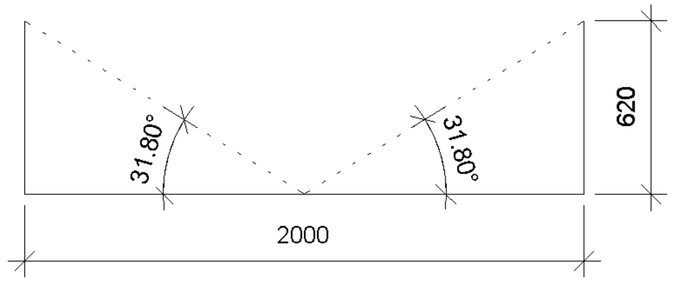
Basement wall			
Layer	Thickness	Thermal conductivity	Isolation property
	d	λ	R
	[m]	[W/mK]	[m²K/W]
Insulation	0.294	0.037	7.95
Steel	0.006	35.000	0.00
Gypsum	0.050	0.520	0.10
		∑R (m²K/W) =	*8.04*
		Simple U-value (W/m²K) =	***0.12***
		Corrected (50%) U-value (W/m²K) =	***0.19***
		Corrected (100%) U-value (W/m²K) =	***0.25***

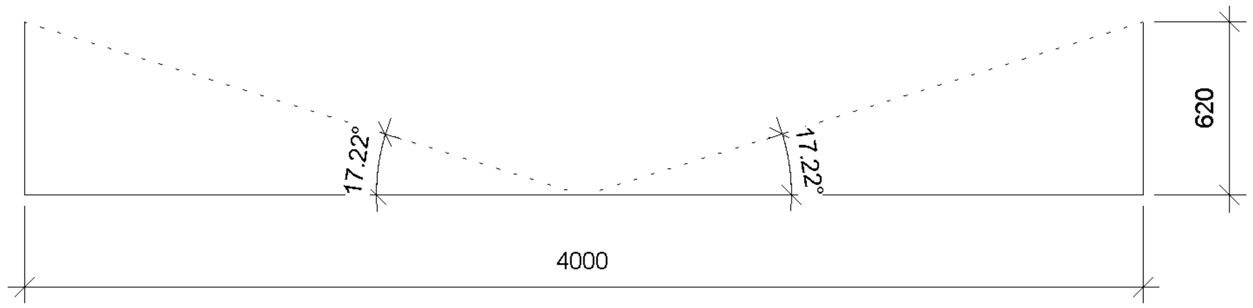
Basement wall



Appendix M – Shading







Appendix N – Be18 documentation

Model: The Building - Low U-values	SBi Beregningskerne 10.19.7.22
Be18 key numbers: 11080 Group 10	
Transmission loss, W/m²	
Tramission loss frame, normal	12,4
Tramission loss frame, low energy	11,4
Tramission loss, calculated	6,7
Renovation class 2, kWh/m² year	
Energy frame renovation class 2, without addition	95,1
Addition for special terms	0,0
Total energy frame	95,1
Total energy requirement	33,0
Renovation class 1, kWh/m² year	
Energy frame renovation class 1, without addition	71,4
Addition for special terms	0,0
Total energy frame	71,4
Total energy requirement	33,0
Energy frame BR 2018, kWh/m² year	
Energy frame BR 2018, without addition	41,1
Addition for special terms	0,0
Total energy frame	41,1
Total energy requirement	33,0
Energy frame low energy, kWh/m² year	
Energy frame low energy, without addition	33,0
Addition for special terms	0,0
Total energy frame	33,0
Total energy requirement	33,0
Contribution to energy requirement, kWh/m² year	
Heating	15,4
El. for service of buildings	10,5
Excess temperature in rooms	0,0
Net requirement, kWh/m² year	
Room heating	8,9
Domestic hot water	6,5
Cooling	1,9
Selected el. requirements, kWh/m² year	
Lighting	5,7
Heating of rooms	0,0
Heating of domestic hot water	0,4
Heat pump	0,0

Model: The Building - Low U-values	SBi Beregningskerne 10.19.7.22
Ventilators	3,5
Pumps	0,5
Cooling	0,7
Heat loss from installations, kWh/m² year	
Room heating	0,0
Domestic hot water	1,2
Output from special sources, kWh/m² year	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0
Total el. requirement, kWh/m² year	
El. requirement	23,9

Be18 model: The Building - Low U-values Date 26.06.2021 23.35

11080 Group 10	
The building	
Building type	Other
Rotation	0,0 deg
Area of heated floor	18953,0 m²
Area heated basement	1953,0 m²
Area existing / other usage	0,0 m²
Heated gross area incl. basement	19929,5 m²
Heat capacity	62,0 Wh/K m²
Normal usage time	45 hours/week
Usage time, start at - end at, time	8 - 17
Calculation rules	
Calculation rules	BR: Actual conditions
Suplement to energy frame	0,0 kWh/m² år
Heat supply and cooling	
Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	No
Wind mills	No
Mechanical cooling	Yes

Room temperatures, set points	
Heating	20,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C
Dimensioning temperatures	
Room temp.	20,0 °C
Outdoor temp.	-12,0 °C
Room temp. store	15,0 °C

External walls, roofs and floors

External walls, roofs and floors					
Building component	Area (m²)	U (W/m²K)	b	Dim.Inside (C)	Dim.Outside (C)
Floor towards terrain	1492,0	0,15	0,700	20	10
Roof	1492,0	0,10	1,000	20	-12
Wall - North	851,0	0,15	1,000	20	-12
Wall - Southeast	1394,0	0,15	1,000	20	-12
Wall - South	725,0	0,15	1,000	20	-12
Wall - East	284,0	0,15	1,000	20	-12
Wall - West	1383,0	0,15	1,000	20	-12
Wall - Basement	696,0	0,19	0,700	20	10
Ialt	8317,0	-	-	-	-

Foundations etc.					
Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Windows	12889,0	0,03	1,000	20	-12
Roof	173,0	0,30	1,000	20	-12
Pedestal	166,0	0,30	1,000	20	-12
Foundation	171,0	0,30	1,000	20	10
Walls towards cold basement	304,0	0,30	1,000	20	10
Ialt	13703,0	-	-	-	-

Windows and outer doors													
Building component	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)	Ext
North	1	15	90,0	934,0	0,70	1,000	0,75	0,37	North	1,00	20	-12	0
Southeast	1	120	90,0	872,0	0,70	1,000	0,75	0,37	East and West	1,00	20	-12	0
South	1	195	90,0	594,0	0,70	1,000	0,75	0,37	South	1,00	20	-12	0
West	1	285	90,0	1383,0	0,70	1,000	0,75	0,37	East and West	1,00	20	-12	0
Ialt	4	-	-	3783,0	-	-	-	-	-	-	-	-	

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
North	15	0	0	0	10
East and West	15	0	32	32	10
South	15	0	17	17	10

Summer comfort	
Floor area	0,0 m²
Ventilation, winther	0,3 l/s m²

Summer comfort	
Ventilation, summer, 9-16	0,9 l/s m²
Ventilation, summer, 17-24	0,9 l/s m²
Ventilation, summer, 0-8	0,6 l/s m²

Ventilation													
Zone	Area (m²)	Fo, -	qm (l/s m²), Winter	n vgv (-)	ti (°C)	El-HC	qn (l/s m²), Winter	qi,n (l/s m²), Winter	SEL (kJ/m³)	qm,s (l/s m²), Summer	qn,s (l/s m²), Summer	qm,n (l/s m²), Night	qn,n (l/s m²), Night
Offices	3906,0	1,00	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Corridors	3396,0	1,00	0,80	0,84	18,0	No	0,08	0,04	0,8	0,80	0,08	0,70	0,04
Toilets	679,0	1,00	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Meeting room - in use	1863,0	0,80	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Meeting room - not in use	1863,0	0,20	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Auditorium - in use	504,0	0,70	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Auditorium - not in use	504,0	0,30	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Sky bar - in use	679,0	0,80	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Sky bar - not in use	679,0	0,20	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Gym	911,0	1,00	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Mixed	2547,0	1,00	1,17	0,84	18,0	No	0,08	0,04	0,8	1,17	0,08	0,70	0,04
Shower room	136,0	1,00	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Kitchen (sky bar)	153,0	1,00	1,20	0,84	18,0	No	0,08	0,04	0,8	1,20	0,08	0,70	0,04
Cores, shaft, and basement	4161,0	1,00	0,70	0,84	18,0	No	0,08	0,04	0,8	0,70	0,08	0,70	0,04

Internal heat supply				
Zone	Area (m²)	Persons (W/m²)	App. (W/m²)	App,night (W/m²)
Whole building	18953	4,0	6,0	0,0

Lighting											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)
Offices	3906,0	0,2	3,3	300	2,00	K	1,00	1,0	0,0	0,2	0,0
Corridors	3396,0	0,2	1,1	100	0,50	K	1,00	0,0	0,0	0,2	0,0
Toilets	679,0	0,2	1,1	100	0,00	U	1,00	0,0	0,0	0,2	0,0
Meeting rooms	1863,0	0,2	5,6	500	1,00	K	0,80	0,0	0,0	0,2	0,0
Auditorium	504,0	0,2	5,6	500	0,10	A	0,70	0,0	0,0	0,2	0,0
Sky bar	679,0	0,2	6,7	100	0,50	K	0,80	0,0	0,0	0,2	0,0

Lighting											
Gym	911,0	0,2	3,3	300	0,20	K	1,00	0,0	0,0	0,2	0,0
Mixed	2547,0	0,2	2,2	200	0,20	K	1,00	0,0	0,0	0,2	0,0
Cores and shafts	4161,0	0,2	2,2	200	0,00	U	1,00	0,0	0,0	0,2	0,0
Shower room	136,0	0,2	2,2	200	0,00	U	1,00	0,0	0,0	0,2	0,0
Kitchen (sky bar)	153,0	0,2	5,6	500	1,50	K	1,00	0,0	0,0	0,2	0,0

Other el. consumption	
Outdoor lighting	0,0 W
Spec. apparatus, during service	0,0 W
Spec. apparatus, always	0,0 W

Basement car parkings etc.											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Mechanical cooling	
Description	Mechanical cooling
Share of floor area	0,73
El-demand	0,25 kWh-el/kWh-cool
Heat-demand	0,00 kWh-heat/kWh-cool
Load factor	1,2
Heat capacity phase shift (cooling)	0 Wh/m²
Increase factor	1,50
Documentation	

Heat distribution plant		
Composition and temperature		
Supply pipe temperature	45,0 °C	DGNB demand
Return pipe temperature	35,0 °C	
Type of plant	2-string	Anlægstype

Pumps				
Pump type	Description	Number	Pnom	Fp
Combi-pump (const. during heating season)	Pumps	2	200,0 W	0,40
Combi-pump (const. during heating season)	Pumps - original (5 pumps)	0	1000,0 W	0,40

Heating pipes					
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
Neassesary if we have a decentralized hot water tank!	0,0	0,00	0,000	N	J

Domestic hot water	
Description	Domestic hot water
Hot-water consumption, average for the building	100,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C

Hot-water tank	
Description	Hot water tanks
Number of hot-water containers	1,0
Tank volume	1000,0 liter
Supply temperature from central heating	60,0 °C
El. heating of DHW	No
Solar heat tank with heating coil	No
Heat loss from hot-water tank	1,8 W/K
Temp. factor for setup room	0,0

Charging pump	
Effect	0,0 W
Controled	No
Charge effect	0,0 kW

Heat loss from connector pipe to DHW tank			
Length	Loss	b	Description

Cirkulating pump for DHW	
Description	PumpCirc
Number	5,0
Effect	200,0 W
Number	0,0
Effect	0,0 W
Reduction factor	1,00 [-]
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes			
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
Pipes for hot water	396,0	0,20	0,000

Water heaters	
Electric water heater	
Description	Elvandvarmer

Electric water heater	
Share of DHW in separate el. water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Temp. factor for setup room	1,00
Gas water heater	
Description	Gasvandvarmer
Share of DHW in separate gas water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Efficiency	0,5
Pilot flame	50,0 W
Temp. factor for setup room	1,00

District heat exchanger	
Description	Ny fjernvarmeveksler
Nominal effect	360,0 kW
Heat loss	5,0 W/K
DHW heating through exchanger	No
Exchanger temperature, min	60,0 °C
Temp. factor for setup room	0,00
Automatics, stand-by	5,0 W

Other room heating	
Direct el for room heating	
Description	Suplemental direct room heating
Share of floor area	0,0
Wood stoves, gas radiators etc.	
Description	
Share of floor area	0,0
Efficiency	0,4
Air flow requirement	0,1 m³/s

Solar heating plant		
Description	New solar heating plant	
Type	Domestic hot water	
Solar collector		
Area 0,0 m²	Start 0,8	-

Solar collector		
Coefficient of heat loss a1 3,5 W/m²K	Coefficient of heat loss a2 0,0 W/m²K	Anglefactor 0,9
Orientation S	Slope 0,0 °	-
Horizon 10,0 °	Left 0,0 °	Right 0,0 °
Solar collector pipe		
Length 0,0 m	Heat loss 0,00 W/mK	Circuit 0,8
Electricity		
Pump in solar collector circuit 50,0 W	Automatics, stand-by 5,0 W	

Solar cells		
Description	Roof PV	
Solar cells		
Area 0,0 m²	Orientation s	Slope 30,0 °
Horizon 0,0 °	Left 0,0 °	Right 0,0 °
Additional		
Peak power 0,160 kW/m²	Efficiency 0,85	

Solar cells		
Description	Facade PV	
Solar cells		
Area 0,0 m²	Orientation S	Slope 90,0 °
Horizon 0,0 °	Left 0,0 °	Right 0,0 °
Additional		
Peak power 0,160 kW/m²	Efficiency 0,85	